Proceedings of the Auburn University Agricultural Conference

Hosted by the Department of Animal and Dairy Sciences

January 14-15, 1999

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PRELUDE

These proceedings are a result of the first Animal Agricultural Conference hosted by the department of Animal and Dairy Sciences at Auburn University. The conference was held January 14 and 15, 1999 on the campus of Auburn University. The presentations were given by faculty from the department as well as by a few invited experts from various fields.

This publication has been arranged primarily by species with additional sections covering forages and biotechnology. For most of the papers, statistics have been used to indicate significant differences. The use of statistics allows scientists to assess the reliability of the data in reference to the animal population as a whole. Most of the data has been presented as means or averages of a specific group (usually the treatment). Statements of probability that treatment averages are different will be found in most tables as well as thoughout the text as $P < .05$. This is the probability that the difference between the means could be due to chance. Using the example of $P < .05$, there is a less than 5% chance that the differences between the two treatment averages are really the same. You may also see some treatment means with an accompanying standard error (e.g., $2.0 \pm .21$). In essence, this indicates that if the treatments being evaluated were applied to the population as a whole, we would expect the true results to be within 2 standard errors of the mean (above or below) 95% of the time. When evaluating the data, if the range provided by the various treatment means and standard errors overlap then they are not statistically meaningful differences. In general, statistics are used as a tool to allow scientists to determine which differences are probably due to chance and which are probably not due to chance and therefore biologically meaningful.

The department feels that there should be something of value for everyone in these proceedings. Thanks for your interest in our programs and we hope to see you at our next conference.

Darrell L. Rankins, Jr.
Conference Chairman

THE DEPARTMENT OF ANIMAL & DAIRY SCIENCES
AUBURN UNIVERSITY
ALABAMA

The Auburn University Animal & Dairy Sciences Department was formed by a merger of the former Animal Science and Nutrition and Dairy Science departments (1970) followed by the addition of the former Extension Animal Science Department (1988). The department has its academic home in the College of Agriculture and is also an integral component of both the Alabama Cooperative Extension System and the Alabama Agricultural Experiment Station.

Departmental personnel includes 23 professorial faculty and extension specialists and 28 associates and technical support staff. Two additional faculty members will join the department in early 1999. Current enrollments are 282 undergraduates and 20 graduate students. Departmental faculty and staff are engaged in instruction, research and extension to serve the people of Alabama.

In the instructional area, the department offers 43 undergraduate courses (beginning to advanced classes). These courses are targeted either toward core disciplinary areas-- reproductive physiology, nutrition, genetics, meat science and growth biology, and biochemistry or toward species-- beef cattle, dairy cattle, swine, horses and companion animals. In addition the department offers integrative subject matter courses, based on principles from the core curricula, such as livestock and companion animal management and production, live animal and products evaluation and livestock merchandising. The department within its major, offers two course of study options, the pre professional option (AD Pre Vet) or production option. Some 220 undergraduates enroll in our pre professional option.

The department has also maintained a vigorous graduate teaching program in the areas of biochemistry, animal physiology, genetics, nutrition and metabolism and meat sciences. Some 23 graduate courses covering these discipline topics are taken by graduate students from Animal & Dairy Sciences, Veterinary Medicine, Human Sciences, Plant Sciences, Microbiology, Fisheries, Aquaculture, Zoology and Wildlife and Poultry Science.

Research is conducted in the department with beef and dairy cattle, swine, horses and companion animals. Emphasis areas with beef cattle have been forage/pasture utilization, use of byproduct feedstuffs in backgrounding-stocker programs, genetic selection for carcass traits and development of expected progeny difference values, factors affecting tenderness and eating quality of beef, effect of growth promotant implants on uterine development and reproductive efficiency and overall reproductive management. Work with dairy cattle has centered on estrus synchronization, effects of heat stress-cooling strategies on milk production, effects of feeding of byproduct feedstuffs on productivity and fine tuning protein nutrition to obtain optimal milk yields in high humidity/high temperature environments.

In the swine area, emphasis has been on developmental aspects of uterine function and reproductive efficiency, nutrient recycling, protein and amino acid needs of pigs, sow nutrition and baby pig nutrition. In addition, waste and lagoon management also have been focus areas. In the waste/nutrient management area, the potential role of constructed wetlands associated with animal feeding operations has been studied

in relation to efficiency of waste/nutrient removal and recycling and environmental microbiology. In addition, the burden of microbial presence in animal wastes (such as E. coli) and potential remediation/elimination strategies are being evaluated.

Emphasis in the growth biology field of livestock has been endocrine control of postnatal growth and embryonic/fetal growth and development in cattle and swine. Protein synthesis mechanisms, in particular the elongation step and role of tmRNA, and the function of the spliceosome are being explored in the biochemistry area.

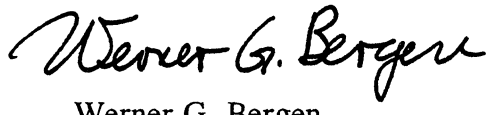
Research with horses has concentrated on behavior and trainability issues. Work with dogs has emphasized exercise physiology and nutrient utilization of aging dogs.

The department provides extension/outreach programs in the areas of beef cattle production and management, swine production and management, animal health, meat science and food safety, dairy cattle production and management, youth and 4H programs, equestrian arts and horse production and management. In discharging their duties, departmental extension specialists work with individual producers, trade associations, animal agricultural organizations, agribusinesses and county and district extension agents.

As a department and faculty, we are honored to serve Alabama and its people in the traditional land grant mission, that is university instruction, research and extension in animal agriculture. Thus on the occasion of the first AU Animal Agricultural Conference, we are pleased to present to our stakeholder groups and producers, students and friends these proceedings which will describe in detail some of the work being carried out within the department. This report does not contain all accomplishments of the department and I encourage the reader to contact us for further or more detailed information. You may also want to visit us at our web page (http://www.ag.auburn. edu/dept/ads/indexhtml).

It is my hope that the conference as well as these proceedings will increase your understanding of animal agriculture and be profitable to you for your personal endeavors.

War Eagle!



Werner G. Bergen

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THE CHANGING FACE OF ANIMAL AGRICULTURE: CURRENT AND FUTURE CHALLENGES FOR SURVIVAL

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SUMMARY

To see the future, we must often first look to the past. Over the last half-century, we see that changes agriculture has viewed as a cure have often become part of the problem. Larger farm sizes result from technologies that enhance productivity, but which also augment economies of scale. Lower farm prices arise from greater production. A global economy increases access to international markets as well international competition in US markets. Although it is perhaps understandable that producers would look for someone or something to blame under these conditions, it is also clear that there is no cure-all. Economic problems are multifaceted. They have no simple answer, nor are they likely to abate in the near future. Agricultural producers have but one option if they wish to survive: **become managers rather than producers**. To illustrate our point, we discuss several important problems affecting US agriculture. We then draw implications for the future and attempt to illustrate the importance of greater management sophistication -- in both production and marketing -- when dealing with these issues. As we move into a future characterized by the information age, it seems clear that no other aspect of animal agriculture could be more important.

Introduction

With $60 cattle, no wool market (and a lamb market that is not far behind)[1], and hogs pushing $25 (from the top down), many animal producers are understandably concerned about their future. They do their very best, as they have for year after year, only to see themselves and their futures slipping away. However, as I read over the title of the paper I was assigned, I must admit that trepidation overcame me. The title somehow suggests that I am omniscience or possess a crystal ball of remarkable clarity. Unfortunately, neither is true. I can not tell you what the future will hold with any certainty or how to avoid all of its pitfalls. I have no panacea to offer nor do I know a quick fix. I can only offer observations about this industry that may aid your own discussions and deliberations in the days to come. In that context, I will certainly be more negative than positive. My role, as the title of this paper suggests, is not to sing your praises or tout your many accomplishments. My role is to identify your problems and shortcomings. In the process, I will probably propose more questions than answers. But if these questions help you organize your own thoughts and make better decisions, then I will judge this paper to have succeeded. It is you, the individual producer, who must make the decisions that will

[1] At the time of this writing, the U.S. Congress has authorized funds to re-establish at least part of the Wool and Mohair Incentive program which may temporarily and artificially alter this condition.

ultimately determine your future and collectively that of the industry. And, it is you who will reap the benefits of correct decisions and bear the cost of incorrect ones. As such, these decisions should be made with careful consideration of their possible consequences.

As we try to envision the challenges confronting U.S. animal agriculture, now and in the future, three areas seem to warrant special consideration:

1. effects of increased U.S. market concentration, corporate agriculture, and larger producing units;
2. implications of an increasingly global economy for U.S. animal agriculture; and
3. technology and the demands for management sophistication in U.S. animal agriculture.

In each case, we shall attempt learn from the past and make every effort to couch our discussion the most meaningful possible terms: dollars. As such, our discussion will differ from the balance of those your will hear at this meeting in that we will not emphasize productivity as much as profitability. However, in process, we hope to provide a framework in which later discussions, technologies, and research results can be evaluated in a meaningful way.

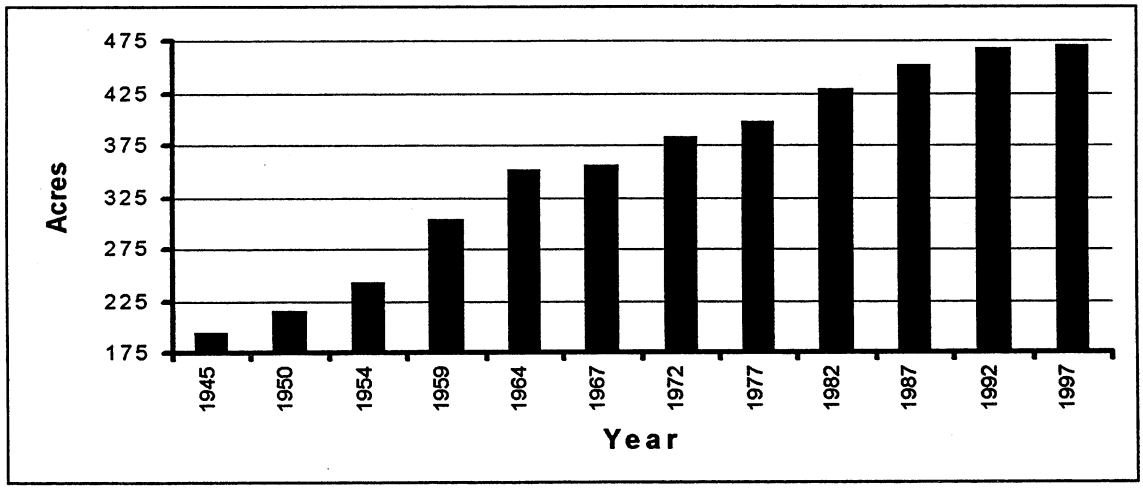
Current Challenges and How We Came To Be Where We Are

Given our faulty and somewhat impaired foresight, our best indication of the future is past trends. Accordingly, we shall attempt to discern trends affecting current and future animal agriculture from a historical perspective. We shall then attempt to discern the underlying factors contributing to these trends and interpret their implications for the future.

The Size and Structure of US Animal Agriculture

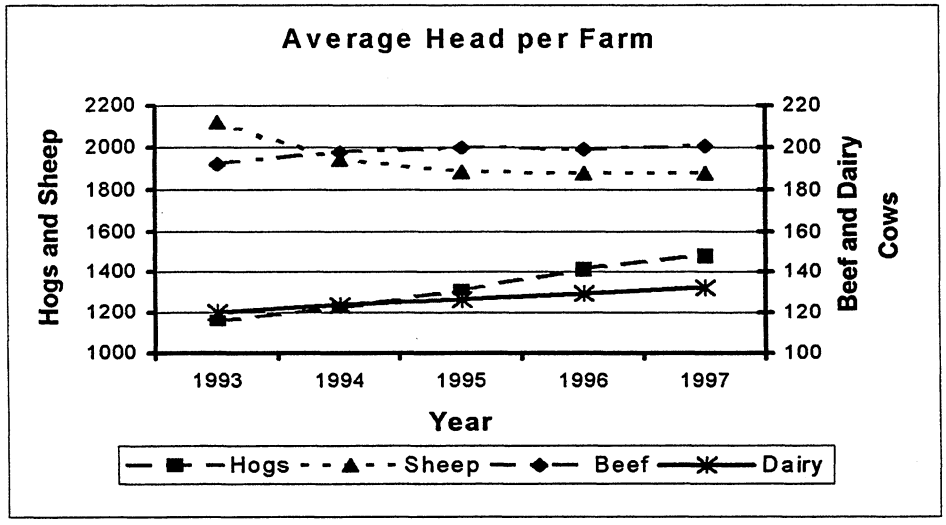
When producers are asked about their concerns for US agriculture, one of the first things mentioned is the increase in the number of "large corporate producers". Is this concern justified? Is the average size of an agricultural producing unit growing and, if so, why? Do size and structural changes mean an end to traditional units?

To examine this issue, we first consider the size of agriculture in general. Specifically, we find that since the end of WWII, the average size of a US farm has increased by over 275 acres or 142%. This represents a compound annual rate of increase of 1.7%, as shown in the following graph.

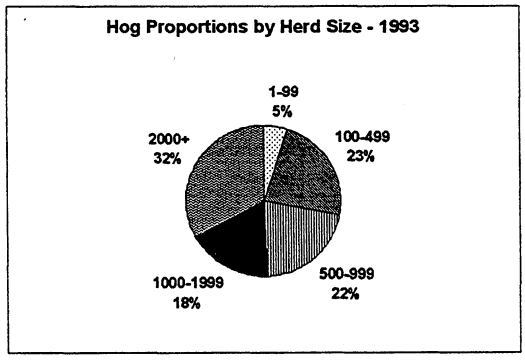


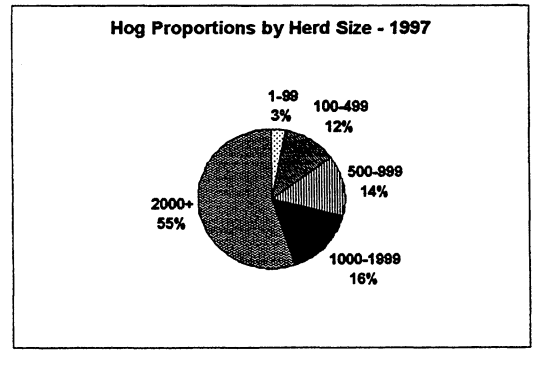
Over the same period, the farm population as a percent of the total US population has declined from over 10% to less than 2%. Hence, we can reasonably argue that the size of US agriculture has increased over time and that this trend has been on-going for a considerable period. It is not a new development or one that has suddenly arisen to threaten agricultural producers.

In general, the livestock sector of the US economy shows similar growth. For example, in the last five years, the average size of a hog operation has increased from about 1150 animals to nearly 1500, an increase of nearly 30%. Dairy herds have increased in size by an average of about 10% and beef cow herds by about 4%, while sheep herds, largely responding to the elimination of the Wool and Mohair Subsidy, have declined by about 11%. These recent trends are illustrated in the following graph.



Of course these increases in average herd size could be a result of all producers increasing their herds. However, the data do not support this conclusion. If we consider hogs, for example, we see that the growth in average herd size has largely been a result of increased proportions in the larger herds at the expense of smaller herds. For example, in 1993 28% of hogs were in herds of less than 500 head and 32% were in herds of over 2000 head. By 1997, the proportion of hogs in herds of less than 500 head had fallen to 15% and 55% were in herds of over 2000 head, as shown in the following graph.





Similar, although admittedly less dramatic, shifts have occurred in beef and dairy: the proportion of the US herd held in large herds is growing at the expense of small herds.
Numerous factors can be cited as contributing to these trends toward larger agriculture, but at their root the cause is simple economics. Larger units are more profitable than smaller units. However, to anticipate whether these trends will persist, we must more fully understand their economic roots and why larger units are more profitable.

Returns to Scale

Returns to scale are an economic indication of profitability due to size. It is the proportional change in profits that would accompany a proportional increase in all inputs of production. For example, if profits doubled when all inputs double, constant returns to scale are said to exist. Similarly, when profits less than double returns to scale are decreasing and when they more than double returns to scale are increasing. In the latter case, there is a clear incentive to increase size and thereby increase profit. When decreasing returns to scale exist, the opposite holds. With constant returns to scale, there is no size incentive.

Just over fifty years ago Earl Heady argued that agriculture exhibited constant or nearly constant returns to scale as evidenced by the simultaneous existence of virtually all sizes of agricultural units. If there were substantial economies of scale, larger farms would dominate and if there were substantial diseconomies of scale the opposite would hold. Today, it is unlikely that he would make the same argument. The evidence strongly suggests that US agriculture has entered an area of increasing returns to scale where added profit is available to larger producing units. The question is why and will it persist.

Technology is the primary source of increasing returns to scale in agriculture. In the post-WWII era significant public and private resources have been devoted to increasing technical efficiency. New and improved capital equipment, improved inputs, enhanced information, and more sophisticated management techniques have all increased the technical efficiency of US agriculture. However, in many cases, the technologies that increased production efficiency were also lumpy (the units came in fixed sizes) and had the effect of being most effective (economical) on larger units -- thereby creating economies of scale.

For example, large tractors reduce the time required to till an acre. However, they are most efficient on farms with enough acres to fully utilize their capacity. That is, average cost per acre is lowest on farms large enough to fully use the tractor's capacity and cost. Between 1950 and 1982 farmers adopted the new technology so rapidly that there over a seven-fold increase in tractor horsepower per farm resulted (from 17.2 to 137.9 horsepower per farm). As a result, farmers have an incentive to increase the number of acres farmed. With limited land area, this can only be accomplished by acquiring a neighbor's farm, thereby reducing both the number of farms and the number of people in US agriculture.

Comparable, though perhaps less extreme, examples of scale-augmenting technologies are evident in all aspects of agricultural production, including animal agriculture. For instance, rotational breeding systems require larger herd sizes to fully utilize sires and avoid potential inbreeding problems. With the widespread introduction and use of such technologies as EPDs, even more traditional breeding systems for improved genetics requires additional management sophistication that is more costly per unit for smaller operations.

Even marketing, a management technology, has begun to augment scale. The majority of marketing cost is incurred on a transaction basis, regardless of the number of units marketed. Hence, a producer selling 100 head has higher average marketing costs than one selling 100,000 units. For example, consider the case of beef. A single packing plant, to be most cost effective because of the capital technologies embodied in their equipment, processes about 2,500 head per day, or about 600,000 head per year. If these slaughter animals had to be acquired from feedlots of 200-head capacity, the packer would have to deal with 1500 different feeders to meet their slaughter requirements. Each of those transactions would have a cost to the packer. However, if the same number of animals is acquired from feedlots of 35,000-head capacity, the packer must only deal with nine feeders. The packer's transaction cost can thus be reduced by as much as 99% and a portion of those savings can be passed on the to the feeders, depending upon their relative market strength and negotiating power, in the form of higher prices. Thus, feeders have an incentive to get larger due to economies of scale reflected in their higher net market prices.

In short, the majority of technologies developed in the last fifty years have been scale-augmenting -- either directly or indirectly. This was clearly an unintended side effect of the research that produced these technologies, but an effect all the same. Researchers were interested in technologies that increased production or reduced average cost, but gave little or no consideration to the scale effects of their research.

Income

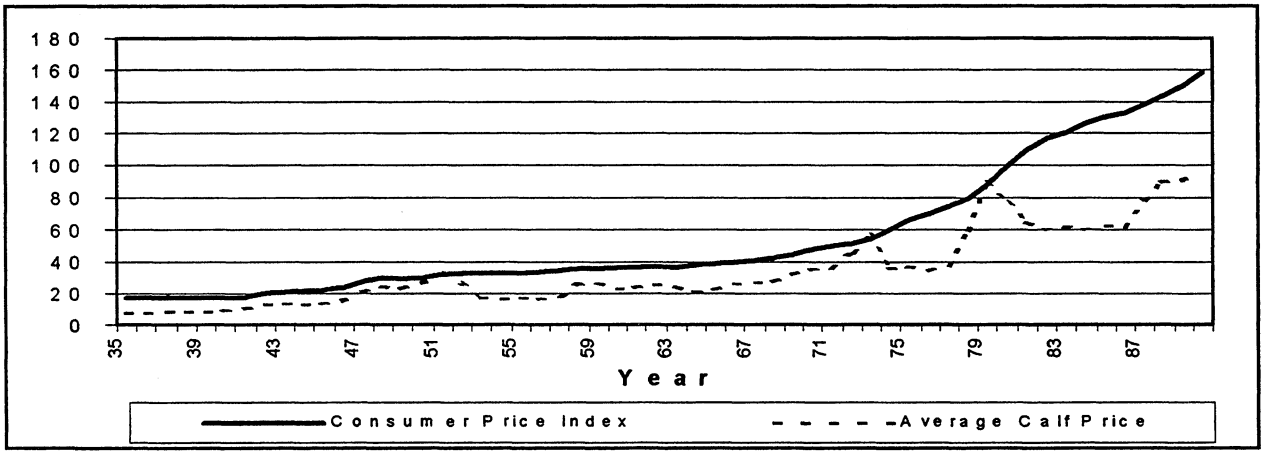
Even had the technological changes in agriculture over the last fifty years been scale and input neutral, it is likely that farm size would have still increased. The basis for this argument relies upon the nature of agricultural demand and a producer's minimum income requirements.

To illustrate, assume that in 1950 an agricultural producer required an annual income of $5,000 to modestly provide for a family of four. If this producer were a commercial cow-calf operator selling weaned calves, 200 cows producing an average annual return of $25 each could meet the producer's annual income requirement. By 1996, however, the same family would require an annual income of just over $32,600 to maintain the same standard of living. Taking account of inflation and prevailing market prices, the producer's herd size would have to increase by about 86% (to 373 head) to achieve this minimum income. This size increase is despite the fact that average weaning weights have nearly doubled in the last 45 years (from 180 to 340 pounds per head) as a result of technological improvements in capital, inputs, and management. Hence, to maintain their income levels, cow-calf producers have needed to double their herds, largely by buying out the neighbor's operation and resulting in many fewer producers.

In Alabama the situation is little different from the national. According to local budgets, a cow-calf operator in Alabama would have to have 424 cows to reach our basic family income level of $32,600 with a return of $76.86 per head, ignoring land, facility, and equipment costs average (Prevatt and Van Dyke). Similarly, a feeder pig producer would require 347 sows with a net return of $94.00 per head to reach the specified income level under the same conditions (Prevatt and Owsley).

One reason for this phenomenon is that agricultural product prices have simply not historically increased at the same rate as either agricultural inputs or the cost of living (CPI), especially since the

1970s as shown in following graph. From this graph it is clear that calf prices would have needed to reach $1.25 to $1.40 per pound by 1990 to keep pace with the cost of living. On one hand, increased output (largely from technological improvements) has relieved some of the price shortfall. On the other hand, increased output has largely been responsible for the price shortfall.



The primary reason for this is the highly inelastic nature of agricultural demand. Elasticity measures the percentage change in the quantity of a good or service that will demanded in response to a small (one percent) increase in price. A good that has less than a one percent decline in quantity for a one percent increase in its price is said to be inelastic. If the percentage decline in quantity is much less than one, the demand for the good is said to be highly inelastic. Most agricultural products meet this definition.

For example, Melton and Huffman analyzed US food consumption demands and expenditures from 1963 through 1987 in an AIDS model that explained over 90% of the variance in consumer expenditures. In their analysis, they found the following price and income elasticities:

Table 1. Own price and income elasticities -- 1963-87.

Item	Own Price Elastiticy	Income Elastiticy	Expenditure Trend	Expenditure Share
Beef	-.309	-.101	+.0004	.015
Pork	-.762	+.288	+.0001	.008
Poultry	-.213	+.801	+.0005	.003
Other Animal	-.397	1.349	-.0002	.026
Plant Products	-.637	-.190	+.0009	.061
Nonfood Items	-.092	1.097	-.0008	.887

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The interpretation of these numbers is as follows:

- A one percent increase in the price of beef causes a .309 percent decline in the quantity of beef demanded.
- A one percent increase in real income per capita (adjusted for inflation) causes a .101 percent decline in the quantity of beef demanded (statistically non-significant result).
- Real expenditures on beef have increased an average of .04 percent per year over the study period, independent of price and income changes.
- 1.5 percent of real income was spent on beef over the period 1963 to 1988.

In the first case, we can imply that if a one percent increase in price results in a .309 percent decline in quantity demanded then the inverse approximately holds as well. That is, a one percent increase in quantity results in a 3.236 percent (1/.309) decline in price. Increased beef production thus results in a more than proportional decline in beef price. Hence, producer revenue falls -- even in the face of greater production.

Markets and the Global Economy

If US animal agriculture can not produce itself to prosperity, as these results would suggest, our attention must turn to the market. Again, producers are in the forefront of this issue since they are notorious for complaining that the price they receive is too low and that their product is under valued. To examine this issue we will initially make a distinction between domestic and international markets. However, as we proceed, it will become apparent that such a distinction is more an artificial convenience

that a reality. When properly specified, the similarities in markets are probably greater than their differences, especially in our increasingly global economy.

US Markets and Consumer Preferences

US producers of livestock and livestock products will typically voice one of two complaints about the market: 1) consumers are not buying enough of our products and we are losing market share or 2) the prices we receive are too low. We shall examine each, but we will also see that the two are contradictory complaints.

Many producers argue that consumer tastes and preferences have changed, causing them to move from meat products to vegetables and other food items. Still others argue that the quality of some US animal products -- especially beef and pork -- has to be improved to recapture lost market shares.

However, the expenditure trend results shown in table 1, show that consumer expenditures (as a percent of total expenditures) have increased over time for each food except "Other Animal" which includes milk and dairy products as well as fish. That is, with constant relative prices between all goods and services and constant income, US consumers have still increased their consumption of most food products at the expense of non-food products. A portion of this increase may, of course, be in the form of increased consumption of higher priced convenience foods, so that expenditures on food increase without a comparable increase in the quantity consumed. However, it denies the argument that US consumer tastes and preferences have turned from meat, as many producers seem to believe.

That is not to say that consumers are not eating less red meat. In fact, red meat consumption (beef, lamb, and pork) has fallen rather steadily since its peak in the mid-1970s. At its peak in 1976, the US consumed nearly 188 pounds of red meat per capita. By 1997 total red meat consumption had fallen nearly 15%, to slightly less than 160 pounds per capita. Over the same time period, poultry (chicken and turkey) consumption nearly doubled from 52.5 pounds to 100.5 pounds per capita. Consumers have shifted from red meat to poultry -- not, we argue, because of changes in their tastes and preferences or health concerns but because of relative price changes.

The results in Table 1 show a positive trend in meat consumption expenditures when prices and income are held constant. However, red meat consumption is falling. Because these results explain over 90% of the variance in US consumption over the study period, prices and income must be considered as the cause. In fact, beef, pork, and chicken retail prices have all risen since 1976, as has per capita income. However, retail beef and pork prices have risen about 79%, on average, in the last 20 years. This is considerably more than chicken, which has increased by about 63%. Hence, consumers have substituted away from beef and pork and toward relatively cheaper chicken in their diets -- irrespective of tastes and preferences. The incentive for consumers to reduce their red meat consumption and increase their consumption of other goods, such as chicken, has been strictly economic. They have moved from higher priced red meats to relatively lower priced goods such as chicken.

Most producers will be aghast at this result. They will argue, with some justification, that the prices they receive are already too low. However, the fact remains that red meat producers have lost market to products such as chicken that by various means, including increased size and greater production efficiency, have managed to reduce costs (and price) proportionately more than beef and pork.

A recent study by Huffman and Evenson holds out little hope that beef and pork are likely to exhibit the same cost savings as poultry through improved technology. Specifically, they find that since 1950 the

marginal internal rate of return on applied public research, such as conducted at Auburn, is negative in the livestock sector, as is public livestock extension -- despite the fact that these two categories represent the largest share of public funds in these areas. Only private R&D and public pre-technology (basic) research show positive marginal internal rates of return (86.6% and 83.2%, respectively) in livestock.

As an alternative, pork production has recently begun to show signs of adopting the poultry model: average size has increased dramatically along with increased vertical integration to further reduce costs and increase efficiency. However, in many respects both beef and pork continue to hold out for an alternative since, to a greater or lesser degree, both are bound by traditions that resist such changes. Instead, both sub-industries seem to believe that they can increase market share and price simultaneously by changing the quality of their product. In theory, this solution has merit. In practice, however, it is unclear what quality changes, if any, could produce the desired result.

While programs such as Certified Angus Beef (CAB) have certainly increased participant revenues, it is not clear that they have also increased profit. The higher costs of producing CAB may, for some producers, more than offset the revenue gains. Furthermore, what may work for a few producers will not work for the industry at large. If the total supply of CAB increases, its price will fall and producers will find themselves in approximately the same position as they were with non-CAB.

It is for this reason that some producers have argued that the overall quality of beef must be improved, with a special emphasis on tenderness. However, at least one study has found that while US consumers prefer more tender meat, they are not willing to pay substantially more (Melton). Furthermore, if beef tenderness were enhanced, one must question how that would effect producers and their net profit. Specifically, tenderness is an issue only in what might be called premium beef cuts: steaks and a few roasts. It plays no role in ground beef, which now comprises about two-thirds of beef consumption. Hence, its value in either the carcass or the live animal would be substantially reduced. That is, if a more tender steak were worth an additional 10¢ per pound (Melton, et. al), and such premium cuts comprised one-third of a carcass, it would be worth only 1.4¢ in the slaughter animal -- if it could be fully identified in the live animal. It is more likely that uncertainty about a carcass trait in the live animal would further reduce its value. If carried to the cow-calf level, it is thus likely that such an improvement would have minimal market value (less than one-half cent per pound).

Pork producers have similar quality concerns, though more focused on fat content and color than tenderness. However, like beef, recent studies (Melton, et. al.) suggest consumers will not pay a large amount for reduced fat content. Furthermore, consumers value fat content differently in appearance than in taste. They prefer the appearance of pork with minimal fat, but prefer the taste of pork with ample fat content. This finding helps explain the problems that have faced European pork of late. These producers found that the demand for Danish pork has dropped dramatically, worldwide, after their breeding efforts reduced fat content to the range of 1%.

Global Markets

In the face of these domestic marketing problems, it is logical that US producers would look overseas. There is little doubt that expanding global markets for US products would bolster producer prices. There is also little doubt that we will progressively move toward a global economy as trade barriers fall to growing economic pressure. NAFTA and the European Community are only the most

visible examples, however it has been estimated that between one-fifth and one-third of US agricultural production currently finds it way into international markets.

However, expanded access to international markets will not, in itself, remedy the ills of US animal agriculture. Many of those who rally most loudly for expanded exports, will protest just as loudly against imports that compete with their products in US markets. A cost of expanded access to international markets is the potential for increased competition in domestic markets. The two must go hand in hand. We can not ask the other countries of the world economy to open their markets to our products while we bar the entry of their products to our markets. US producers must come to grips with this reality.

US producers will argue that imports are inferior to US products and that their products are the best in the world. However, quality in international markets, as in the domestic markets, is an elusive concept: it rests in the eye of the beholder, or consumer in this case. It is true, for instance, that the US dominates in grain-fed beef. However, in many areas of the world, grain-fed means fat and the taste is undesirable. To be effective in international markets, US producers must abandon the idea that "our product is best and thus deserving of a premium price". They must truly market their product. At the same time they must accept the reality of a US market dominated by ground beef. Grass fed beef from Latin America and Australia will produce lean ground beef that, once any health issues have been resolved, may compete very effectively with US beef -- potentially lowering US average retail beef price.

Sheep producers, better than most, must be aware of the potential pitfalls of global markets. Lamb consumption has fallen steadily for years and only the US Wool and Mohair Subsidy, combined with trade restrictions, provided any real substance for the US sheep producers. With the elimination of this subsidy, the bottom fell out of the sheep market. As trade barriers are relaxed it is likely that Australia and New Zealand, who currently have enormous stocks of wool and relatively lower costs of production, will enter the US market to keep prices low.

That is not to say that such global markets should be avoided or that producers should resist the removal of trade barriers that will inevitably fall and foster a truly global economy. In point of fact, such an economy is likely to evolve with or without the support of US producers. Furthermore, its result can be positive, but it requires US producers to assess their strengths and weaknesses relative to producers around the world with clarity and a lack of passion -- then market their products in such a way as to take advantage of their relative strengths.

Management Sophistication

A common thread underlying our prior discussions is management. Management sophistication is required to recognize opportunities, adjust to changing market conditions, and capitalize on emerging technological advances. Furthermore, as these issues become more complex, the demand for management sophistication increases. It is, unfortunately, in this area that U.S. agriculture, and livestock producers in specific, have lagged.

Agriculture has strong traditions that often retard the adoption of new technologies and impede the management changes that are necessary in a dynamic economy. There is a mistaken belief that one can not be a farmer without tilling the soil and time that should be devoted to information gathering, analysis, and decision-making is spent riding the seat of a tractor. As a result, labor tends to be ineffectively

substituted for management. Animal agriculture, especially beef, is further hampered by a "romanticism" that, in the minds of many producers, is inconsistent with profit. Hence, management decisions are based frequently upon tradition (i.e., "That's the way we have always done it!") and emotion rather than innovation or the desire to enhance profit.

Many producers will resent this assessment, but the facts are undeniable. For example,

- It took US beef producers nearly 20 years after researchers proved its advantage to widely adopt cross breeding as a means of capturing the potential heterosis in economically important traits.

- Artificial insemination was introduced in cattle in the early 1940's. By 1970, less than half of dairy cows (and only about 2% of beef cows) were being artificially inseminated, despite its clear genetic and economic advantages in these confined herds.

- By 1990 less than half of U.S. agricultural firms and less than 25% of beef producers had personal computers for business use, whereas over 80% of non-agricultural firms had adopted them.

A recent study of the Iowa beef industry (Iowa Beef Industry Task Force) tends to sum up the problem:

- "... our approach to incorporating greater professionalism (in management) is inadequate." (p. 78).

- "In sum, many of the factors that are real disadvantages (in cattle feeding) can be changed through individual management: weighing feed, performance monitoring, keeping records, and seeking outside advice where expertise is limited." (p. 93).

- "The key to success still will be effective management and adaptability of the producer. The producers in our survey may be very concerned about learning about new technologies, but they did not express strong concern for the effect of new technologies on their ability to make a profit." (p. 168).

Over and over this study emphasizes the deficiencies of management in the Iowa beef industry and its importance to the industry. It is likely that the complaints leveled at the Iowa beef industry also extend to other parts of the country.

Producers in the Iowa study, and elsewhere we suspect, tend to focus too much attention on circumstances beyond their control as being at the root of their problems. They tend to look for someone or something external to their own operations to blame. They want a panacea or one-step cure-all to their ills, which must have an external cause. After all, if they were able to correct the problems affecting their operations themselves, wouldn't they do it? Perhaps, but only if they are able and willing to recognize that there is not a panacea and that what they do or do not do may be a big part of the problem,

as well as of the solution. For example, factors that average beef producers in Iowa listed as having the strongest impact on their profits included consumer preferences for other meats, concerns for food safety, fat content, and cholesterol as well as winter weather/mud and a two year drought. Factors listed as having the least impact were access to credit, production technology, production costs, production efficiency, market price information, debt level, and facility condition.

Producers can do little about the first set of factors, but much about the second. Furthermore, the data show that those beef producers who have addressed the second set of factors, increased their production efficiency, and improved their own management have production costs that are 40% lower than those who have not. As a result, their annual net return to labor and management per cow is +$156.30 compared to -$56.90 for low management producers, a difference of over $213 per head per year.

High return managers differ from low return managers in several important ways. Perhaps the most significant of these is in the area of record keeping. High return managers keep records that allow them to ascertain where they are prospering and where they are deficient. Furthermore, they keep these records for decision-making purposes (rather than just for tax purposes) and spend considerable time analyzing the records so that informed management decisions can be made in a timely fashion -- before problems become catastrophic. In addition, astute managers are taking advantage of the information age, personal computers, and the Internet to acquire data and management insights that supplement their own records and enable them to make better-informed decisions on a regular basis. In the process, the stock of information, management knowledge, and sophistication held by top managers is increased. As a result, the gap in returns between top and bottom (or average) managers is likely to grow at an increasing rate.

Future Challenges and Opportunities

Past trends are likely to continue, at least in the foreseeable future. Farm sizes will continue to increase. The number of producers will continue to decline. New technologies will continue to expand agricultural production and, to a lesser degree production efficiency. US agricultural prices will remain low as output expands faster than domestic demand. Increased competition will accompany increased market opportunities as US producers face increasingly global markets for agricultural products. Through it all, the demand for management sophistication will increase and it, more than any other single factor, will determine who survives and who does not in agricultural production.

In the face of these challenges, these are certain specific actions that a producer can take to improve his or her economic well being. Some of these are discussed below.

Adopt Only New Production Technologies That Enhance Profit

It is likely that production oriented technologies will continue to emanate from universities and private industry. However, producers must make a conscientious effort to seek out and adopt only those technologies that increase their profit -- not just their production. That is not to say the two are mutually exclusive. Many technologies that increase profit do so by increasing production levels with less than proportionate increases in input use or cost. These technologies warrant consideration. Others,

however, increase both output and cost such that the effect on profit is negligible or negative. These have no merit.

For example, there has been considerable discussion of late about ultrasounding beef cattle. Such a step involves considerable cost to the producer, including expertise to conduct and analyze the ultrasound as well as "wear and tear" on cattle. When considering whether or not to adopt ultrasounds, the producer must determine how the results will be used. If they are intended to make better and more timely decisions, and thereby enhance revenue, the potential added revenues must be weighed against these added costs to determine the effect on net profit and thus the merit of ultrasounding. However, if the ultrasound results are only intended to establish baselines for the industry or breed, without enhancing the individual producer's profit, they have no place in that producer's production practices. Technology and the decision whether or not to adopt, can not be an altruistic gesture on the part of individual producers if those producers are to survive.

When considering a new technology or research finding, the producer must judge new technology or research findings by one question: "How will this finding affect my profit?" It is only against this standard that future technologies can be judged if the producer is to survive.

Researchers in both universities and industry can assist with this evaluation if their clientele, the producers, demand it. This will not be pleasant for most university researchers who will argue academic and intellectual freedom to pursue research of interest to them regardless of its economic impacts. In point of fact, there is ample room for both intellectual curiosity and economic significance in applied research. Producers, however, must be able to separate the two and researchers must be held accountable for their efforts. In the process, the meager returns to applied livestock research reported by Huffman and Evenson will be improved.

Recognize and Capitalize on the Scale Effects of New Technologies

Among technologies that have the potential to increase profits, producers will encounter a wide range of scale effects. Most will enhance economies of scale, as they have in the past. However, the degree will differ from one technology to another. With some, there may be little advantage to larger size. With others, the size advantage may be considerable. Producers should consider these effects and, where possible, adjust the size of their operation to capitalize on the economies of scale.

Many producers will encounter capital constraints as they attempt to increase the size of their operations to take advantage of technologies. Traditional credit sources for agriculture have declined over time -- especially since 1981 -- but capital is still available to those who can demonstrate a substantial return. Accordingly, producers must begin to approach capital markets in this way. They must de-emphasize their collateral value (land), which history has shown can vary dramatically, and demonstrate a positive return to capital adequate to justify the risk. In the process, they must explore alternative capital markets, including those associated with the separation of capital ownership and capital management such as public capital markets. It is the management of the assets that makes one a farmer or rancher, not their ownership. After all, the president of General Motors is not the company's owner, but there is little doubt who runs the company.

Move from Selling to Marketing Animal Products

US agricultural producers have traditionally been price takers, as set by either the government or the market, rather than marketing their products. Animal agriculture has been no exception. As a result, producers probably receive a price that, on average, is less than the value of their product. A portion of this discounting arises from uncertainty regarding the value of the product on the part of either the buyer or seller. Another portion is due to the high cost of a marketing transaction, which must be born equally by the number of units offered. A final portion is simply due to lack of marketing sophistication of the part of the seller.

To more nearly extract the true value of their products, animal producers must ascertain that value and market accordingly. That is not to say that producers set value. In fact, most values are set in the consumer market, from which producers are far removed. Instead, it is to say that producers should know what the attributes of their product are and market accordingly.

For many producers this means retained ownership or other forms of vertical integration so that values that can not be ascertained with certainty in the live animal become apparent over time -- in the feedlot or the carcass. For others it means marketing cooperatives or joint ventures that will increase the size of unit offered and thereby reduce the marketing cost per unit for seller and buyer alike. For still others it means the development and exploitation of small niche markets (CAB?) where unique attributes can be marketed at their full value to consumers, including foreign markets. In all cases it means that producers must devote as much emphasis and attention to marketing as to production. It is foolish, at best, to devote a year or more, to producing something with no reasonable idea of its value and no clear strategy to market it at its highest possible price.

Prevent Poor Performance with Proper Planning

The most immediate, and important, change animal producers can make to cope with whatever the future may hold is to improve their management ability. They need to discard decisions based exclusively on "that's the way we have always done it" in favor of those that increase their profits. They need to improve their record keeping and analytical skills so that they are able to identify problem areas in time to remedy them. Most important they need to devote considerably more effort to planning. Planning will not always avoid a problem, and even the best of plans can go awry, but planning is an inexpensive way to explore alternatives and consider remedies to potential problems before they arise. As a result, the producer is in a better position to act and make a decision when the pressure is on. In short, animal producers need to become animal managers. They need to make conscious decisions about technology, production practices, and marketing strategies rather than drifting with the current. In doing so, they will be able to take control of their own destiny and find the "cure-all" they have sought for decades.

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ANIMAL BIOTECHNOLOGY AND INDUSTRY: CHALLENGES AND OPPORTUNITIES IN THE REAL WORLD

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SUMMARY

Biotechnology was originally defined as any line of work by which products are generated from raw materials with the aid of living organisms. Today, advances in cell and molecular biology, biochemistry, and computer science are changing the way we look at the world and revolutionizing agriculture and medicine. Here we review, in brief, the evolution of animal biotechnology and discuss events that are changing the face of animal agriculture, redefining animal industries, catalyzing alliances between universities and the private sector, and creating unimagined challenges and opportunities for agriculturalists, scientists and entrepreneurs. Basic knowledge of biological processes, the currency of progress in biotechnology, has never been more important or valuable.

Introduction

What is biotechnology? The prefix - 'bio'- means 'life'. Technology is defined as a branch of knowledge dealing with applied science; the application of knowledge to practical ends. Thus, biotechnology involves application of scientific knowledge to the regulation of life processes. The word itself, coined in 1919 by Karl Ereky, was originally defined to mean "all lines of work by which products are produced from raw materials with the aid of living organisms". Animal agriculturalists and scientists, faced constantly with the challenge of increasing the efficiency of food and fiber production, continue to be pioneers in development and use of animal biotechnologies.

Historically, domestication of animals might be considered one of the earliest and most important biotechnologies. Recognition that: (i) animals, such as dogs, could be trained to assist with the hunt and reduce work required to ensure the next meal; (ii) animals could be herded or kept in flocks to ensure a steady, convenient source of food and fiber; and that (iii) large draft-type animals could be harnessed and used to increase the work done by one person, enabled nomadic societies to become more stable and changed human society forever. Now that we could stay in one place and be reasonably assured of a higher quality diet at less cost in terms of human capital, we had more time to think, more time to fantasize, and more time to envision a "brave new world" (Huxley, 1946).

Today, the word 'biotechnology' conjures visions of the DNA (deoxyribonucleic acid) double helix and cloned sheep. The road that brought us to this point is a long one. However, since the first accurate description of the structure of DNA in 1953, humankind has embarked on an intellectual and technical odyssey unprecedented in history. Already, efforts to understand DNA - the stuff that genes are made of - and how gene expression affects the behavior of cells, the structure of tissues, the development of organisms, and the fate of individuals, has revolutionized our understanding of the natural world in which we have evolved

and our relationships with it. Continued efforts to unravel these mysteries promise to provide answers to questions that will enable us to prolong our lives, enjoy our futures, and even to solve problems that we have caused through our own impetuosity and desire to improve our position in the world.

History

Milestones in the evolution of animal biotechnology are listed in Table 1. Clearly, animal biotechnology, as we know it today, did not simply appear on the scene with the discovery of DNA, but evolved over millennia in concert with the development of animal agriculture and the biological sciences. Advances in science and biotechnology now occur at a pace that challenges comprehension. The impact of such advances on our lives and futures continues to be both exciting and sobering. Implemented wisely, new biotechnologies hold incredible potential for the advancement of humankind

Feeding the World in the 21st Century

Providing food to a current, yet growing population of almost 6 billion people could not be accomplished using technologies of the 1940's. In 1999, there will be about 140 million births and 50 million deaths. On the day of this conference alone, global population will increase by about 250,000 hungry people. Just as 1940's technology could not meet current demands for food, technologies and practices available in 1999 are not likely to be sufficient to feed a population of 8 billion, expected by 2020, or 10 billion predicted to exist on the earth by the year 2030. In fact, by some estimates it can be argued that if population growth stopped this instant, we would have to double world agricultural production in order to simply meet the needs of our current population in the year 2030. The latter calculation assumes some upward trends in affluence. Still, demand for meat, milk and eggs is increasing even now.

American citizens have rarely experienced food shortages. However, from a caloric view, about 20% of the global population is considered to be undernourished. According to the Food and Agricultural Organization (FAO), Asian countries produce 17 grams of animal protein per capita per day for 3.3 billion people. In the U.S., we consume about 65-70 grams, and other countries are increasing in consumption as well. Globally, it is speculated that agriculturalists will need to produce approximately 55 grams of animal protein per person/day by 2030. Certainly, economic crises, such as those occurring in the Asian sector today, will continue to affect patterns of affluence and global demand for agricultural products. For the sake of economic, environmental and political stability, it is essential that methods of food production from animal sources not only be refined, but that new approaches be developed that will allow us to meet global demands for animal products more efficiently, without endangering our futures. The biological law is "adapt or die".

While it is easy to paint a dire picture of a hungry world, current global food supply has, in fact, out-stripped demand. In the short run, this may be fortunate. Decreased demand, over-supply, and phased out domestic commodity support programs have contributed to one of the most disheartening livestock markets in years. Producers able to withstand such extreme economic conditions will continue to be faced with real issues of air and water pollution regulations, animal health and well-being, rising production costs and food safety. Never the less, consumers, in ever increasing numbers,

will continue to expect safe, economical products. Meanwhile, producers, whose ranks are diminishing, will be challenged to meet these demands under circumstances that will permit them to realize a fair profit. For this to happen production *efficiency* must be improved, but how? One approach to the solution, being pursued vigorously in this complex economic, regulatory and political landscape, is the development and application of biotechnologies that may enable the engineering of genetically modified organisms (GMO's), or the generation of metabolically enhanced organisms, both plant and animal, with the goal of designing more robust, efficient, productive and profitable bioagricultural systems.

Genetic engineering of economically important large domestic animals is already technically, if not yet practically feasible. Use of such GMO's, engineered to grow and reproduce more efficiently, resist disease, accommodate extreme environments, produce higher quality nutrients, and even to produce molecules of value in human and veterinary medicine, could provide solutions to many of the challenges we now face. To be sure that we can exploit these technologies to their best ends, it will be essential to secure support for aggressive research and development efforts, and to recruit the best and brightest young minds into the bioagricultural sciences. Additionally, it will be essential to establish effective educational programs that will help the public understand and believe in the value of the work, as well as the potential and safety of technologies and products derived from it.

Biotechnology: The New Frontier

The nature of biotechnology was changed forever by the development of recombinant DNA technology (commonly referred to as genetic engineering). This modern biotechnology enables both the design and transfer of foreign genes into target organisms (transgenics) and, thereby, permits engineering of specific traits.

The first recombinant DNA experiments, carried out in 1973, involved *Escherichia coli (E. coli)*, a common and usually harmless bacterium found in human gut. Significant advances in molecular biology and related disciplines over the past 25 years provided necessary information and new tools once envisioned only in the realm of science fiction. Examples include: growing human cells and tissues outside of the body (cell/tissue culture); targeting genetic modifications of plants and animals; designing drugs that can be targeted to specific organisms or malignant cells; and engineering microorganisms to destroy polluting chemicals. Development of new molecular tools has already had tremendous impact on many overlapping human activities including agriculture, medicine and commerce, and is opening up opportunities for refashioning our way of life in the next century.

Genomics. The Human Genome Initiative provides a solid foundation for the biotechnological revolution. Initiated by a handful of scientists working in different areas of molecular biology, this project is now embraced by thousands of physicians, agriculturalists and entrepreneurs. Begun in 1990, the goal of the human genome project is to determine the sequence of the 3 billion bases that make up the human genome (genetic blueprint). This information will be stored in computer databases accessible to scientists worldwide. Molecular biologists are also analyzing the genome of several other target organisms including *E. coli*, fruit fly, mouse, pig and cow.

Sequencing and cataloging hundreds of thousands of genes is an enormous task,

requiring an investment of billions of dollars from public and private sectors. In addition, this initiative involves collaborations between thousands of molecular biologists, who isolate and sequence DNA, engineers, who build powerful sequencing robots, and computer scientists, who develop novel technologies for storage and analysis of DNA sequences. Information generated by the Human Genome and related initiatives is quickly disseminated through public electronic databases and used by all researchers who have access to the Internet.

To date, only about half or less of the human and pig genomes have been sequenced. Even so, data generated through these efforts have had tremendous impact on biomedical and agricultural research and practice, providing unprecedented understanding of genetic and cellular mechanisms regulating reproduction, growth and disease. Whether enabling identification of molecular markers of production traits in domestic animals, facilitating the identification of heritable diseases, or providing unique insight into mechanisms regulating critical life processes or disease states, discoveries spinning out of the Human Genome Initiative are occurring at a truly staggering pace.

Transgenics. Progress in genomic research stimulates development of novel technologies that not only allow precise characterization of small (e.g. bacteria) and large (e.g. plants and animals) organisms, but also provide information necessary for customizing their genetic blueprint. Until recently, selective breeding was the only way to improve domestic animals genetically for traits such as milk yield, rate of weight gain, meat quality, and wool characteristics. During the 1980s, advances in genetic engineering and embryo manipulation technologies made the first genetic customization of domestic animals possible, through procedures involving the introduction of specific foreign genes into fertilized eggs (see Table 1). Adoption of new molecular techniques by agricultural scientists led to the development of transgenic (containing foreign genes) animals and crops. Over the last 10 years transgenesis has become an increasingly powerful technique for the expression of pharmaceutically valuable proteins in the mammary glands of large animals. This led to the development of "pharming", a new agricultural industry born from the idea that milk from transgenic farm animals can be a source of novel drugs of medical and commercial value. Examples of proteins made by transgenic approaches include: (i) protein C, a blood clotting agent, made by a cow genetically modified by GenPharm researchers; and (ii) the cystic fibrosis transmembrane receptor protein expressed in goats and produced by Genzyme Transgenics as a therapy for cystic fibrosis. Transgenesis has also been applied to modify commercially important plants. Agricultural scientists have introduced many foreign genes into crops to improve pest and drought resistance, as well as other traits. Recent developments in plant transgenics make it possible to design plants that can actually produce synthetic polymers used in plastics or as lubricants. Such technology could provide alternatives to petrochemicals. Similarly, plants can be engineered to express animal proteins, such as insulin, used in the treatment of diabetes. Clearly, transgenics has the potential to redefine agriculture and our concept of renewable resources.

Animal cloning. "Pharming" technology moved a step closer to commercial reality when DNA from the mammary gland of an adult sheep was substituted for that in an otherwise normal egg in order to produce a sheep named 'Dolly', the first mammal to be cloned from an adult. Such experiments were

quickly replicated in other laboratories, which soon announced successful cloning of mice, pigs, cows and chimpanzees.

The ability to make identical copies of mammals represents an important milestone not only in animal research but also in agricultural and medical biotechnology. The prospects for animal cloning are endless. Animal cloning will provide researchers with genetically identical animals. Consequently, fewer animals will be needed for experimentation and research efficiency will be dramatically improved. One of the most immediate advantages of animal cloning will be in the area of commercial production of pharmaceutically important proteins in transgenic goats, pigs and cows. Genetic manipulation and cloning, when combined, will allow scientists to produce genetically customized domestic animals with the efficiency and predictability required by industrial quality controls. Engineered animal clones may also be used to provide organs for human transplantation.

The Business of Biotechnology

The business future for biotechnology should be considered robust, albeit with high competitive economic risk. Today, breakthroughs and innovations in biology, such as discovery of a new biochemical pathway, a new hormone, a new gene, or development of a new technology with applications to human health and(or) agricultural productivity always seem to be just around the corner. This is the "engine" driving the biotechnology era and the industry. Recent examples of such discoveries include: leptin, myostatin and human embryonic stem cells. These breakthroughs can have remarkable economic impact. For example, in the fall 1998, a start-up biotech company Geron Corp, released a report on the derivation of human embryonic stem cells. With these cells, it may be possible to grow tissues or organs for human transplants, to replace cells of the immune system when they malfunction, and to treat a host of degenerative diseases. Upon announcement, Gyron Corp. stock instantaneously leaped from under $10/share to nearly $25/share. While stock prices stabilized and declined, the prospect of this breakthrough illustrates the volatility, and some of the business economics of biotechnology. For an agricultural example, if a biotechnology came on line for the swine industry that had a return/cost ratio of $5 and 50% penetrance in the slaughter hog market, and assuming this represents 50 million hogs/year, a company could recoup its R&D investment in one year. Without a competitor, the technology could be a "cash-cow" for several years.

Many small start-up companies have appeared in recent years, built completely around a few selected products from molecular biotechnology. As with any industry, these biotech companies create jobs and multiplier economics for their state and region. In some cases, these small companies can develop proof of a concept more easily than established corporate giants. Regardless of size, the single most important aspect of corporate business landscape which favors investment in discovery and development of selected biologies or technologies relates to the ability to patent and/or license rights. Patent laws, which start the patent clock from the point of filing disclosure as opposed to the time of patent issuance, have made competition more fierce. In fact, it may be financially more logical to purchase or form alliances with companies possessing intellectual property rights than to develop a technology or product directly. Nevertheless, a high percentage or exclusive market share of a breakthrough technology with patent protection could be worth billions. The magnitude of the

financial gain must be substantial and worth the risk, as it may take a company a decade to bring a product or application to the market with discovery and development costs exceeding a quarter of a million dollars before a single dollar is invested into marketing!

Development of a biotechnology-driven product with application to agriculture occurs in phases and usually takes several years before it enters the marketplace. Efficacious technologies may be shelved for many reasons. The decision making process for product development, while relevant to the future of biotechnology, is quite complex and beyond the scope of this presentation. An established company typically has multiple, focused divisions. Within each of the divisions there are opportunities for people with a variety of skills. A list of corporate divisions and therefore areas of expertise needed could include: Research and Development (which may or may not include Discovery), Quality and Production Control, Sales, Marketing, Regulatory Affairs, Legal Affairs, and Management. People with virtually all levels of education are needed. The broad area of biotechnology represents one of the fastest growing areas in the workforce. By 2000, over 1500 US biotechnology companies will be producing over $50 billion in revenue and employing over 500,000 people.

Through employment, agribusiness will continue to touch the lives of 60-70% of the US population and biotechnology is permeating all of agribusiness at ramp speed. From an animal science perspective, young people with knowledge of animal agriculture, who possess skill sets and understanding of cell and molecular biology, as well as mathematical requirements and computer skills needed for bioinformatics, should have a bright employment future. As with nearly all disciplines, corporations rate highly the need for graduates to have effective communication, leadership and problem solving skills to complement the technical skills. For the livestock producers in the next millennium, there will be ever increasing pressure to be familiar with scientific and technological advancements just to survive.

University-Industry Alliances

All commercial technologies and inventions are born from human understanding of fundamental processes. Animal biotechnologies are no exception. The fact that biotechnology is on Wall Street illustrates both the practical and real economic value of basic life sciences. Obviously, whether we are motivated purely by curiosity or profit, knowledge remains our most important form of capital. However, in science as in industry, funds fuel the fire.

If the cost of knowledge is high, the cost of innovation is higher, both in terms of cash and human capital. Provided with a base of operation that may include an office, a laboratory and some rudimentary equipment, university faculty are expected to identify and obtain much if not all of the support for their research from sources outside of their institutions. University scientists conducting research involving animals must compete for support from federal agencies such as the National Science Foundation (NSF), the National Institutes of Health (NIH), and the United States Department of Agriculture (USDA). Even with very recent projections of increased funding in some of these arenas, competition for support is fierce, and many excellent ideas remain little more than that due to lack of funds. However, the demonstrated profit potential inherent in novel applications of basic knowledge has established the university-industry alliance as an increasingly important venue for research funding.

Industry sponsorship of research at universities is growing as opportunities for technology development and transfer to the private sector increase, and other funding resources change or disappear. Funding pressures in both university and industry sectors have faculty members learning about patent procedures and intellectual property, and industry sponsors evaluating the relative merits of sponsoring research and development (R&D) programs at institutions of higher learning as a means of reducing their costs in terms of both facilities and personnel.

Under the best of circumstances, university-industry alliances can benefit all parties. Faculty members obtain funds for research. Universities recover costs that can be used to improve facilities, upgrade equipment and enhance the academic environment for students and faculty alike. Royalties from patents or inventions generated through collaborative R&D programs may be shared. Industry sponsors and the pubic profit from the realization of ideas and generation of products and(or) processes that enhance corporate and general economic growth. Increasingly, 'biotech incubators', supported through university-industry collaborations, are spawning start-up biotech companies that can enhance the economic viability of the university community, the region and, in time, even the nation.

Summary

The challenge of developing environmentally sound technologies and systems that will ensure a nutritious, safe, economical food supply for the people of the world is immense. To meet this challenge in the face of increasing world population and changing economic and political landscapes will require every bit of our resolve, and a tremendous investment of intellectual capital.

Though tenets of animal husbandry and breeding will remain important, an armamentarium of new ideas and, technologies, born from understanding of fundamental processes such as gene expression, growth, development, reproduction and metabolism, will be essential if we are to progress at an adequate pace. In this regard, the future is bright. Opportunities abound for students of bioagricultural sciences to explore, imagine and, ultimately, invent solutions to the many problems we face. It is very clear that the language of agricultural biotechnologies in the new millennium, as is already the case, will be grounded in cell and molecular biology, biochemistry, physiology and computer-based bioinformatics.

Lines between biomedical and agricultural sciences have never been more blurred. Discoveries with biotechnological applications in one arena inevitably have complementary applications in the other. Increasingly, it may not only be pointless, but malignantly myopic, from scientific, economic, and administrative standpoints, to make gross distinctions between fundamental efforts in these areas. University-industry alliances will play increasingly important roles in facilitation of discovery, as well as in stabilizing academic environments and ensuring a source of bright young scientists and agriculturalists. Though challenges will always loom, opportunities in animal biotechnology have never been greater.

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Table 1. Milestones in the History of Biosciences and Animal Biotechnology

Date	Event	Implication(s)
3-9000 B.C.	Domestication of cattle and horses / livestock.	Birth of animal agriculture.
8-9000 B.C.	Orchiectomy of young bulls.	Growth/behavior modification.
1400 B.C.	Artificial incubation of eggs.	Birth of poultry 'industry'.
3rd Century B.C.	Embryo development systematized.	Birth of embryology.
1651	Circulation of blood (Harvey).	Modern Physiological principles.
1665	Plant compartments called "cells" (Hooke).	Concept of "cells" born.
1674	Simple lenses used to see microscopic organisms (Leeuwenhoek).	Birth of microscopy.
1760	Genetic selection to improve livestock.	"Engineering" of livestock begins.
1780	Successful artificial insemination (dogs).	Birth of "AI".
1856	Existence of microbes demonstrated (Pasteur).	Germ theory described.
1859	*On the Origin of Species* published (Darwin).	Theory of evolution.
1891	First successful embryo transfer (Heape).	Embryo manipulation technology established.
1900	Application of artificial insemination in food animal breeding (Ivanov).	Increased pace of genetic improvement.
1919	Term "biotechnology" coined (Ereky).	'Biotechnology' in the lexicon.
1935	First virus discovered.	Vectors for genetic mutations.
1944	DNA identified as the genetic material.	Molecular basis of heredity.
1947	Elements of DNA are transposable (McClintock).	Concept of natural genetic engineering.
1949	Cryoprotectants / cyropreservation of sperm.	Freezing/shipping gametes & cells.
1950's	Mammalian tissue culture technology.	Tissues/cells grown in laboratory.
1953	DNA described as 'double-helix' of nucleotides (Watson and Crick).	Gene structure described.
c1957	Liquid nitrogen cyropreservation	Long-term storage of cells/gametes.
1960	Radioimmunoassay (RIA) of hormones (Yalow).	Assay of hormones at physiological levels.
1966	Microinjection technology developed.	Physical manipulation of genes.
1973	DNA from one organism 'recombined' with that of another.	"Recombinant DNA" technology.
1975	Monensin approved as feed additive.	Improved metabolic efficiency (cattle).
1977	Human gene cloned (Itakura).	Genes can be copied.
1978	Commercial estrous synchronization (cattle).	Timed 'AI' and embryo transfer.
1980-81	First transgenic mice (mice bearing foreign genes).	Mammalian genetic engineering.
1981	Transfer of murine embryonic stem (ES) cells.	Totipotent ES cells aid transgenics.
1983	Polymerase chain reaction (PCR) described (Mullis).	Rapid amplification, detection and cloning of genes.
1985	First transgenic domestic animals produced (pig).	Genetic engineering of livestock.
1987	Targeted gene disruption (gene 'knockout').	Loss of gene function studies/therapies.
1989	Targeted DNA integration and germ-line chimeras (mice).	Potential for tissue engineering and gametic transmission of transgenes.
1993	Recombinantly produced growth hormone (rbGH / 'POSILAC') approved for dairy cows.	Pharmacologically enhanced milk production.
1993-95	Functional nucleic acid vaccines introduced.	Engineering medicines.
1996	Sheep cloned by somatic (body) cell transfer.	True mammalian cloning possible.
1998	Human embryonic stem cells derived.	Multiple therapies for genetic and immunological disorders.

FORAGE QUALITY: IT'S IMPORTANCE TO EFFICIENT LIVESTOCK PRODUCTION

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Successful livestock production is dependent on a forage program which will supply large quantities of adequate quality, homegrown feed. A major percentage of the feed units for beef (83%) and dairy (61%) cattle come from forages. In addition, forages supply an estimated 91%, 72%, and 15% of the nutrients consumed by sheep and goats, horses, and swine, respectively. I think Dr. Don Ball addresses the importance of "Forages in Alabama" best in the heading of the Auburn University Forage Update Newsletter: "Forage crops occupy more open land in Alabama than all other crops combined. They provide nutrition for beef and dairy cattle, horses, sheep and other livestock. They are important in crop rotations. They protect the environment by reducing erosion and improving water quality, they provide food and cover for wildlife, and they beautify rural settings."

There are many important factors involved in efficient livestock production: animal genetics and breeding, reproduction, herd health, nutrition and marketing to name a few. From the nutrition, feeding and forage standpoint, I consider four factors to be of paramount importance: 1) establish for stand, 2) produce for yield, 3) harvest for quality, and 4) market for profit.

Establish for stand - Certainly we need a good stand if we are going to get high yields. There are many important steps in forage crop establishment that can help ensure the potential of getting a good stand of the desired species/mixture including: soils, fertility, species and varieties, quality seed and inoculum, seeding method, rates and dates, pest control and harvest management. Getting a good stand is the first and an important step in achieving higher yields, acceptable quality and stand persistence.

Produce for yield - High yields are important from an agronomic and economic standpoint. The more bales of hay, loads of silage, or days of grazing obtained from a particular field with the same inputs will usually improve production efficiency. Fertility, pest control and utilization management can have a marked impact on overall yields.

Harvest for quality - At some point during the production phase, we bring in harvest equipment or open gates to allow animal access. It is at this point that we determine the potential quality. Many factors and opportunities are important and will be discussed later.

Market for Profit - Up to this point we have only spent money. It is during the market phase that we have a potential for profit. We must market our forages directly as hay, silage, seed, sprouts, etc. or indirectly as meat, milk, wool, animals, hunting permits, etc. before we have a potential for profit.

Each of the four major factors above are important and other speakers on the program and other programs will deal with many important aspects concerning these points. I want to spend the remainder of my time focusing on the "QUALITY" aspect.

What is Forage Quality?

Forage quality means different things to different people. Forage quality varies tremendously among and within forage crops. Forage quality needs varies among and within animal species. Forage quality has been defined in terms of protein, fiber, lignin content, relative feed value, color, smell, leafiness, fineness of stems, total digestible nutrients, and other physical and/or chemical components. All of these components have some merit, but all fall short of clearly defining forage quality in useful/practical terms. However, factors such as average daily gains, conception rates, milk production, wool production, etc. are reliable indicators of forage quality. Forage quality can be defined as: the extent to which a forage (pasture, hay, silage) has the ability to produce a desired animal response. With this working definition we realize that we must consider the animal. As an example, a high producing dairy cow needs a higher quality feed than a dry pregnant beef cow. A basic principle in efficient livestock production is to know forage quality and match that quality to animals needs.

Factors Affecting Forage Quality

Animal Considerations - The ultimate test of forage quality is animal performance. Quality can be considered satisfactory when animals give the desired level of performance. Factors which influence animal performance include: 1) Palatability - Will the animals eat it? In general, high quality forages are highly palatable and vice versa. Animal selection of one forage species over another depends on smell, touch and taste. Palatability may be affected by texture, leafiness, fertilization, dung and/or urine patches, moisture content, pest infestation, or compounds that cause a forage to be sweet, sour, or salty. 2) Intake - How much will they eat? Forage must be palatable if it is to be consumed in adequate quantities to meet animal needs. In general, the higher the quality, the more that will be consumed. 3) Digestibility - Of the forage consumed, how much will be digested? Once the forage is consumed, it must be digested to be converted to animal products. Digestibility (the portion of the forage consumed in passage through the alimentary tract) varies greatly, depending on the type of material consumed by the animal. Immature, leafy grasses may be 80 to 90 percent digested, while digestibility of mature stemmy material is often below 50 percent. 4) Nutrient content - Once digested, does the forage provide an adequate level of nutrients? Leafy growing forage plants usually contain 70 to 90 percent water. With this variation, it is best to express forage yield and nutrient content on a dry matter basis. The constituents of forages can be divided into two main categories: a) those present as cell contents or the non-structural part of the plant tissue (protein, sugar, and starch); and b) those which make up the structural components of the cell wall (cellulose, hemicellulose, and lignin). High quality forages are high in protein, energy, vitamins and minerals and low in fiber and lignin. 5) Anti-quality factors - Depending on the plant species, time of year, environmental conditions, and animal sensitivity, various compounds can reduce animal performance, cause sickness, or ultimately death of the animal. Included in this group of compounds are: tannins, nitrates, alkaloids, cyanoglycosides, estrogens, mycotoxins, and other unidentified constituents. High quality forages must be free of anti-quality factors which are harmful to animals consuming it.

Plant Considerations

Many factors affect quality of the forage crops we grow for pasture, hay, or silage

including: species, varieties, fertility, pest damage, growing conditions, harvest and storage techniques, grazing management, plant age, stage of maturity, and climate and weather changes. Of the above factors, species and stage of maturity usually offer the greatest opportunity to improve forage quality the most.

Plant Species - Considerable variation exists in quality among and within forage species. In general, legumes are higher in quality than grasses. Cool season grasses are generally more digestible than warm season grasses. Cool season annual grasses are usually more digestible than cool season perennial species at the same stage of maturity. Considerable variation also exists among varieties within species. Plant breeders have improved, and continue to improve forage quality within species. For example, Coastcross-1 bermudagrass is approximately 12 percent more digestible than Coastal. Other examples include low-tannin sericea lespedeza varieties, multi-leaf alfalfa varieties, grazing tolerant alfalfa, and reduced-bloat alfalfa.

Stage of Maturity - Of all the factors affecting forage quality consumed as pasture, hay or silage, stage of maturity when harvested is the most important and the one in which greatest progress can be made. As legumes and grasses advance from the vegetative (leafy) to the reproductive (seed) stage, they become higher in fiber and lignin content and lower in protein content, digestibility, and acceptability to livestock. Grasses may have a protein content of over 30 percent when in an immature leafy stage but drop to less than 8 percent when mature. Digestibility drops with age in both grasses and legumes and may decline at rates of over 0.5 percent per day. The optimum stage for harvesting forage crops for hay or silage is always a compromise among yield, quality, and stand persistence. In general, the best compromise position for first harvest is when the plants are changing from the vegetative to reproductive stage. In grasses it represents the boot to early head stage; in legumes bud to early flower.

Summary

Efficient livestock producers must produce high forage yields, but additional emphasis must be placed on quality. Producing high quality forage requires attention to details from pre-establishment to post-harvest. It is not necessary to understand how forage quality is measured in a laboratory, but some understanding of how forage quality affects animal performance is important to efficient livestock production. We need to know the quality of feed available either as pasture, hay or silage and the nutritional needs of the animals we are feeding. Knowing this we can match feed based on quality to animal based on requirements. We need to realize the impact plant species and stage of maturity have on forage quality and animal performance. It is the total quantity of available nutrients in a given amount of forage, and not the total quantity of forage, that is of primary importance in obtaining good animal performance.

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EFFECTS OF GROUND-LEVEL OZONE EXPOSURE ON BIOMASS YIELD AND QUALITY CHARACTERISITICS OF SELECT WARM-SEASON FORAGES

Russell B. Muntifering

SUMMARY

Early (May 7, 1997)-planted and late (July 10, 1997)-planted 'Pensacola' bahiagrass (*Paspalum notatum* Flugge) and a single planting (May 9, 1997) of 'Interstate '76' sericea lespedeza (*Lespedeza cuneata*) were grown in open-top chambers to which added air had been carbon-filtered (CF), representative of that found at the cleanest air quality sites in the USA; non-filtered (NF), representative of ambient air in the Auburn, AL area; or enriched with ozone (O_3) to twice ambient level (2X), representative of that found in large metropolitan areas of the southeastern USA. Biomass yield of primary-growth forage was greater ($P<.1$) for CF than NF (1165 vs 779 lbs dry matter/acre), and tended to be greater for CF than NF regrowth forage from early-planted bahiagrass. Concentrations of neutral detergent fiber (NDF) were greater ($P<.1$) for 2X than NF primary-growth forage (67.2 vs 64.8%) and for 2X than NF regrowth forage (67.2 vs 64.6%) from early-planted bahiagrass. Similarly, concentration of acid detergent fiber (ADF) was greater ($P<.1$) for 2X than NF regrowth forage (31.3 vs 29.5%) from early-planted bahiagrass. No differences in biomass yield or chemical composition were observed among treatments for primary-growth forage from late-planted bahiagrass, although biomass yield tended to be lower and concentrations of NDF and ADF tended to be greater for 2X than NF regrowth forage. Sericea lespedeza did not germinate nor grow well under 2X conditions, and biomass yield of neither primary-growth nor regrowth forage differed between CF and NF treatments. However, CF regrowth forage had greater ($P<.1$) concentration of crude protein (15.9 vs 14.3%) and lower ($P<.1$) concentration of NDF (44.3 vs 47.1%) than did NF regrowth forage. Altered biomass yield and quality of warm-season forages exposed to ground-level O_3 may have nutritional implications to their utilization by herbivores.

Introduction

Tropospheric (i.e., ground-level) ozone (O_3) is the most significant phytotoxic air pollutant in the USA, (US EPA, 1986), and climate change models predict that O_3 concentrations globally will continue to increase from 0.3 to 1.0% per year for the next 50 years (Thompson, 1992). Once thought to be confined exclusively to large metropolitan areas, air pollutants such as tropospheric O_3 are now known to be transported long distances from urban centers such as Atlanta, GA and Birmingham, AL to rural agricultural areas (Chameides and Cowling, 1995). In the South there were 26 localities which had been classified in non-attainment of the National Ambient Air Quality Standard (NAAQS) for O_3 (NRC, 1991) prior to its most recent revision, with approximately 12% of the region's agricultural cropland located in these non-attainment areas (Lefohn, 1992). Visible foliar injury from O_3 is widespread throughout the region, including many other areas currently classified as being in attainment of the NAAQS for O_3 (Shaver et al., 1994).

Negative impacts of O_3 on growth and nutrient composition of numerous cool-season forage species have been well documented (Miller, 1988). However, nothing is known about O_3 effects on these characteristics in warm-season forage species commonly utilized for animal production and other applications in the southern USA. Understanding how tropospheric O_3 influences these economically important forage species is of tremendous importance to policymakers and resource managers, particularly in light of EPA's recent modification of the human health-based (primary) NAAQS for O_3 and the agency's interest in establishing a new secondary standard based on ecological impact.

Experimental Procedures

Early (May 7, 1997)-planted and late (July 10, 1997)-planted 'Pensacola' bahiagrass (*Paspalum notatum* Flugge) and a single planting (May 7, 1997) of sericea lespedeza (*Lespedeza cuneata*) were grown in large (4.8 m ht. x 4.5 m dia.) open-top chambers (OTC) to which added air had been carbon-filtered (CF), representative of that found at the cleanest air quality sites in the USA; non-filtered (NF), representative of ambient air in the Auburn, AL area; or enriched with ozone (O_3) to twice ambient level (2X), representative of that found in large metropolitan areas of the southeastern USA. Ozone was generated by passing pure oxygen through a high-intensity electrical discharge source and was added to the OTC 12 hr/day (0900-2100 hr), 7 days/wk.

Forages were planted in pots (15-L capacity) at recommended seeding rates and depths, and eight pots of each forage planting were placed into each of six OTC and exposed to CF, NF or 2X treatment (two OTC replications/O_3 treatment). The soil used was a Norfolk sandy loam characteristic of the Southern Coastal Plain. Six weeks postseeding, each pot of early-planted bahiagrass and the single planting of sericea lespedeza received 4 g of a slow-release fertilizer (14-14-14), and bahiagrass received an additional 4 g of a commercial 29-3-4 fertilizer. Late-planted bahiagrass received 4 g/pot of each fertilizer type at the time of seeding. Plants were watered as necessary to maintain moisture at near field capacity.

Primary growth of early-planted bahiagrass was harvested at 12, 18 and 24 wks postseeding at approximately early-vegetative, late-vegetative and early-bloom stages of maturity, respectively, and vegetative regrowth forage from the first primary growth cutting was harvested at 4-wk intervals. Late-planted bahiagrass was harvested at 9 and 15 wks postseeding at approximately early-vegetative and early-bloom stages of maturity, respectively, and vegetative regrowth forage from the first primary growth cutting was harvested at 3-wk intervals. Sericea lespedeza was harvested at 12, 18 and 24 wks postseeding at approximately early-vegetative, early-bloom and mid-bloom stages of maturity, respectively, and vegetative regrowth from the first primary growth cutting was harvested at 6-wk intervals. Forages were cut to 1" aboveground length, dried at 120° F, ground in a Wiley mill and analyzed for select chemical quality characteristics using standard procedures (AOAC, 1990; Goering and Van Soest, 1970). Paired comparisons were made between CF and NF treatments and between 2X and NF treatments in order to evaluate biological response to ground-level O_3 reduction and elevation, respectively, compared with ambient conditions.

Results and Discussion

Average daytime O_3 concentrations over the entire 24-wk experiment were 22, 45 and 91

ppb, respectively, for CF, NF and 2X treatments. Average ambient daytime O_3 values peaked in mid-May and again in late August-early September at 50-60 ppb, and highest individual ambient O_3 values were recorded in late July, late August and mid-September at >90 ppb.

Biomass yield of primary growth forage was greater ($P<.1$) for CF than NF and tended to be greater for CF than NF regrowth forage from the early-season bahiagrass planting (Table 1), indicating a positive yield response to ground-level O_3 reduction. Concentrations of neutral detergent fiber (NDF, or total fibrous constituents) were greater ($P<.1$) for 2X than NF primary growth and regrowth forages. Similarly, concentrations of acid detergent fiber (ADF, or lignocellulose) were greater ($P<.1$) for 2X than NF regrowth forage and tended to be greater for 2X than NF primary growth forage. Crude protein concentration was lower ($P<.1$) for CF than NF regrowth forage, presumably reflecting dilution by carbohydrate and a trend toward greater biomass yield compared with NF. However, differences in total protein yield between CF and NF forages suggest that O_3 reduction may favorably alter plant nitrogen metabolism by mechanism(s) other than simply increasing biomass yield. No differences in biomass yield or chemical composition of primary growth forage from late-planted bahiagrass were observed in response to ground-level O_3 reduction or elevation, although yield tended to be lower and concentrations of NDF and ADF tended to be greater for 2X than NF regrowth forage (Table 2). Similar negative forage quality changes due to O_3 have been observed in cool-season grasses such as tall fescue. Inconsistency of response in primary growth forage appears to be influenced by seasonal fluctuations in O_3 levels relative to time of planting, whereas the fairly consistent negative effect of O_3 on regrowth forage suggests a possible cumulative impact from which the forage does not readily recover, even with frequent cutting.

Sericea lespedeza did not germinate nor grow under 2X conditions, so remaining treatments enabled an evaluation solely of O_3 reduction effects (CF) compared with ambient conditions (NF). Biomass yield of neither primary-growth nor regrowth forage differed between CF and NF treatments (Table 3). However, CF regrowth forage had greater ($P<.1$) concentration of crude protein and lower ($P<.1$) concentration of NDF than did NF regrowth forage. Unlike the response of early-planted bahiagrass to O_3, total protein yield favored the NF treatment for reason(s) that are not readily explainable. Interestingly, similar responses to O_3 reduction have been reported elsewhere for cool-season legumes such as white clover, and they are thought to be related more to canopy structure and resource (e.g., light, water, nutrients) acquisition patterns in CF forages rather than ozone exposure, per se. Such considerations would certainly be more relevant in a newly-seeded than established forage stand because new seedlings are continually being recruited throughout the first growing season and must compete with more mature plants for resources during establishment.

Implications

Altered biomass yield and quality characteristics of select warm-season forages to ground-level O_3 may have negative nutritional implications to their utilization by herbivores in the short term. Longer term, changes in plant establishment, growth, resource acquisition and allocation, and chemical composition could lead to large-scale modifications of structure, function and productivity of forage ecosystems.

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Table 1. Biomass yield and chemical composition of early-planted bahiagrass exposed to ground-level ozone[a]

Item	Ozone exposure[b]			SEM
	CF	NF	2X	
Primary-growth forage				
Biomass yield, lbs/acre[c]	1,165	779	780	130
Crude protein, %	15.6	15.9	16.5	.7
Neutral detergent fiber, %[d]	64.7	64.8	67.2	.6
Acid detergent fiber, %	28.1	28.1	30.9	1.5
Regrowth forage				
Biomass yield, lbs/acre	749	537	555	110
Crude protein, %[c]	16.2	18.8	18.0	.5
Neutral detergent fiber, %[d]	65.2	64.6	67.2	.6
Acid detergent fiber, %[d]	29.3	29.5	31.3	.5

[a]Values expressed on a dry matter basis.
[b]CF = carbon-filtered air; NF = non-filtered (ambient) air; 2X = twice ambient air.
[c]CF vs NF ($P < .10$).
[d]2X vs NF ($P < .10$).

Table 2. Biomass yield and chemical composition of late-planted bahiagrass exposed to ground-level ozone[a]

Item	Ozone exposure[b]			SEM
	CF	NF	2X	
Primary-growth forage				
Biomass yield, lbs/acre	698	743	676	129
Crude protein, %	10.5	13.4	13.4	1.2
Neutral detergent fiber, %	62.5	64.1	64.2	1.1
Acid detergent fiber, %	28.4	28.7	28.3	1.7
Regrowth forage				
Biomass yield, lbs/acre	585	530	448	89
Crude protein, %	18.2	18.9	19.9	.4
Neutral detergent fiber, %	61.8	61.2	63.9	.9
Acid detergent fiber, %	26.6	26.2	27.6	.6

[a]Values expressed on a dry matter basis.
[b]CF = carbon-filtered air; NF = non-filtered (ambient) air; 2X = twice ambient air.

Table 3. Biomass yield and chemical composition of sericea lespedeza exposed to ground-level ozone[a]

Item	Ozone exposure[b]		SEM
	CF	NF	
Primary-growth forage			
Biomass yield, lbs/acre	1,120	1,029	270
Crude protein, %	15.2	16.4	.6
Neutral detergent fiber, %	47.3	47.4	.3
Acid detergent fiber, %	32.9	32.4	.1
Regrowth forage			
Biomass yield, lbs/acre	253	338	27
Crude protein, %[c]	15.9	14.4	.4
Neutral detergent fiber, %[c]	44.3	47.2	.1
Acid detergent fiber, %	32.7	34.1	.5

[a]Values expressed on a dry matter basis.
[b]CF = carbon-filtered air; NF = non-filtered (ambient) air; 2X = twice ambient air.
[c]$P < .10$.

SUPPLEMENTATION STRATEGIES FOR STOCKER CATTLE

Stephen P. Schmidt

SUMMARY

A source of fermentable starch fed in small quantities may improve the utilization of forage protein in cattle grazing immature, growing forages without decreasing cellulose digestion and result in faster gains. Previous Auburn research has shown that starch and protein utilization is greater when urea-treated, high-moisture (UT) milo is fed in high-grain feedlot diets than when dry milo is fed. Thus, the objective was to evaluate UT milo as a supplement for steers grazing cool-season forages. In each of three years, 45 crossbred steers (500 to 600 lb initially) were assigned to one of five supplement treatments: (1) control, no supplement; (2) UT milo at 0.4% of BW (body weight); (3) UT milo at 0.8% of BW; (4) UT milo at 0.4% of BW + Rumensin-60 at 0.15% of supplement; (5) dry milo at 0.4% of BW. Milo was cracked prior to feeding and was fed daily in feed bunks in the paddocks. The response to supplement was linear, *i.e.*, gains increased as the amount of milo increased; UT milo was equal to dry milo as a supplement; and Rumensin had no effect on gain.

Introduction

Supplements, such as corn, sorghum grain (milo), broiler litter and cottonseed meal, can be used successfully to improve the overall utilization of forages by grazing livestock. The type of supplement used, however, will depend upon the type of forage being grazed and the goals of the producer. One of these goals is to provide a better balanced supply of nutrients to increase daily gains of stocker cattle grazing cool-season forages, but at the same time, a concurrent goal should be to optimize forage utilization and minimize substitution of supplement for forage.

Concepts that determine the type of supplement to provide for cattle grazing cool-season forages are different from those for lower quality forages. Generally, high-protein feeds such as soybean meal, cottonseed meal, and legumes are good choices for lower quality forages because they result in improved digestibility and greater consumption of the forage by cattle. However, cool-season forages such as rye, ryegrass, and wheat have a high protein content and are highly digestible, but steers grazing these forages seldom gain faster than 2.2 lb. per day. Recent research has shown that the protein in cool-season forages is rapidly digested by the rumen microorganisms, and much of the nitrogen is lost in the urine. The problem appears to be due to inadequate amounts of readily available energy in grass that prevents the microorganisms from converting excess nitrogen to new microbial protein that can be utilized by the steers.

Recent research conducted at Oklahoma State University, Texas A&M, and Clemson indicates that the amount of corn fed (and presumably other grains) is important. When 2 to 3 lb. of grain was offered to 500-lb. calves (0.4% to 0.6% of body weight), the efficiency of added gain was excellent (5 to 6.5 lb. of grain per lb. of added gain). When the amount of grain exceeded 0.75% of body weight, there was an approximate one-to-one substitution of grain for forage. Thus, there was an improvement in the rate of gain, but it took more grain per pound of added gain. The higher levels of grain may be used to stretch

forage supplies or increase stocking rate and the lower levels be used to attain efficient added gains.

Sorghum grain (milo) grows well in Alabama and is more tolerant than corn of the hot, sometimes dry summer weather. Research conducted at the Auburn University E. V. Smith Research Center has shown that urea has the potential to preserve milo harvested at a high-moisture content and to improve milo feeding quality. Urea mixed with high-moisture grain prior to storage cracks and softens the seed coat, prevents the growth of molds, reduces bacterial counts, and, at least in low-tannin varieties, makes the starch more digestible. The main objective of the research reported here was to evaluate high-moisture milo that had been preserved with urea as a grain supplement for stocker cattle grazing cool-season forages. Urea treatment of milo results in a supplement that has more crude protein than necessary, but the improved starch availability should improve utilization of the forages by cattle. In this situation, the urea should be considered simply as a preservative that allows high-moisture milo to be stored in an open bay without spoilage due to molds or microbial growth.

Experimental Procedures

Milo was grown at the E. V. Smith Research Center, harvested at approximately 30% moisture content, mixed with urea (3 lb. urea per 100 lb. of milo dry matter), and stored in a covered bay. Fifteen 1.5-acre paddocks were seeded with 'Marshall' ryegrass and were stocked with three steers per pasture to provide a stocking rate of two steers per acre. Steers averaged between 550 and 590 lb. at the start of each trial over the three years. A salt/mineral premix was available free choice. All steers were treated with Ivermectin and given Synovex-S at the initiation of the trial. Five treatments (3 pastures per treatment) were compared (UT = Urea-treated, high moisture):

1) No supplement
2) UT Milo at 0.4% of BW (body weight) daily
3) UT Milo at 0.8% of BW daily
4) UT Milo + Rumensin (0.15% of supplement) at 0.4% of BW daily
5) Dry Milo at 0.4% of BW daily

The amount of grain offered was based on the average weight of the steers on a particular paddock and was adjusted every two weeks. All milo was cracked before being fed. Forage availability was determined every 28 days by measuring forage height with a disk meter.

Results and Discussion

A 3-year summary of steer performance is given in Table 1. Steers grazed 145 days (3-year average), and the overall average daily gain (ADG) was 2.78 lb/day.

TABLE 1. Effect of Milo Supplementation on Daily Gains of Steers Grazing Ryegrass (3-year average)

	Daily gain (lb/day)
No supplement	2.62
UT Milo at 0.4% BW	2.73
UT Milo at 0.8% BW	2.87
UT Milo at 0.4% BW + Rumensin	2.87
Dry Milo at 0.4% BW	2.87

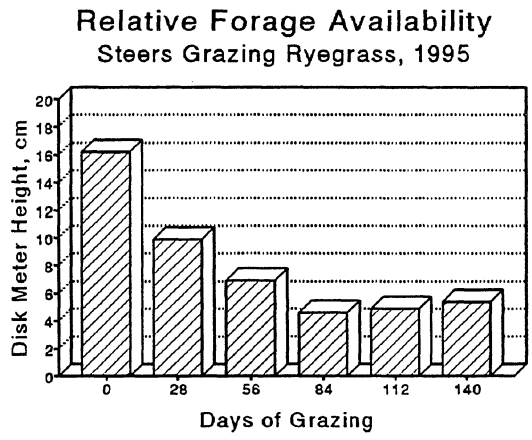
As might be expected, the response to supplement was linear; comparing no supplement to supplement at 0.4% and 0.8% of body weight,

there was a progressive increase in gain. Steer gains using UT milo was not statistically different from gains with the dry milo. Based on other Auburn grazing trials, it was hypothesized that steers receiving Rumensin in the milo at 0.4% of BW would gain as fast as those receiving the milo supplement at 0.8% of BW; this appeared to be true in this trial, but the difference was not statistically significant. One problem of feeding a grain supplement to grazing cattle is that a substitution of grain in place of forages can occur, leading to a decreased efficiency of added gain (compared to gains when no supplement was fed).

The efficiency of added gain (lb. milo consumed/lb. additional gain above the no supplement group) was approximately 2 times better at 0.4% BW compared to 0.8% BW (6-8 vs. 12-15, respectively), indicating substitution of grain for forage at the higher amount of supplement.

The main objective of this research project was to evaluate high-moisture milo that has been preserved with urea as a grain supplement for stocker cattle grazing cool-season forages. The results indicate that urea-treated milo can be used as a supplement. It is interesting that dry milo tended to result in slightly better gains in the grazing trial whereas urea-treated, high-moisture milo always was superior to dry milo in the earlier feedlot trials.

Relative forage availability (as indicated by disk meter height) for the first year of the grazing trial is shown in the Figure. Data for the last 28-day period, which would include most of April and some of May, are missing. There was a rapid reduction in forage availability during the first 56 days, then a leveling off during the middle 56 days (January to March), and an increase in forage availability during the spring growing season. Steer gains were affected both by consumption of supplement and forage availability.



Implications

The type of supplement and the amount of supplement fed are important considerations for grazing cattle. For cool-season annuals, grain is generally recommended, but it should be fed at less than 0.6% of body weight if the goal of the producer is to provide a balanced supply of nutrients for the animal. Greater amounts of supplement will decrease forage digestibility and result in substitution of supplement for forage. The latter situation may be acceptable if the goal is to stretch forage supplies or increase stocking rate.

NATIVE GRASSES: DO THEY FIT IN AN ALABAMA FORAGE SYSTEM?

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SUMMARY

Native warm-season grasses of temperate origin offer an opportunity to significantly broaden the forage base for Alabama livestock production, expand the warm-season grazing period, and provide more forage options for Black Belt and north Alabama producers. There is currently interest in the potential for multiple-use that native grassland can support however, seeding failures during native grass establishment are common. Although many of the factors that lead to seeding failures can be overcome with specialized planters and seed treatment, there are soil factors involved that still need to be identified. The objective of this project was to determine if establishment success is linked to soil type and seeding date in Black Belt landscapes. Switchgrass, big bluestem, indiangrass, and a native grass mixture were broadcast seeded onto Sumter and Vaiden soils in spring, late summer, and after frost. Establishment success was higher on Sumter (pH 7.4-8.4) versus Vaiden (pH 4.5-6.5) soil. Grasses planted on Sumter soil had higher establishment success in spring and/or after frost than late summer; seasonal differences in establishment were rare on Vaiden soil. Native grasses appear to be an option worth consideration where multiple-use is a management goal.

Introduction

In the second half of the twentieth century, Alabama row crop agriculture has been eclipsed by forestry activities and livestock production. For example, 1997 cash receipts from poultry and livestock accounted for 75% of all non-forestry commodities; row crops accounted for the other 25% (AL Agric. Stats. Ser. 1998). However, the Alabama livestock industry is heavily dependent on grassland agriculture: the cow/calf industry for forage and the broiler and swine industries for management of waste nutrients. Currently, the warm-season perennial forage base in Alabama consists of a relatively small number of introduced forages of sub-tropical origin and consequently, forage availability that is highly seasonal. Native warm-season perennial grasses of temperate origin offer the opportunity to significantly broaden the forage base for Alabama livestock production, expand the warm-season grazing period (Miller and Owsley 1994) and provide more options for producers in the Alabama Black Belt and northern part of the state where the warm-season forage base is limited and fescue toxicity a serious limitation. In addition, although well-adapted to marginal soil conditions, native grasses also provide numerous advantages in terms of soil and water quality (Clark et al. 1998, Pitts et al. 1997). Indeed, until 19th century farming, logging, overgrazing, fire suppression, and forage plant and weed introductions, native perennial warm-season grasses dominated the understory of the longleaf pine-bluestem range that reached virtually unbroken from west Florida to east Texas and included the southern Coastal Plain in Alabama (Grelen and Duvall 1966). Could native grasses fit back into Alabama forage systems? And if so, what do we know about their culture, and what are the major cultural problems we still need to overcome?

One potentially viable fit for native grasses in Alabama is in situations where multiple-use of grassland is desired. There are indications that interest in permanent forage enhancement for wildlife is a growing interest. For example, Goodman et al. (1995) surveyed Conservation Reserve Program (CRP) landowners in the Alabama Black Belt and reported that >90% of them practiced, or were interested in methods for enhancement of CRP grass acreages for wildlife habitat quality. Many of these landowners established annual food plots, especially to enhance the diet of northern bobwhite they released, but they were also interested in establishment of permanent vegetative cover that would enhance both diet and sites for nesting, brood-rearing, and roosting. Observations from wildlife habitat studies in the southeast have indicated that the thick sods developed by introduced sub-tropical forages such as bermudagrass and bahiagrass restrict movement of upland bird species and their foraging activities for seeds and insects, and provide poor structural cover for nesting habitat (Askins 1993, Capel et al. 1995). On the other hand, bunchgrasses like the warm-season natives resist compaction over winter and allow wildlife to move between the bunches while overhead protection from predators is provided at the same time. However, enthusiasm for reestablishment of native warm-season perennial grasslands has been damped by lack of dependable, economically efficient stand establishment systems as well as information relative to optimum seeding rates, quantity and quality of seasonal production, and grazing capacity in Alabama environments.

A major cultural problem with all warm-season native grasses is that stand establishment is usually very slow, it often takes two to four years to reach full production potential, and complete establishment failures are quite common. Some failures may result from improper seeding depths that reduce the extent and/or rate of germination, emergence, and seedling development and thereby allow weeds to overwhelm the stand. Planting too deeply, in large part a problem related to conventional seedbed preparation and planting equipment, has been overcome in other regions of the country by no-till seeding with small-seed attachments on special grassland drills into crop residues or chemically-killed sods. Metering of native grass seed can also be difficult because of pubescence, awns, and other appendages that remain with the seed and resist removal during cleaning. Special grassland drills with aggressive seed-feeding mechanisms are needed to handle this chaffy seed. However, most Alabama forage producers are not familiar with these drills, the drills are not available locally, and the current purchase price can exceed $15,000.

Other factors known to contribute to establishment failures with native grasses are seed dormancy and water stress during development of the permanent root system. Far less is known about the relationship between soil physical, chemical, and/or biological conditions and establishment success. However, results of greenhouse studies under favorable environmental conditions indicated that soil texture is an important factor in emergence and early seedling development of switchgrass (Miller and Owsley 1994). These controlled studies of environmental factors that affect native grass establishment have been expanded to the field at the Black Belt Substation, Marion Junction to test the hypotheses that 1) landscape-level differences in soil pH and water relations can influence establishment success, and that 2) non-traditional seeding dates may offer an advantage for establishment since the life cycles

of certain problem weeds could possibly be avoided.

Experimental Procedures

Seedbeds were prepared using Roundup® and tillage on 30' by 36' plots in two separate pastures that differed in pH and water relations at the Black Belt Substation. One pasture occurred on a Sumter soil (pH 7.4-8.4; water capacity 0.12-0.15 in/in; permeability 0.06-2.0 in/hr), the other pasture on a Vaiden soil (pH 4.5-6.5; water capacity 0.10-0.15 in/in; permeability 0.06-0.20 in/hr. After tillage, plots were cultipacked then seeds of 4 different native grass cultivars and one native grass mixture were broadcast over the plots in spring (early April), late summer (early August) and after frost (mid-November); sand was added to seed to facilitate even distribution over the plots. Plots were cultipacked a second time immediately after broadcast. Four replications per season were established between spring 1995 and spring 1997. Frequency per 10 ft^2 and basal cover (BLM 1996) of native grasses were measured October 1997. Data were analyzed for each grass and the grass mixture within year, soil type, and season by analysis of variance with $P \leq 0.05$ as the level of statistical significance.

Results and Discussion

There were no differences in establishment success between years, however, significant interactions occurred between season and soil type therefore, data were combined for analysis by year and will be presented by soil type and season for each grass and the mixture.

In general, establishment success measured by both grass plant frequency (Fig. 1) and basal cover (Fig. 2) was higher for the native grasses studied when sown on the Sumter versus the Vaiden soil. Sumter soils have higher pH than Vaiden soils because of differences in parent material: calcareous Selma chalk (Sumter) versus acid, clayey sediments (Vaiden). This is consistent with the occurrence of these grasses on tall grass prairie soils that have higher base saturation levels. However, establishment success of big bluestem seedlings has been linked to the presence of mycorrhizal fungi. We do not know how Sumter and Vaiden soils may differ in microbial ecology or how pH differences between the two soils may be linked to possible differences in microbial ecology. For all grasses planted on Sumter soil, establishment success was consistently greater for the spring and/or after frost plantings than the late summer plantings (Figs. 1 and 2). Seasonal differences in establishment were confined to Cave-in-Rock switchgrass on the Vaiden soil. We were encouraged that the after frost planting was as successful as observed, however, one major drawback was that this date was most prone to cancellation because of wet field conditions.

Frequency and basal cover will be monitored for several more years since three years is the accepted minimum amount of time before establishment success of a native grass seeding can be evaluated reliably. In addition, species composition will be monitored in the mixture beginning October 1999. Also, microbial ecology, in particular, the occurrence of mycorrhizal spores and relationships with native plant roots will be compared between the two soil types.

Implications

Establishment success for native grasses appears to vary spatially and temporally within Alabama Black Belt landscapes. However, the fact that soils with higher pH tend to increase establishment success suggests that native grasses may be particularly attractive for wildlife habitat

enhancement on Black Belt soils that will not support pine trees. In addition, seeding after frost appears to be a viable alternative to spring seeding, as long as soil moisture does not prevent field operations. Further study with a grassland drill modified for small and chaffy seed is planned on 15- 30-acre pastures so that both grazing and wildlife community responses can be evaluated.

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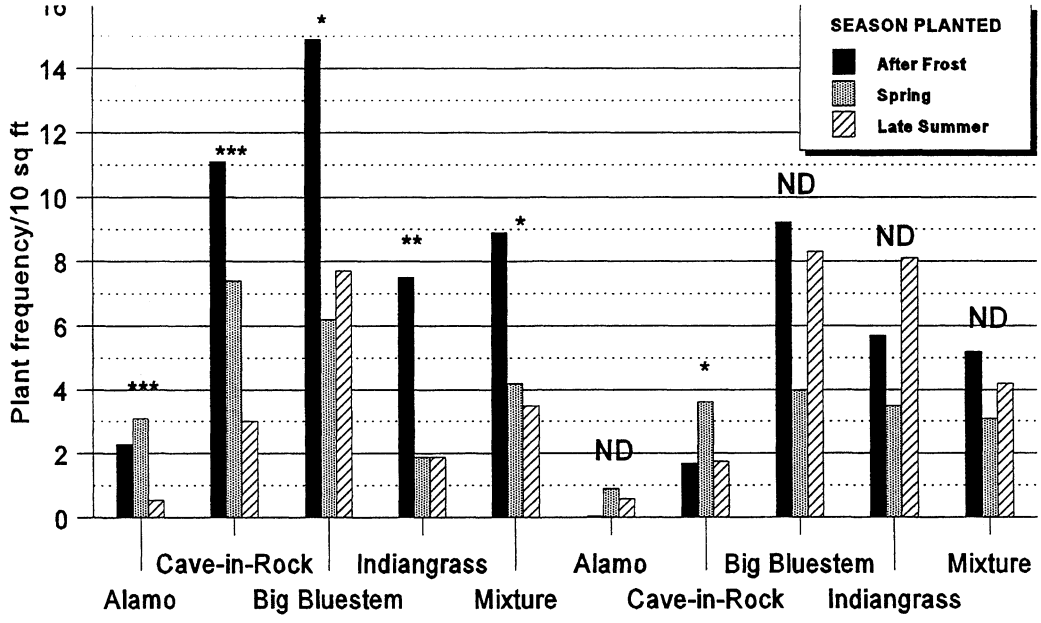

Figure 1. Average plant frequency in plots of four native grasses and one native grass mixture on two soils, Black Belt Substation, Marion Junction, AL, October 1997. *P<0.05; **P<0.01; P<0.001; ND=no difference.

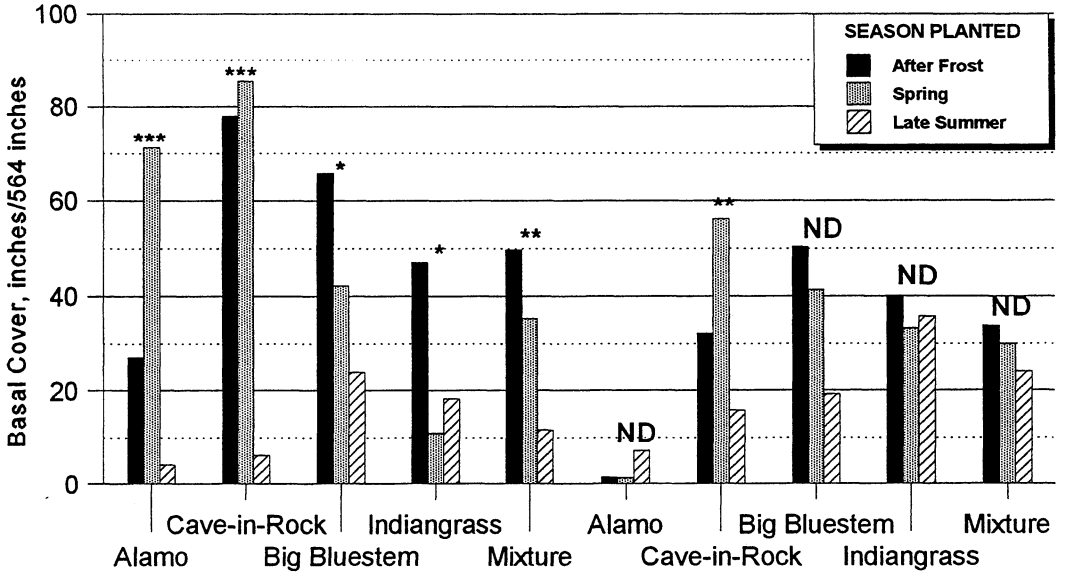

Figure 2. Average basal cover in plots of four native grasses and one native grass mixture on two soils, Black Belt Substation, Marion Junction, AL, October 1997. *P<0.05; **P<0.01; ***P<0.001; ND=no difference.

ADVANCES IN ESTROUS SYNCHRONIZATION

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SUMMARY

Estrous synchronization facilitates the use of artificial insemination and can increase the number of cows conceiving early in the breeding season, resulting in more calves born earlier in the calving season and older, heavier calves at marketing. Numerous "tried-and-true" estrous synchronization protocols are available, newly emerging protocols are proving effective, and even more loom on the horizon. This paper summarizes various protocols available, how they work and how they might fit into your management program to improve the reproductive efficiency of your beef herd.

Introduction

Decades (and some might argue centuries) of basic research unveiled the mysteries of how hormones control reproduction in livestock. With this knowledge, and with the aid of pharmaceutical companies, scientists were then able to turn reproductive hormones (natural and synthetic) into tools for controlling key reproductive events. One reproductive event that has attracted much attention is induction of estrus - and more recently - the actual time of ovulation. Controlling the time of estrus and ovulation is important for producers who want to take advantage of the superior genetics available through artificial insemination with minimum additional burden on management for detection of estrus. The list of hormone "tools" available to producers includes: progestins, estrogens, prostaglandins, and gonadotropin-releasing hormone. Each will be discussed below in the context of estrous synchronization protocols.

Progestins

Research in the 1960's focused on the use of progestins to mimic pregnancy and stop cyclicity for a brief period of time. When the progestin is removed, cyclicity resumes in a predictable manner, much like at the end of a normal estrous cycle. If one treats a group of females with progestin, they all stop cycling. They all then resume cycling in a synchronized fashion when the progestin is removed - resulting in a synchronized estrus following the end of progestin treatment. Two currently popular commercial progestin products are Syncro-Mate-B® and MGA®.

Syncro-Mate-B® (SMB) uses a progestin-releasing 9-day ear implant and an oil-based injection given at the time of implant (Figure 1).

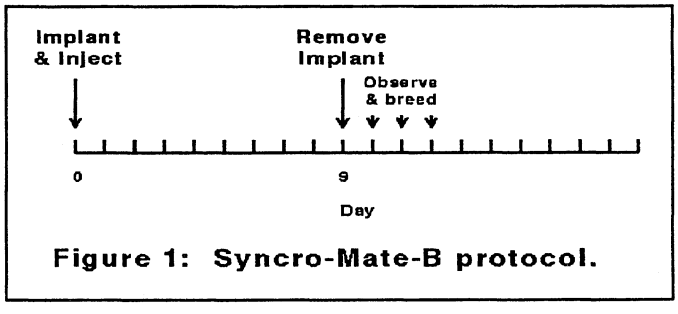

Figure 1: Syncro-Mate-B protocol.

The injection contains a long-acting estrogen to regress any pre-existing corpus luteum (CL) as well as a quick-release dose of progestin to

prevent a new ovulation from forming a CL. Regardless of the stage of cycle when treatment is initiated, healthy cyclic females should come into estrus 48-72 hours after removal of the implant on day 9. SMB treatment results in a tightly synchronized estrus of good fertility. However, the treatment requires catching the head twice (to place and then remove the implant) and is relatively expensive (see Table 1).

MGA® (melengestrol acetate) is an orally-active progestin originally labeled for suppression of estrus in feedlot heifers. Similar to the action of the ear implant described above, females consuming MGA (.5 mg/day) stop cycling. Then, when MGA is removed from the feed, the females resume cycling and come into estrus in a predictable manner. However, the first estrus is somewhat delayed and more variable, is accompanied by heavy mucus flow, and is notoriously low in fertility (usually <25%). As a consequence, the current recommendation is to feed MGA for 14 days, not breed to the first estrus but rather wait 17 days, then give a single injection of a luteolytic agent (like Lutalyse®, see below) and breed at the second estrus (Figure 2). MGA is cheap, easy to

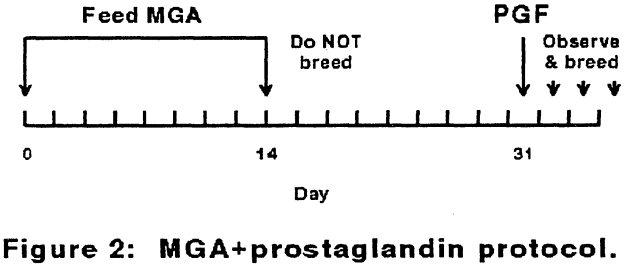

Figure 2: MGA+prostaglandin protocol.

administer, and might even induce some anestrous animals to begin cycling. However, the initial low fertility and the length of the total treatment period to get around this low fertility (14+17=31 days) can make MGA treatment unattractive to some.

You might also be hearing more about PRID's and CIDR's in the near future. The PRID (progesterone-releasing intravaginal device) and the CIDR (controlled internal drug release) are both progestin-releasing devices used in foreign countries and being studied for use in the U.S.

Prostaglandins

Although first characterized by biochemists in the 1930's, the ability of prostaglandin-$F_{2\alpha}$ (PGF) to regress the CL and start a new cycle at a predictable time wasn't discovered until the 1970's. PGF mimics the natural hormone produced by the cells lining the inside of the uterus that, in essence, signals the ovary that pregnancy did not occur, regresses the CL, and starts another cycle. Now commercially available as Lutalyse® and Estrumate®, PGF can be used alone, or in combination with other hormones (see above and below), to control onset of estrus.

Perhaps the most common use of PGF to synchronize estrus is simply giving two injections 11 days apart (Figure 3). If a female

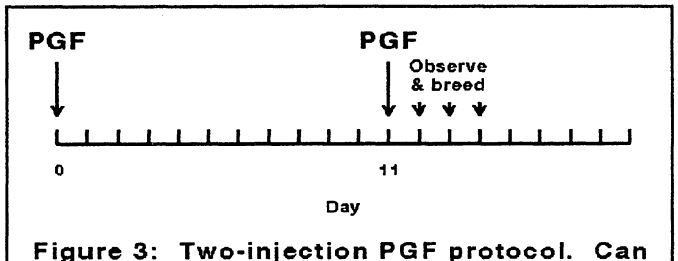

Figure 3: Two-injection PGF protocol. Can also AI after first PGF (see caution in text).

had a CL at the time of the first injection, it would regress, and another CL would form. This second CL would then regress in response

to the second injection of PGF. Any cyclic female that did not have a functional CL to regress at the time of the first injection should have formed one by the time of the second injection, and it would regress in response to the second injection. Therefore, all cyclic females should show a synchronized estrus in response to the second injection. Some producers will go ahead and observe for estrus after the first injection of PGF and breed any cow that comes into heat. Only those that were not bred after the first injection would get the second injection. This requires a few more days of heat checking, but it also requires less drug and gets more cows pregnant earlier in the breeding season. (WARNING: You must keep accurate records and not re-treat any cow that was bred - otherwise, those that conceive after the first injection will abort to the second injection.) Another common protocol that saves on the cost of drug is to observe for estrus for 5 days and breed any female that comes into estrus naturally, then inject all cows not bred with a single injection of PGF (Figure 4).

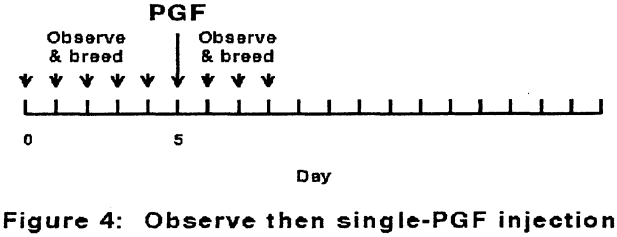

Figure 4: Observe then single-PGF injection protocol.

The "Monday Morning Program" program (Figure 5) has been promoted to producers who want to do all their breeding during the middle of the work week when hired labor can be optimized. In general, all females eligible for breeding are given a first injection of PGF on a

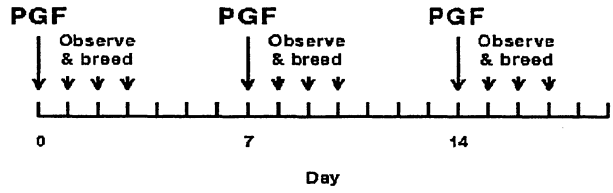

Figure 5: "Monday Morning Program" protocol (see caution in text).

Monday, and those that display estrus in response are bred. Those not bred are given a second injection of PGF the following Monday, observed and bred, etc. (WARNING: Do NOT reinject any cows that have been bred and might be pregnant or you will induce abortion.) After three weeks, greater than 90% of the healthy cycling females should have responded to one of the three injections and been bred. Moving the injections to Thursday evening would concentrate breeding on the weekend for those who work off-farm during the week

The "Targeted Breeding Program" (Figure 6)

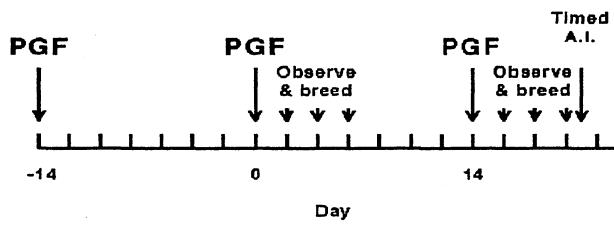

Figure 6: "Targeted Breeding Program" protocol (see caution). Can time breed 80 hr after 2nd PGF.

stages females to be ready to breed at the start of a pre-determined breeding season. An injection of PGF is given 14 days prior to the start of the breeding season to ensure that a large proportion of the breeding herd will have a CL present at the start of the breeding season. A second injection is given to all females on the first day

of the breeding season, and females are observed and bred. Those not bred are given a third PGF injection 14 days later, females are observed and bred. Any female not bred to standing estrus after the final PGF treatment can be time-bred 80 hours after that final injection.

PGF is relatively inexpensive (see Table 1), easy to administer (i.m. injection), and results in a fertile estrus. However, PGF works only if there is a functional CL, and it can cause abortion if administered mistakenly to a pregnant female.

Gonadotropin-Releasing Hormone

A truly tight synchrony of estrus and ovulation that would allow high fertility to a "timed" insemination would be ideal. However, variation in when a female actually shows estrus and ovulates in response to treatment remains a problem. This lingering variation has been attributed, at least in part, to the stage of maturity of the dominant follicle at the time of CL regression. If a large mature follicle is there and ready to go, estrus occurs soon after regression of the CL (48-56 hours); however, if the dominant follicle has already initiated atresia (regression), and another smaller follicle must be recruited to ovulate, estrus occurs significantly later after regression of the CL (72-84 hours). As a consequence of this variation in interval from CL regression to ovulation, observation for behavioral estrus remains a requirement to ensure highest fertility.

Recently, scientists have "tweaked" an old treatment for cystic ovaries to synchronize follicle growth - thus ensuring a mature dominant follicle will be ready to ovulate when the CL is regressed. This treatment involves an injection of gonadotropin-releasing hormone (GnRH) to ovulate or luteinize any "old" follicles and initiate growth of a new dominant follicle. Seven days later, females are injected with a single dose of PGF to regress any pre-existing or induced luteal tissue and allow the new dominant follicle to ovulate. Females would then be bred after observed estrus (Figure 7).

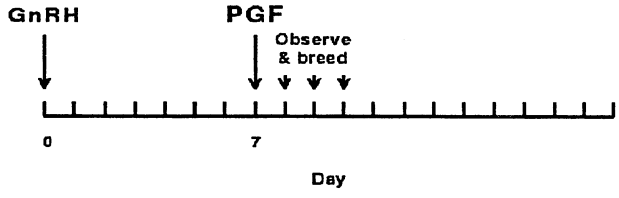

Figure 7: GnRH+PGF protocol.

To further fine-tune the actual time of ovulation and provide acceptable fertility to a timed A.I. breeding, a second injection of GnRH can be given 48 hours after PGF to "force" the new dominant follicle to ovulate at a predicted time (Ovsynch™; Figure 8). Females can then

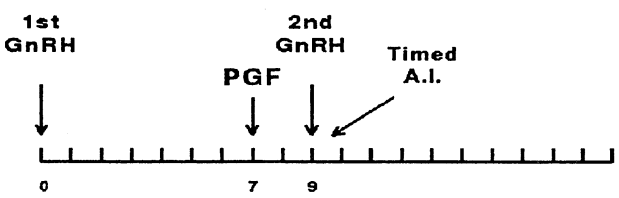

Figure 8: The "Ovsynch" protocol.

be bred at a fixed time 16-18 hours after the second injection of GnRH. (For some reason, heifers have been less responsive to the GnRH injections, and fertility has not been as high as observed in cows.) Ovsynch provides acceptable fertility to a single timed insemination; however, it involves handling all cattle four times (three times for the injections, once for breeding), and the combined cost of treatment can be excessive (see Table 1).

Table 1: Example costs of estrous synchronization protocols.

Protocol	Cost per head*
Syncro-Mate-B	$10.75
Two injections of PGF	$7.50
Ovsynch	$16.25

**Prices quoted 11/98: Lutalyse® = $3.75/dose; Cystorelin® = $6.25/dose.*

IMPLANTS, HORMONE EXPOSURE AND REPRODUCTIVE DEVELOPMENT[1]

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SUMMARY

Commercially available, growth-promoting implants can be used effectively to increase efficiency of lean growth and optimize feed efficiency in beef heifers. Never the less, cattle producers should be aware that the bioactive compounds released by such implants can affect developing reproductive tissues. Here, basic concepts of reproductive development are reviewed, some effects of early neonatal exposure to specific, developmentally disruptive steroids on adult uterine structure in beef heifers are described, and recommendations for the judicious use of implants are given.

Introduction

In cattle, as in other mammals, reproductive performance is an acquired trait. While potential for reproductive success may be defined genetically, actual reproductive performance is determined by the extent to which ideal developmental and physiological programs governing organization, integration and function of reproductive organs and systems are realized.

In female mammals, reproductive success requires development of a functional axis of organs and tissues that includes: (i) ovaries; (ii) tubular genitalia, including the oviducts, uterus, cervix and vagina; and (iii) the central nervous system and anterior pituitary gland. Gonadal phenotype (♀ = ovary vs ♂ = testis) can be determined in the bovine embryo by gestational day 40. Differentiation and organization of both the urogenital tract and central nervous system begins prenatally, but is completed postnatally [2,5].

Bioactive agents that alter developmental programs can affect the structure and function of adult reproductive tissues and compromise reproductive performance. Moreover, the potential for exposure of immature tissues in domestic animals to developmentally disruptive compounds is real (Figure 1). Exposure can occur: (i) physiologically, as a consequence of inappropriate production of naturally occurring hormones during critical developmental periods; (ii) naturally, as a consequence of the consumption of feedstuffs containing phytoestrogens (plant estrogens) or mycotoxins (from molds); (iii) pharmacologically, as a

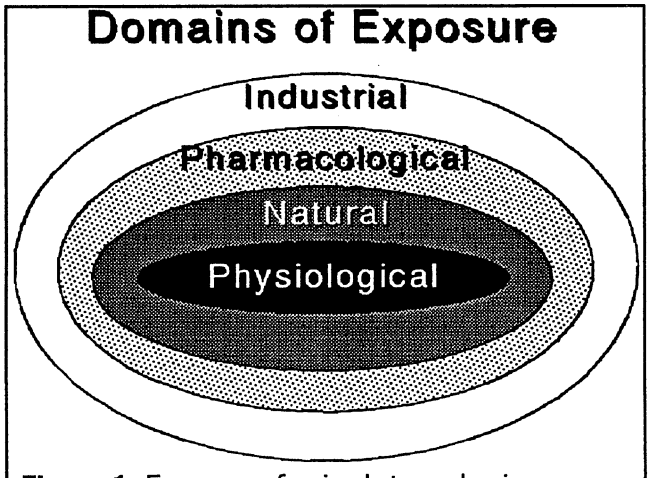

Figure 1. Exposure of animals to endocrine disruptors ("EDs") of development can occur in different domains.

consequence of the intentional use of bioactive agents to enhance growth or related performance traits; and (iv) unintentionally, as a consequence of the presence of bioactive industrial pollutants in the environment [2,5]. Bioactive agents encountered by animals in natural, pharmacological and industrial domains of their environment, that can disrupt development by altering critical physiological and endocrinological events are referred to as "endocrine disruptors" or EDs.

Even transient exposure of immature urogenital tract tissues to steroids (estrogens, progestins, androgens) or related compounds during 'critical' developmental periods can have permanent and profound effects on the structural and functional integrity of the adult reproductive tract [2,5,7]. Steroids and related EDs that induce permanent changes in developing target tissues are said to elicit organizational effects. Susceptibility of urogenital tract tissues to organizational effects of steroidal EDs tends to be inversely related to tissue maturity (more mature = less effect), and directly related to tissue expression of steroid receptors; a functional requirement for steroid responsiveness.

For cattle, risk of exposure to conditions that could compromise the normal program of reproductive tract development is very real. With increased use of steroid-releasing implants for enhancement of growth [7], as well as the potential for exposure to environmental EDs [2,6], the importance of identifying steroid-sensitive, developmentally critical periods and, ultimately, the role of steroids and steroid receptor systems in reproductive development is obvious. At present, much of what is known of these important relationships is inferred from studies of the effects of postnatal steroid exposure associated with the use of growth-promoting implants.

Commercial implant use has increased dramatically in the last decade and is recognized to be one of the most cost effective means of stimulating lean growth and improving feed efficiency in beef cattle [7]. Obviously, the possibility that overall growth characteristics, adult skeletal structure and even general maternal ability might be improved through strategic exposure of suckling or growing heifer calves to steroids or related compounds released from implants is attractive. Consequently, a good deal of attention has been given to evaluation of the effects of various implants and implant strategies on growth and reproductive development in beef heifers [2,4,6,7].

Materials and Methods

Studies in this laboratory have involved the use of a growth-promoting implant designed to release both progesterone (P, 100 mg) and estradiol benzoate (E, 10 mg; Synovex-C®, Fort Dodge, KS) systemically over a payout period of approximately 150-200 days (chronic exposure). The product is labeled for use in beef heifers that are at least 45 days old, including potential breeding replacements. Studies were designed to determine effects of: (i) age at first PE exposure [birth vs postnatal day (PND) 21 or PND 45]; and (ii) duration of PE exposure from birth [21 days vs 150-200 day chronic exposure] on specific structural and functional characteristics of the adult uterus and uterine lining (endometrium) in crossbred beef heifers. In all cases, responses of unimplanted control heifers were compared to those of PE-implanted heifers ($N \geq 5$/group). Experimental details and extensive discussions are published elsewhere [2,3,4,5].

Results and Discussion

Functions of the uterus in adult cattle

include generation of the luteolytic signal required to ensure normal ovarian cycles, transport and maturation of sperm, recognition and reception of embryos, provision of an embryotrophic environment for support of conceptus development, and expulsion of the fetus and placenta at parturition. With the exception of those events requiring contractile force (sperm transport and parturition), all of these functions are borne by the mucosal lining of the uterus or endometrium [1].

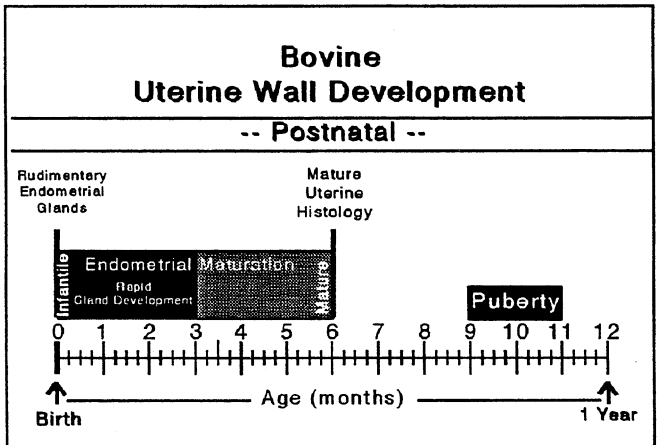

Figure 2. Timing of postnatal events in bovine uterine wall development.

Bovine endometrial development is completed postnatally (Figure 2). Uterine glands, presumed to make substances required to support embryo development and fetal growth, proliferate rapidly during the first weeks of neonatal life, and the endometrium is neither structurally nor functionally mature in heifers less than six months of age. Thus, to the extent that uterine tissues are or become steroid-sensitive during the early postnatal period, exposure of heifers to EDs during this time should be expected to alter the normal program of endometrial development.

Heifers given PE implants at birth or later reached puberty and displayed regular estrous cycles of normal length. When exposure to PE was limited to the first 21 days from birth (PND 0), neither uterine weight nor endometrial structure (histology) were affected in adult heifers [3,5]. However, effects of chronic PE exposure (150-200 days), beginning at either birth, PND 21 or PND 45, were consistently negative when evaluated in cyclic adult heifers at either 15 or 26 months of age during diestrus (luteal phase) [4,5]. Regardless of age at first PE exposure, chronic PE reduced adult uterocervical weight by 35%, uterine muscle (myometrial area) by 23%, and endometrial area by 27% [2,4].

Treatment effects on endometrial glandularity were clearly related to age at first PE exposure (Figure 3). The PE-induced

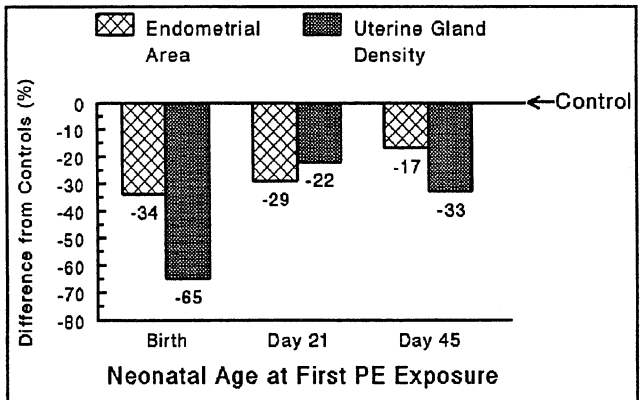

Figure 3. Effects of chronic (~200 day) exposure to PE from birth, PND 21, or PND 45, on endometrial area and uterine gland density in adult beef heifers during diestrus at ~15 months of age [4].

reduction in endometrial area was accompanied by a dramatic decrease in the relative number of uterine glands per unit area of endometrium (gland density). This effect was most severe when PE exposure began at birth. In these heifers, endometrial gland density was reduced by 65%. Consistently, uterine luminal fluid protein content was reduced in adult, neonatally PE-exposed heifers by approximately 45% [4].

Overall, generalized uterine hypoplasia,accompanied by severe loss of endometrial glands was observed in cyclic adult heifers as long as 15 to 26 months after initiation of PE exposure on or before PND 45. Effects on endometrial glandularity, though evident in all groups, were most severe when PE exposure began at birth [3,4,5].

Compared to unexposed controls, PE exposure from birth reduced uterine horn volume by 45% (141.6 mm vs 78.2 mm) and uterine horn volume by 60% (5019 mm^3 vs 2020 mm^3) when measured at surgery in calves on PND 21. However, when one uterine horn was removed from these calves on PND 21 and uterine histology compared, the smaller PE-exposed uteri did contain rudimentary glands. Thus, while negative effects of PE were evident by PND 21, loss of endometrial glands, which can be complete in some adult, PE-exposed heifers, may be associated with steroid withdrawal [4,5].

Mechanisms through which PE and related compounds affect patterns of uterine development and the functional integrity of the adult uterus are now being investigated by this and other laboratories [5]. Studies are underway to determine the impact of PE exposure from birth on fertility in adult beef heifers.

From a husbandry standpoint, the pharmacological domain of exposure to EDs is one of the easiest to define and manage. This is particularly true with respect to the judicious use of hormone-releasing implants. Some general recommendations for use of growth-promoting implants in beef heifers are given below [2,7].

- ***Always*** use implants according to label directions.
- ***Do not*** implant heifers intended for use as breeding replacements.
- If heifers are not selected as replacements until weaning, implant only those born after the birth of an adequate number of potential replacements. Consider retaining more replacements to compensate for potential negative reproductive effects.
- If the objective is to maximize weaning weights and replacements cannot be identified until weaning, implant all heifers per label instructions, but be sure to feed selected replacements to reach target breeding weights (65% of mature weight).
- When investigating heifer fertility problems or considering purchase of breeding heifers, determine implant (ED) exposure history.

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Acknowledgements

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DOES IVERMECTIN AFFECT CATTLE FERTILITY?

J.G. Floyd, Jr. and N.J. Van Dyke

SUMMARY

In order to determine if bull sperm quality is decreased after treatment with a pour on ivermectin dewormer, fifty-one two-year-old beef bulls were divided into two experimental groups: treated with Ivomec© Pour-On For Cattle (Merial) at 1 cc/22 lbs body weight, or non-treated controls. Bulls were randomly assigned to treatment groups, with equal numbers assigned to each on the basis of breed, pasture being grazed, and previous average daily gain. A semen sample was collected with an electroejaculator and evaluated for sperm quality at the time of treatment and again 22 days later. Pour-on ivermectin treatment had no effect on sperm motility, percent normal sperm cells, or percent secondary (minor) sperm cell abnormalities. Treated bulls had fewer primary (major) sperm cell abnormalities than untreated bulls (7.3% vs. 10.8%, p=0.05). Ivermectin did not decrease sperm quality during the three weeks immediately following treatment.

Introduction

Ivermectin is a chemical compound effective against a wide range of internal and external parasites. Ivomec©, the first ivermectin for use in cattle in the U.S., was approved by the Food and Drug Administration in 1984. Ivermectin is classified as an avermectin, which includes other dewormers very similar in chemical structure such as doramectin (Dectomax©). Ivermectin removes internal (nematodes, or "worms") and external parasites (mites and lice) by interfering with a chemical which transmits signals within their nervous systems.[1] This chemical, gamma amino butyric acid (GABA), is also present in the nervous systems of mammals, such as cattle. In the mammalian brain ivermectin stimulates release of GABA, which in turn has the ability to inhibit the secretion of LHRH (luteinizing hormone releasing hormone). LHRH is important for reproduction in mammals because it stimulates the release of pituitary gland hormones which then stimulate reproductive organ functions in males (testes) and females (ovaries). It has been suspected that, because of the potential decrease in LHRH after ivermectin treatment, an animal's fertility might be decreased. However, a barrier exists between the blood and brain of most mammals which prevents ivermectin from entering. In addition, despite the potential for ivermectin to alter LHRH secretion, a controlled study in ewes failed to demonstrate any such alteration.[1]

Several ivermectins have been approved for use in various species, including cattle, horses, dogs, and humans on the basis of extensive product effectiveness and safety testing. Additionally, studies specifically investigating infertility have failed to document adverse affects of ivermectin treatment on fertility in females of various species including sheep,[1] cattle,[2,3,4,5,6,7,8] horses,[9] dogs,[10] and humans.[11] In rams administered twice the recommended dosage of ivermectin 6 times at 21-day intervals, no adverse effects were demonstrated on any measurement of semen quality, including volume, density of sperm, motility of sperm, or sperm morphology

(shape).[12]

Despite the published scientific evidence to the contrary, producers' questions have persisted about the potential adverse effects of ivermectins on bull semen and fertility shortly after treatment. Particular concerns expressed about the effects of Ivomec® Pour-On For Cattle (Merial) led us to conduct a study to investigate its short term effects on bull sperm quality following treatment.

Experimental Procedures

Fifty one two-year-old beef bulls of four breeds in three different pastures were blocked by breed, pasture group, and previous average daily gain (ADG) and randomly allocated to one of two treatment groups: Ivomec® Pour-On For Cattle treatment, or non-treated controls. Bulls were weighed and treated with Ivomec ® Pour-On For Cattle at the label dose (1 cc/22 lbs body weight). A semen sample was collected by electroejaculation at the time of treatment, and again 22 days later. The semen samples were evaluated for the following measures of quality[13]:

- Sperm Motility - estimation of the percentage of individual sperm cells moving in a forward, progressive fashion
- Sperm Morphology - classification of the microscopic shape and structure of 100 stained sperm cells classified into three categories:
  - Percentage of sperm cells with no abnormalities (normal)
  - Percentage of sperm cells with secondary abnormalities (minor abnormalities in sperm shape which decrease fertility, but may indicate the damage is reversible)
  - Percentage of sperm cells with primary abnormalities (major abnormalities in sperm shape which decrease fertility, and indicate some degree of degeneration of the sperm-forming tissues in the testes)

Statistical analysis utilized the General Linear Models procedure of SAS, with the following independent variables accounted for in the statistical model: pasture-breed group, previous ADG, interaction between pasture breed group and ADG, treatment, interaction between ADG and treatment, interaction between pasture-breed group and treatment, interaction between pasture-breed group, ADG, and treatment, and the dependent response variable of interest at time of treatment included in the model as a covariate.

Results and Discussion

There were no statistical differences between treatment and control groups for any measure of sperm quality at the time of treatment. Twenty two days after treatment there were no differences in motility, percent normal sperm, or percent secondary sperm abnormalities between treatment and control groups (TABLE 1). The bulls in the treatment group had a decrease in percent primary sperm abnormalities as compared to the control group, 7.3% vs. 10.8% respectively (P=.05).

Treatment with ivermectin had no effect on sperm motility, percent normal sperm cells, or percent secondary sperm abnormalities. Since deworming generally decreases weight loss and unthriftiness associated with parasitism, the increased body condition of cattle in herds with good deworming programs may translate into improved fertility.[5,7] However, the increase in sperm quality as evidenced by the smaller percentage of primary sperm abnormalities seen in the ivermectin treated group in the study reported here is not necessarily an expected outcome. This finding should not be interpreted

to indicate that pour on ivermectin treatment should be utilized as a method to increase sperm quality in bulls. The primary conclusion of this study is that no detrimental effects on bull sperm quality were observed as a result of pour on ivermectin treatment during the period of evaluation.

Because approximately 9 weeks are required for production of a mature sperm cell by a bull, the sperm which were evaluated 22 days after treatment had undergone only the last one-third of their development coincidental with ivermectin exposure. The availability of the bulls for this study restricted their continued evaluation for a longer period of time.

Table 1. Sperm quality measurements (least squares means) 22 days after treatment with ivermectin pour-on formulation (Ivomec® Pour-On For Cattle)

	Control Group	Treatment Group	Statistical Significance (≤ 0.05 indicates significance)
Number Bulls	27	24	-----
Sperm Motility (%)	61	63	0.64
Sperm Morphology: % Normal Sperm	78	80	0.63
% Secondary Abnormalities	10	11	0.78
% Primary Abnormalities	10.8	7.3	0.05

Implications

Pour on ivermectin treatment did not adversely affect certain indicators of bull sperm quality measured three weeks after treatment. The pour on ivermectin used in this study is an FDA approved product for treating certain internal and external parasites in cattle and is safe for use in beef bulls.

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GENETIC SELECTION FOR CARCASS TRAITS

Lisa A. Kriese-Anderson

SUMMARY

Beef quality and consistency in the U.S. has been identified as one of the industry's top concerns. From beef breeding projects conducted at Auburn University, it has been determined there are sire breed differences for carcass traits in sire breeds commonly used in the Southeast. This suggests breed complementarity must be taken into account when making breeding decisions. Additionally, individual bull selection is critical. However, there were few differences among marbling score means between breeds in the project, which determine USDA Quality grades. There were no significant differences among sire breeds for palatability traits. This may be due to the young age in which the cattle were slaughtered (450 days) and aging of top loin steaks for 14 days. Additionally, measuring backfat thickness, ribeye area and percent intramuscular fat using real-time ultrasound technology at yearling age should identify potential breeding animals superior for carcass traits. There were carcass trait differences of carcasses from steers, bulls and heifers for weight, 12th rib fat thickness, ribeye area, USDA yield grade and quality grade. However, there are no differences in palatability traits or Warner-Bratzler shear values in steer and heifer steaks ages 14 days. A standard practice of aging meat 14 days prior to sale in the industry, however, is not feasible.

Introduction

The 1995 National Beef Quality Audit (NBQA) addressed issues concerning product tenderness, product consistency and uniformity, and palatability aspects with regard to U.S. beef products. NBQA (1995) concluded for beef to maintain market share, the quality and consistency of beef needed to improve, along with palatability.

There are two strategies for increasing quality and consistency in beef and eliminating undesirable eating experiences. Researchers have developed several post-mortem techniques for improving beef tenderness. These techniques include electrical stimulation, blade tenderization and calcium chloride injections. Although these methods have been found to be successful in increasing beef tenderness and palatability, few packers have implemented these procedures because of expense, time and perceived danger to workers. The other strategy to improve beef quality and consistency is through genetic improvement of beef cattle for carcass and palatability traits without sacrificing economically important reproductive, growth and maternal traits. Genetic improvement of carcass and palatability traits represent a permanent change.

The 1995 NBQA task force developed recommendations for desirable carcass specifications for all slaughter cattle (Table 1). Alabama cattle, on average, fit these targets (Table 2, Alabama Pasture to Rail data, 1994-1997, unpublished). However, examining the standard deviation values and ranges for each of the traits illustrates the problem with the U.S. beef product. On average, Alabama cattle meet the specifications exactly, but the ranges show cattle which span the entire spectrum.

Two beef cattle breeding projects were designed to examine carcass and palatability traits in beef cattle commonly used in the Southeastern United States. The project located at the Black Belt Substation was designed to examine sire breed differences. The breeding project at the Lower Coastal Plan Substation was designed to investigate the use of ultrasound technology for selecting breeding cattle for ribeye area and to examine carcass differences of bulls, steers and heifers.

Table 1. Carcass Window of Acceptability

Trait	Range of Values
Slaughter Weight	1000 to 1300 lbs.
Carcass Weight	600 to 800 lbs.
Backfat Thickness	.30 to .45 in.
Ribeye Area	12.5 to 14.0 in^2
USDA Yield Grade	2.5 or less
USDA Quality Grade	Select+ to Choice-

Experimental Design

Back Belt Substation

One hundred and fifty Simmental x Angus females were obtained for this project at the Black Belt Experiment Station in Marion Junction, AL. Females were stratified by age and weight and assigned to one of three lines. A control line of approximately 40 females was mated to Hereford (HE) sires throughout the study. The other two lines, designated as 'A' and 'B', consisted of approximately 55 females each. Line 'A' was mated to Beefmaster (BM) sires for the first two years and (LM) Limousin sires for the next three years. Line 'B' was mated to Brahman (BR) sires for the first three years of the project and Gelbvieh (GV) sires for the next two years. This sire rotation system allowed for evaluation of several sire breeds over the study, yet only three sire breeds were evaluated in any given year to produce adequate numbers of calves for each sire breed.

Sire selection was based on a sire's accuracy for weaning weight (WW) EPD within his own breed evaluation. AI sires had a minimum accuracy of .90 or were in the top 10% of their breed for WW EPD. Natural service sires, which served as clean-up bulls, were required to be at least breed average for WW and yearling weight (YW) EPDs. At least two AI sires were used per breed per year with one or two of these sires being replaced each year. One clean-up bull was utilized per breed yearly.

Five calf crops were produced between 1991 and 1995. Calves were born from late October to early January. Calves were weighed and tagged and bull calves were castrated at birth.

At weaning, steer calves were placed into a total confinement feedlot and fed a high concentrate diet and fed ad libitum until slaughter. Steers were fed to an average 12th rib fat thickness of 10 mm (.4 in.) as determined by real-time ultrasound. Finished steers were slaughtered in two groups per year at Central Packing in Center Hill, FL between 13 and 15 mo of age Carcass data was collected on 229 slaughter steers at the slaughter facility by a USDA grader. Carcass traits measured included ribeye area (REA), 12th rib fat thickness (FT), kidney pelvic and heart fat (KPH), hot carcass weight (HCW), marbling score (MS), USDA yield grade (YG), and USDA quality grade (QG). MS were assigned as factors of 100 (300 = traces, 400 = slight, 500 = small, etc.). QG were assigned according to MS (400-449 = Select, 450-499 = Select $^{+}$, 500-599 = Choice^{-}, 600-699 = Choice, 700-799 = Choice $^{+}$, etc.).

Top loin samples were collected 24 hr postmortem from the left side of each carcass and brought back to Lambert Meats Laboratory at Auburn University where two 1 inch steaks were cut from each top loin sample for sensory and Warner-Bratzler shear analysis. Steaks at 48 hr postmortem were cut, vacuum-packed, aged for 14 d at 4°C and then frozen at -20°C.

Table 2. Alabama Pasture to Rail Data: 1994 through 1997

Trait	No.	Mean	Std. Dev.	Range
Slaughter Weight	2075	1225 lbs.	132.5 lbs.	780 to 1786 lbs.
Carcass Weight	2008	765 lbs.	85.6 lbs.	470 to 1107 lbs.
Backfat Thickness	1988	.40 in	.18 in	0.0 to 1.12 in
Ribeye Area	1998	13.4 sq. in.	1.8 sq. in.	9.0 to 20.3 sq. in.
USDA Yield Grade	1992	2.53	.79	0 to 5.72
USDA Quality Grade	1970	Select+	⅓ grade	Standard- to Prime

Statistical models and analysis. Carcass and quality traits were analyzed using the General Linear Models (GLM) procedure of SAS (1989). The model for carcass and quality traits included fixed effects of slaughter group, sire breed, sire nested within sire breed and a covariate for slaughter age. Sire breed differences for carcass and quality traits were tested using the sire nested within sire breed. All other effects were tested using the residual error term. Least squares means and standard errors for sire breed were obtained from the LSMEANS option of SAS (1989). Sire breed differences were determined using Tukey's mean separation procedure for unequal numbers of observations (Lentner and Bishop, 1993). Sire breed means were considered statistically different at $P < .05$.

Lower Coastal Plain Substation

In 1989, a herd of purebred Brangus cattle was established at Auburn University to determine if genetic selection could be effective in increasing ribeye area based on ultrasonic measurement of ribeye area at yearling age. Two hundred Brangus females were purchased from various sources throughout the Southeastern United States and transported to the Lower Coastal Plain Experiment Station in Camden, Alabama. Females were randomly assigned to one of three lines.

Line 1 (H) is the high ribeye area line. Females were mated using artificial insemination (AI) to the top EPD bulls for ribeye area based on ultrasound measurement at yearling age. Between two and four AI bulls were used in this line each year with overlapping AI sires used across years. AI sires with an accuracy value of .6 or higher associated with their ribeye area EPD were used. Two cleanup sires were chosen each year within line based on top yearling ultrasound ribeye EPDs and used as cleanup sires as two-year olds.

Line 2 (M) is the balanced growth EPD, moderate ribeye area line. AI bulls must be at least breed average for weaning, yearling and milk EPDs. Once this criterion was met, the top ribeye area EPD sires based on ultrasound measurement were selected. Similar numbers of AI sires were used in the M line as the H line. Cleanup sires were chosen in the same manner as those in the H line.

Line 3 (C) is the control line. The control line was used to monitor environmental changes during the duration of the project. Dams were mated to the same control line sire each year. Three control line sires were purchased at the beginning of the project and semen collected on these bulls.

Calves were born from February through April. One-half of bull calves born were castrated randomly across sires. At weaning, calves were fed a corn silage based growing ration. Ultrasound measurements for 12th rib fat thickness and ribeye area were taken at weaning, yearling and at a halfway point between weaning and yearling ages. After yearling measurements were taken, replacement cattle for the H and M lines were selected based on ultrasound ribeye area EPDs. Control line females were chosen randomly. All cattle not chosen as replacements were fed a corn silage based finishing ration. When a group of cattle averaged 10 mm (.4 inch) backfat, cattle were transported to Central Packing in Center Hill, FL. The same carcass and palatability measurements were obtained as described for the Black Belt experiment. The first calves in this project were born in 1990. To date, calves born through 1997 have been slaughtered.

Statistical models and analysis. A general linear model (GLM) of SAS (1989) was used to analyze the effectiveness of selection for ribeye area based on ultrasound measurement in this herd of Brangus cattle. Only cattle with carcass measurements were used in this analysis. The model included independent variables of birth year, sex of calf, line (H, M, C), sire of calf and all two way interactions. A covariate of slaughter age was also included in the model. The effect of line was tested for significance with sire within line as the error term.

Results and Discussion

Black Belt Substation

Two hundred twenty-nine steers averaged 450 days of age at slaughter. Table 3 shows distribution of percentage USDA yield grades and percent steers grading USDA Choice$^-$ to Choice$^+$ per sire breed. Table 4 contains least squares means for hot carcass weight, 12th rib fat thickness, ribeye area, USDA yield grade, and marbling score analyzed at an age constant basis.

At a constant slaughter age (SLAGE), Brahman (BR), Gelbvieh (GV) and Limousin (LM) sired carcasses had HCW of 747.5 lb, 749.7 lb and 743.1 lb, respectively and were significantly heavier than Hereford (HE) sired carcasses which had HCW of 694.6 lb ($P<.05$). Beefmaster (BM) sired carcasses at 729.9 were not different from HE, BR, GV or LM sired carcasses for HCW. Comerford et al. (1988) reported HCW of 612.5 lb, 605.7 lb and 593.8 lb for LM, HE and BR sired carcasses, respectively, at an average of 455 days of slaughter age. These means are considerably less than those reported in this study, but like this study, Comerford et al. (1988) found no differences between LM, HE and BR sired carcasses for HCW. Wheeler et al. (1996) reported different HCW of 707.8 lb and 738.7 lb for natural service (NS) Hereford and NS Gelbvieh sired carcasses, respectively ($P<.05$). Differences in HCW in these studies can probably be expected at similar slaughter ages due to larger frame sizes of Continental (GV and LM) and Zebu

(BR) cattle compared to breeds of British origin (HE).

Table 3. Distribution of USDA yield grades (%) and steers receiving USDA choice grade (%) of higher by sire breed

		USDA Yield Grade (%)				
Sire Breed	USDA Choice (%)	1	2	3	4	5
Beefmaster	57	4	40	52	4	0
Brahman	59	6	66	22	3	3
Gelbvieh	80	20	71	9	0	0
Hereford	71	2	53	30	7	8
Limousin	48	40	56	2	2	0

Table 4. Least squares means for carcass traits at constant age by sire breed

	Carcass Traits[a]				
Sire Breed[b]	HCW (lbs)	FT (in)	REA (sq in)	YG	MS
Beefmaster	729.9^{c,d}	.56^{c}	12.33^{c}	3.3^{c}	522^{c,d}
Brahman	747.5^{c}	.46^{c,d}	12.80^{c}	2.9^{c}	501^{c,d}
Gelbvieh	749.7^{c}	.30^{d}	13.82^{d}	2.2^{d}	532^{d}
Hereford	694.6^{d}	.52^{c}	12.49^{c}	3.0^{c}	516^{c,d}
Limousin	743.1^{c}	.33^{d}	14.13^{d}	2.1^{d}	490^{d}

[a]HCW = hot carcass weight, FT = 12th rib backfat, REA = ribeye area, YG = USDA yield grade, MS = marbling score (400-499 = select, 500-599 = choice, etc.)
[b]Values within a column with different superscripts are significant at ($P < .05$)

Beefmaster (BM) sired carcasses had greater FT (.56 in) than GV and LM sired carcasses at .30 in and .33 in FT, respectively ($P<.05$). No differences were observed between BM, BR and HE sired carcasses which is in contrast to reports by Crouse et al. (1989) who reported Brahman cross calves had significantly less ($P<.01$) FT than Hereford and Angus cross

calves. BR sired carcasses in this study had .46 in FT and were leaner than BR sired carcasses at .57 in FT as reported by Koch et al. (1982) at similar slaughter age (445 d). Crouse et al. (1989) reported FT of .45 in for BR sired calves which is closer to FT for BR sired calves in this study.

LM and GV sired carcasses had REA of 14.13 in^2 and 13,82 in^2, respectively, and were larger than REA of BM and HE sired carcasses at 12.33 in^2 and 12.49 in^2, respectively ($P<.05$). BR sired at 12.80 in^2 carcasses were not different from BM, GV or HE sired calves for REA. Crouse et al. (1989) reported similar REA differences for Brahman cross and Hereford cross calves. Additionally, larger REA might be expected from LM and GV sired calves because larger carcasses tend to have larger REA as indicated by positive genetic correlations of .25 and .17 between carcass weight and REA (Gregory et al., 1995 and Wheeler et al, 1996).

GV and LM sired carcasses had YG of 2.2 and 2.1, respectively and were different from BM, BR and HE sired carcasses which had YG of 3.3, 2.9 and 3.0, respectively ($P<.05$). These results are consistent with reports of Comerford et al. (1988) that LM sired calves with YG 2.07 were leaner than HE or BR sired calves with YG of 2.90 and 2.59, respectively ($P<.05$). BR sired calves in this study had considerably lower YG compared to BR sired calves with YG of 3.7 reported by Koch et al. (1982). Huffman et al. (1990) reported YG of 3.1 for 50% BR calves. GV and LM sired calves tend to be later maturing so at constant slaughter age they might be expected to have less total fat which equates to lower YG compared to their Zebu- and British influenced contemporaries.

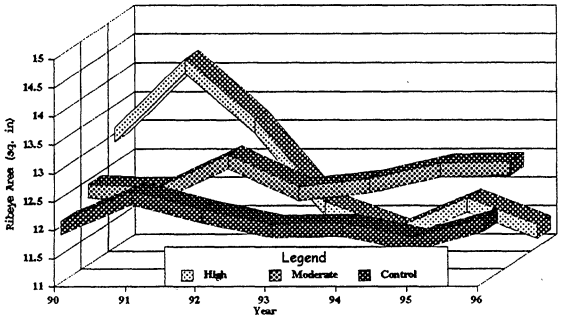
GV sired carcasses had a MS of 532 which equates to a USDA quality grade of Choice$^-$ and were different ($P<.05$) from LM sired calves with MS of 490. Additionally, 80% of GV carcasses graded USDA Choice$^-$, Choice or Choice$^+$ which is a function of marbling scores. No differences were detected between LM, BM, BR or HE sired calves for MS. This is in contrast to reports by Crouse et al., 1989, Koch et al., 1982 and Crockett et al., 1979. Crouse et al. (1989) reported significantly less marbling for 50% Brahman cross calves when compared to Hereford x Angus cross calves ($P<.01$). This study reported marbling scores for 50% BR calves which equated to a USDA quality grade of Select$^+$. This is in contrast to BR sired calves in this study which averaged a USDA quality grade of Choice$^-$. Additionally, Koch et al. (1982) reported *Bos indicus* cross calves marble significantly less than *Bos taurus* cross calves. Crockett et al. (1979) reported in subtropical conditions of Florida, Brahman cross, Beefmaster and Brahman carcasses had higher marbling scores than Limousin, Maine Anjou and Simmental sired calves. Wulf et al. (1996) reported 38 % of LM sired calves at .43 in FT achieved USDA Choice grade compared to 48 % at .43 in FT for LM sired calves in this study.

No significant sire breed differences were detected in the model for sensory panel or Warner-Bratzler shear values. This is in contrast to results in which Koch et al. (1982) reported significant differences for sensory panel tenderness scores between HE and BR sired calves. In this study BR sired calves had the highest shear values at 19.27 lb compared to HE sired calves with a shear value of 15.46 lb however these values were not significantly different. Conversely, Shackelford et al. (1994) reported values for Warner-Bratzler shear force at 9 d aging in which Nellore (*Bos indicus*) and Gelbvieh (Continental) cattle were significantly higher shear force values than Hereford (British) sired calves ($P<.05$). Steaks from this study were aged for 14 d and this extra aging period may have been the reason no differences were detected for Warner-Bratzler shear determination.

Lower Coastal Plain Study

Table 5 provides raw means and ranges of carcass characteristics. Least squares means for these same slaughter traits are found in Table 6. Slaughter bulls produced carcasses with heavier weights, less fat, larger ribeye areas and lower marbling scores than carcasses from slaughter steers and heifers. Additionally, steers produced carcasses which weighed more with larger ribeye areas than carcasses from heifers.

Figure 1. Genetic Change in Brangus Ribeye Area



The original objective for this herd of Brangus cattle was to see if genetic change was possible in slaughter progeny when parents were selected on yearling ultrasound ribeye area EPDs. To date, a complete generation has not been turned in any line. From the statistical analysis, line is not a significant effect for slaughter ribeye area in progeny. No two way interactions are significant at the .05 level. However, line by birth year of calf is approaching significance. Figure 1 depicts the least squares means for slaughter ribeye area by line and birth year of calf. Line means are very similar for ribeye area in slaughtered progeny. In effect, very little genetic change has been realized since the beginning of the project. There are two main reasons for this. When this project was initiated in 1988, there was not an EPD for ribeye area, based on ultrasound or carcass data, for the Brangus breed. The bulls selected to sire either high line or moderate line cattle in the beginning were low accuracy sires. There was little data known about the sires for ribeye area, thus making them low accuracy sires. Mistakes were made which caused the lack of change in the high and moderate lines of cattle. Additionally, the three bulls selected to be control line sires still rank highly for ribeye area EPDs based on their progeny's ultrasound data. However, genetic correlations, determined from this data, among ultrasonic measurements of ribeye area and backfat with carcass measurements of backfat thickness and ribeye area are positive. This indicates genetic selection for 12th rib fat thickness and ribeye area based on EPD values from ultrasound measurements taken at yearling should be effective.

In 1996 and 1997, three rib steaks per animal were collected on Brangus slaughter bulls, steers and heifers. Each rib steak was aged in the cooler either 2, 7 or 14 days postmortem. At day 2, 7 and 14 postmortem, steaks were cooked and evaluated for Warner Bratzler Shear Force (WBS). Data shows rib steaks from bulls required more force to shear through a sample that rib steaks from steers after aging 2 or 7 days postmortem. However, after aging steaks for 14 days postmortem, there were no differences in shear force values between steaks from bulls and steers.

At day 14, an experienced taste panel evaluation was conducted. Table 7 contains least squares means for taste panel attributes. At day 14, Brangus bulls, steers and heifers received acceptable ratings or above for all taste panel attributes. The analysis did find bulls were less tender than steers (5.1 vs 5.6). The experienced taste panel results mimics Warner Bratzler shear results for tenderness.

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Table 5. Number of observations and simple averages for slaughter traits

Trait[a]	Number	Mean	Range
Age, days	638	477	379 to 581
HCW, lbs.	638	696	441 to 997
BF, in.	636	.36	.1 to 1.7
REA, sq. in.	637	12.47	6.5 to 17.5
QG	598	Select	Std- to Ch+

[a] HCW = hot carcass weight, BF = 12th rib fat thickness, REA = ribeye area, QG = USDA quality grade

Table 6. Least squares means for carcass traits by sex of calf

Trait[a]	Bulls	Steers	Heifers
HCW, lbs.	752[a]	706[b]	590[c]
BF, in.	13.7[a]	12.3[b]	11.1[c]
REA, sq. in.	.24[a]	.42[b]	.44[b]
MS	370[a]	488[b]	498[b]

[a] HCW = hot carcass weight, BF = 12th rib fat thickness, REA = ribeye area, MS = marbling score (300 to 399 =practically devoid, 400 to 499 = slight, 500 to 599 = small)
[a,b,c] Rows with different superscripts differ (P < .05)

Table 7. Least squares means for taste panel attributes

	Juiciness	Tenderness	Off Flavor	Flavor Intensity	Connective Tissue	Overall Accept.
Bulls	5.2	5.1[a]	7.4[a]	6.1	7.1	5.4
Steers	5.2	5.6[b]	7.2[b]	6.2	7.2	5.7
Heifers	5.3	5.3[ab]	7.2[b]	6.1	7.2	5.6

Scale: 1 = extremely unacceptable; 5 = slightly acceptable; 8 = extremely acceptable
[a,b] Columns with different superscripts differ (P < .05)

MOLECULAR FACTORS INFLUENCING BEEF TENDERNESS

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SUMMARY

Inconsistent fresh beef quality continues to be an issue of concern to the beef industry. Our objective is to define factors that bring about variations in beef tenderness. We have concluded that the rate of tenderization during postmortem storage of beef is a major factor in the often-reported variation in beef tenderness. Furthermore the rate of tenderization may is regulated by the activity of specific proteases - called calpains - in postmortem muscle. These enzymes break down structural proteins within the muscle and fracture the integrity of muscle cells. This enzymatic activity results in tenderization of beef during postmortem aging. Calpain enzymes are inhibited by a muscle protein called calpastatin. High calpastatin activity will minimize the tenderizing activity of the calpains and slow the rate of tenderization. Steaks that have high calpastatin activity will therefore tenderize more slowly during the aging period than product with low calpastatin activity. Further, it is apparent that calpastatin activity and the form of the calpastatin impact the rate of proteolysis and tenderization. Ultimately, this information will be utilized to develop selection strategies and in systems designed to classify beef based on predicted eating quality.

Introduction

The 1995 National Beef Quality Audit revealed that beef tenderness continues to be among the top quality concerns facing the beef industry. The audit reported product toughness costs the beef industry $7.64/head or approximately $217,000,000 annually. Specifically, this "cost" is caused by an inconsistency in beef tenderness and our inability to accurately predict aged beef tenderness.

It might be argued that beef tenderness is only one component of beef palatability. Indeed, beef juiciness and flavor also impact consumer acceptability. However, Boleman et al. (1995) reported that: 1) consumers can detect differences in tenderness; 2) tenderness classifications impact overall satisfaction based on sensory panels; and 3) consumers are willing to pay a premium for beef they are confident is tender. Additionally, Koohmaraie (1995) summarized several studies that demonstrated a greater coefficient of variation for sensory panel tenderness scores than sensory panel juiciness or flavor scores. Therefore most evidence points to tenderness as the most important and most variable component of beef palatability.

Calpains are muscle proteolytic enzymes that break down the structural proteins in muscle and meat. The rate and extent of the degradation of several structural proteins directly impacts the structural integrity and therefore the texture of the muscle component of meat. The endogenous specific inhibitor of the calpains, calpastatin, is also present in muscle. The regulation of calpain

activity in postmortem muscle is modulated through calcium concentration and calpastatin (Goll et al., 1992; Koohmaraie ,1995; Koohmaraie, 1992;). Our hypothesis is the rate and extent of proteolysis and tenderization is due to variation in the activity of the calpain enzymes on muscle proteins that affect the integrity of muscle. Furthermore, we hypothesize that inhibition of the calpains by calpastatin can delay the proteolysis and tenderization process.

We have hypothesized that the rate of tenderization during postmortem storage of beef is a major factor in the often-reported variation in beef tenderness. Our objectives in this study were to identify factors that affect postmortem tenderization and overall acceptability of beef. The study was conducted in two separate experiments with separate objectives: 1) to determine the effect of sex condition (steer and bull) of Brangus cattle on beef tenderness, and 2) to determine the effect of sire breed on beef quality characteristics.

Experimental Procedures

Brangus bulls (n=43) and Brangus steers (n=47) were utilized for the first objective. Sixty-five steers from Gelbvieh (n=20) Hereford (n=27) or Limousin (n=18) sires out of Angus-Simmental dams were used utilized to address the second objective. Calves were fed until a group averaged .25 inches 12th rib fat as determined by real-time ultrasound. All calves ranged from 14-17 months of age at slaughter. Calves were slaughtered at Central Packing Company in Center Hill, FL. A USDA beef grader documented carcass yield and quality characteristics. At approximately 24 hours postmortem, short loins were removed from the left side of each carcass and transported back to Auburn University for sampling and aging.

Warner-Bratzler shear force (a measurement of tenderness) was measured on 1-inch top-loin steaks aged 2, 7 and 14 days postmortem at 36°F. Samples from each animal were utilized for calpastatin activity assays (Lonergan et al., 1995) and determination of myofibrillar protein degradation by immunoblotting (Huff-Lonergan et al., 1996) after 2, 7 and 14 days aging at 36°F. Immunoblotting techniques improve the ability of researchers to monitor changes in a particular protein. This technique involves fractionating a mixture of proteins by SDS-PAGE, PAGE (Sodium Dodecyl Sulfate Polyacrylamide Electrophoresis) transferring the fractionated protein to a membrane and detection of specific proteins using antibodies.

Results and Discussion

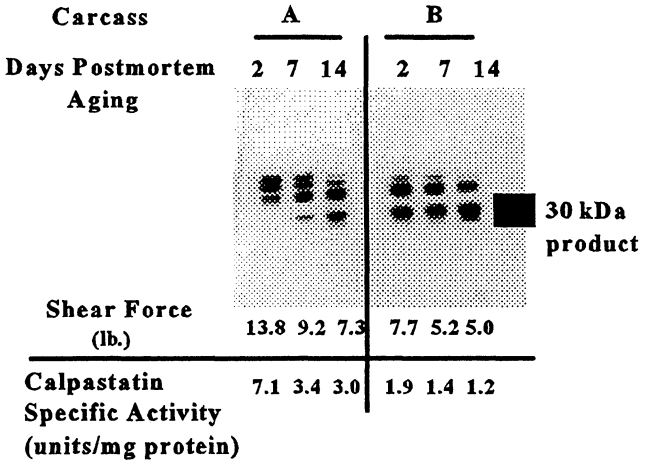
Objective 1: *Determination of sex condition (steer and bull) of Brangus cattle effect on beef tenderness.*

In general, carcasses from bulls had lower quality grades and higher cutability yield grades. Marbling score - the major determinant of USDA quality grades - explained 16 % of the variation of WBS after aging 2 days, and less than 5 % of the variation of WBS after aging 7 and 14 days. Warner-Bratzler shear force (WBS) decreased with aging time. Beef from bulls had significantly higher shear forces than beef from steers after aging 2 and 7 days. However, differences due to sex were not observed in steaks aged 14 days. This clearly indicates that while the extent of tenderization is not different between the two groups, the rate of tenderization is. The question, then, is "what is the cause of the observed slower rate of tenderization?". Calpastatin activity was higher in samples from bull carcasses at 2, 7 and 14 days aging and, may be a good indicator of the rate of

tenderization.. Calpastatin activity after aging 2 days explained over 50% of the variation in shear force of steaks aged 7 days It appears that calpastatin activity is a good predictor of the aging response between days 2 and 7 postmortem.

Calpastatin acts as an inhibitor of proteolysis of myofibrillar proteins and, therefore, it might be hypothesized that steaks with high calpastatin activity would exhibit less proteolysis (as monitored by documentation of proteolytic changes in troponin-T) and less tenderization (as measured by WBS). To test this hypothesis, we monitored changes in proteolysis and WBS in steaks from all animals. Figure 1 represents a comparison of steaks from 2 steer carcasses. Proteins extracted from beef aged 2, 7 and 14 days postmortem were fractionated by size with Sodium Dodecyl Sulfate-Polyacrylamide Gel Electrophoresis. Fractionated proteins were transferred to a supportive membrane where an antibody against troponin-T was used as a molecular probe to detect where troponin-T and its degradation products migrated on the gel (Figure 1).

Figure 1. Protein degradation, WBS and Calpastatin activity



Degradation (enzymatic breakage) of troponin-T results in a band that migrates faster (lower on the gel) than the larger, intact troponin-T protein. This band is labeled the 30 kDa product.

In this comparison, it is apparent that the steaks from the carcass with the higher calpastatin activity (carcass A) had the highest WBS at all times postmortem. Further, steaks from carcass A demonstrated less proteolysis (as indicated by less intense bands corresponding to the 30 kDa product in samples aged 2 and 7 days) than steaks from carcass B. Therefore it appears that calpastatin activity is a good predictor of the rate of proteolytic tenderization that occurs in beef during the aging process.

The rate of proteolysis is associated with the rate of tenderization and calpastatin activity appears to be associated with the both processes. Clearly, the 30 kDa product may also be a valuable "marker" for beef tenderness.

These observations suggest that application of our understanding of the mechanisms of beef tenderization could be used to predict the tenderness and eating quality of beef. An accurate classification of beef carcasses based on eating quality will, in part, address concerns of inconsistent tenderness in graded beef.

Objective 2: *Determination of the effect of sire breed on beef quality characteristics.*

Sire breed significantly affected carcass traits of marbling score, quality grade and yield grade. (Table 1). Hereford sired calves had significantly higher marbling scores and higher yield grades (indicating a lower percentage yield of retail cuts) than Gelbvieh or Limousin-sired calves. Marbling explained less than 10 % of the variation in Warner-Bratzler shear force in steaks aged 7 and 14 days. Table 1 shows the decline in Warner-Bratzler shear force (an indication of improvement in tenderness) over postmortem aging time for each sire-breed group. After aging two days, steaks from Gelbvieh-sired calves had significantly higher shear force values (were tougher) than steaks from Hereford-sired calves. Warner-Bratzler shear force values of steaks from Limousin- and Hereford-sired calves were not different after 2 days aging.

Table 1. Sire-breed effects on beef quality traits.

Breed	Marbling Score	Yield Grade	Day 2 WBS (lb.)	Day 7 WBS (lb.)	Day 14 WBS (lb.)	Day 2 Calpastatin Activity (units/mg)
Gelbvieh	Small [20 ab]	2.5[a]	7.5[a]	6.7[a]	5.5	2.8[a]
Hereford	Small [55 a]	3.9[b]	6.2[b]	5.2[b]	4.8	2.5[ab]
Limousin	Slight [97 b]	2.1[a]	7.0[ab]	5.5[b]	4.7	2.3[b]

[ab]Means in the same column with different superscripts are significantly different.

Steaks from all sire-breed groups became significantly more tender over the 14 day aging period. After seven days aging, steaks from Gelbvieh-sired calves had significantly higher shear force values than steaks from Limousin-sired calves or Hereford sired calves. After aging 14 days, there were no sire breed differences in shear force. Furthermore, a trained sensory panel did not discern differences in tenderness due to sire breed in steaks aged 14 days. This indicates there is a distinct sire-breed difference in the *rate* of postmortem tenderization, but not the *extent* of postmortem tenderization.

Our objective was to determine a biological basis for this variation in the rate and extent of postmortem proteolysis. Our hypothesis is that variation in calpastatin activity is related to variation in tenderness. As a whole,

calpastatin specific activity in samples aged 2 days explained 10% of the variation in shear force in samples aged 7 days. In contrast, marbling score explained approximately 6.5% of the variation in shear force. As marbling score increased, shear force decreased.

Variation in calpastatin activity appears to explain variation in the rate of tenderization. Steaks from Gelbvieh- and Limousin-sired calves did not differ in shear force at day 2 postmortem. However, calpastatin activity was significantly higher in steaks from Gelbvieh-sired calves at that same point (Table 1). By day 7 postmortem, steaks from Limousin-sired calves had lower shear forces than steaks from Gelbvieh-sired calves. One can infer the rate of tenderization in the Limousin group was greater between day 2 and 7 and this is associated with the observed differences in calpastatin activity at day 2.

Although the rate of tenderization is different in the sire breed groups, it is apparent that there are no differences in shear force or sensory panel tenderness scores in steaks aged 14 days at 36° F. This observation points out that most steaks will reach acceptable tenderness levels if aged under the appropriate conditions. The challenge continues to be development of a method to predict what the rate of tenderization will be. We believe that calpastatin activity may be a good predictor of the rate of tenderization. Further investigations should also include development of optimum aging conditions to improve the rate of tenderization.

Implications

The data summarized in this report indicate that, while there is little variation in the extent of tenderization (after aging 14 days) in beef due to sex or sire-breed of the calves, there appears to be a wide variation in the rate of tenderization due to these factors. Our challenge, then, is to predict what the rate of tenderization will be and to develop processing and handling procedures to enhance the rate of tenderization in steaks that may have a slower rate of tenderization. Factors such as calpastatin activity and degradation of myofibrillar proteins (such as troponin-T) appear to be viable candidate "predictors" of the rate of tenderization during the normal aging process.

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COLOR STABILITY AND TENDERNESS PROPERTIES OF BEEF FROM VITAMIN E FED CATTLE.

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SUMMARY

Market heifers (n=12) were fed a standard finishing diet with minimal levels of vitamin E (C group). Another twelve market heifers were fed the C diet with 1000 IU of DL-α-tocopherol (vitamin E)/head/day for the last 125 days on feed (E group). Animals were slaughtered after 125 d on experimental diets. Loins were removed from all carcasses at 24 hours postmortem. Half of the muscles from each group (C and E) were immediately pumped to 10% over the original weight with 250 mM $CaCl_2$ (Ca treatment). Remaining muscles were pumped to 10% over the original weight with water (W treatment). Color was evaulated both instrumentally and by a trained panel. TBA values were measured on days 1 and 7 post-injection (PI). Warner-Bratzler (W-B) shear force values and trained sensory panel evaluations of tenderness and flavor at 1, 3, and 7 d PI were obtained. Immunoblotting techniques were used to monitor the 30 kDa degradation product of troponin-T at 1, 3, and 7 d PI. At 4 d PI E/Ca steaks were the least discolored. E/Ca steak TBA values were not significantly different from C/W steaks at 7 d PI, while C/Ca steaks had greater TBA values after 7 d PI compared to all other groups. Ca treatment resulted in higher off-flavor scores. E/Ca samples had the most rapid tenderization and proteolysis. W-B values were lower in E/Ca samples than in E/W samples at 1, 3, and 7 d PI. Injection of $CaCl_2$ may result in more rapid and immediate tenderization if beef from animals supplemented with vitamin E is used.

Introduction

Beef color is one of the most important factors influencing consumers' purchasing decisions at the grocers' retail meat case. Beef purchasers expect fresh beef to have a bright cherry-red color. Any discoloration is perceived as indicating that the product is no longer fresh and/or wholesome. As a consequence, fresh beef that is discolored, but otherwise wholesome is often sold at a discounted price, or not sold at all. Discounts due to color can represent a loss in revenue that eventually affects all facets of the industry. Recent meat science/ruminant nutrition studies have found that premature beef discoloration can be greatly reduced by supplementing feedlot cattle with supranutritional levels of vitamin E. The recommended vitamin E supplementation program for feedlot beef cattle destined for domestic retail markets is 500 International Units (IU) per head per day for the last 100-125 days of the feeding/finishing period and 1000 IU/head/day for the last 100-125 days of the feeding/finishing period for beef destined for international markets. Feeding the lower level of vitamin E (500 International Units (IU) per head per day for the last 100-125 days of the feeding/finishing period) has been shown in numerous shelf-life studies to extend the desirable color of fresh beef by as much as 2 to 5 days when compared to beef from cattle fed traditional feedlot diets. This increase in color shelf-life could have a significant impact on the demand for fresh beef.

Beef color is dependent upon the state of the iron containing muscle pigment known as myoglobin. The bright cherry-red color of fresh

beef is due to the state of myoglobin and is known as oxymyoglobin. After oxymyoglobin has been exposed to air for a period of time a grayish-brown form of the pigment, known as metmyoglobin is formed. This conversion of pigments is enhanced by conditions that oxidize the iron in myoglobin. Vitamin E, which can be found in cell membranes functions as an antioxidant and may be able to slow down the conversion of oxymyoglobin (desirable cherry-red color) to metmyoglobin (less appealing gray-brown color) and thus extend the color shelf-life of the product (Faustman et al., 1989). In addition, some research has indicated that vitamin E may also delay the development of off-flavors due to the oxidation of lipids found in muscle.

In addition to color stability of the products, it has also been noted that a lack of consistent tenderness can impact consumer satisfaction with beef products. Much research has shown that injection of fresh beef products with a calcium chloride ($CaCl_2$) solution may greatly enhance the tenderness of beef from a wide variety of sources, including beef from older animals. However, one of the problems with $CaCl_2$ injection that has surfaced is the fact that beef products injected with $CaCl_2$ tend to discolor and become visually unappealing to the consumer more rapidly than do non $CaCl_2$ injected samples (Wheeler et al., 1996; Milligan et al., 1997). This discoloration may lead to discrimination against $CaCl_2$-injected products by consumers at retail meat counters. This discrimination could off-set any increase in revenue that might be realized from the potentially more consistently tender $CaCl_2$-injected beef products. Much of the discoloration that occurs in $CaCl_2$-injected products is due to salt ($CaCl_2$) induced oxidation (St. Angelo, et al., 1991). The antioxidant properties of vitamin E may make beef from vitamin E supplemented cattle more resistant to discoloration when injected with $CaCl_2$. It may be possible to enhance color stability of these $CaCl_2$ injected products by using beef from animals fed high levels of vitamin E in order to produce premium products that retain an appealing color and have adequate tenderness.

Experimental Procedures

The objective of the study was to determine if beef from vitamin E supplemented cattle is more resistant to discoloration from calcium chloride injection than is beef from non-supplemented cattle. Twelve market heifers were fed a standard finishing diet with minimal levels of vitamin E (C group). Another twelve market heifers were fed the C diet with 1000 IU of DL-α-tocopherol/head/day for the last 125 days on feed (E group). Animals were slaughtered after 125 days on experimental diets and upon reaching an ultrasound backfat thickness of 10 mm. Loins were removed from all carcasses at 24 hours postmortem. Half of the muscles from each treatment group (C and E) were immediately pumped to 10% over the original weight with 250 mM $CaCl_2$ (Ca treatment). Remaining muscles (C and E) were pumped to 10% over the original weight with water (W treatment). All muscles were vacuum packaged overnight. Steaks were overwrapped with O_2-permeable film and stored at 8°C for 7 days PI. Hunter L, a, b values were obtained each day of storage. Trained panelists evaluated color on days 1, 4, and 7 PI. TBA values were measured on days 1 and 7 PI. Warner-Bratzler (W-B) shear force values and trained sensory panel evaluations of tenderness and flavor at 1, 3, and 7 days PI were obtained. Immunoblotting techniques were used to monitor the 30 kDa

degradation product of troponin-T at 1, 3, and 7 days PI.

Results and Discussion

Dietary supplementation did not have a significant effect ($P > .05$) on any of the carcass characteristics measured (lean maturity, skeletal maturity, marbling, hot carcass weight, rib eye area, 12th rib fat and percent kidney, pelvic and heart fat). As expected, Vitamin E supplementation did significantly increase ($P < .001$) the amount of Vitamin E that was measured in the fresh (non-cooked) top loin steaks (4.03 μg/g of meat in steaks from the Vitamin E supplemented animals vs. 2.13 μg/g of meat in the control group).

The vitamin E treatment did aid in improving the color shelf-life of the fresh steaks in this study. As has been seen by others, calcium chloride injection overall had a detrimental effect on the color stability of beef steaks, however, at 4 days post-injection, the vitamin E/calcium chloride injected steaks were evaluated as being the least discolored, indicating that vitamin E supplementation may have a limited, and short-term ability to retard oxidative discoloration due to injection of calcium chloride.

Vitamin E supplementation also significantly reduced the TBA values (measure of lipid oxidation) after 7 days of post-injection aging ($P < .05$), while calcium chloride injection significantly increased the TBA values ($P < .05$). However, when the steaks from the vitamin E treated animals were injected with calcium chloride and stored seven days the TBA values were not significantly different from the control group (non-vitamin E, no calcium chloride group). This indicates that some of the oxidizing effects of calcium chloride can be alleviated by utilizing beef from animals that have been supplemented with 1000 IU of vitamin E.

As has been reported in other studies, calcium chloride injection did result in significantly higher off-flavor scores ($P < .05$). Vitamin E treatment did not affect off-flavor scores.

The injection of calcium chloride results in an elevated calcium concentration in beef. Hypothetically, this elevated calcium may allow greater activity of the calcium dependent proteases (calpains). This increased activity of calpains during postmortem aging will cause greater structural degradation of muscle proteins, which, in turn results in greater tenderization of meat. Injection of calcium chloride into beef from animals fed 1000 IU of Vitamin E resulted in a more rapid rate of tenderization than in any other treatment. In fact, after one day of aging these samples had 21% lower Warner-Bratzler shear force values than their counterparts (samples from vitamin E fed animals not injected with calcium chloride). After further aging for 3 and 7 days post-injection, calcium chloride effected a 22% and 30% reduction in shear force in samples from vitamin E fed animals. In contrast, while calcium chloride injection resulted in increased tenderization over time in the non-vitamin E fed cattle, it was apparent that the rate of tenderization was not as rapid. For example, after one, three and seven days of post-injection aging there was no significant reduction in tenderness when comparing calcium chloride injected samples with water injected controls within the non-vitamin E group. These results demonstrate that injection of calcium chloride results in much more rapid and immediate tenderization if beef from animals supplemented with vitamin E is used. This may be because the vitamin E supplementation may act to protect the calpain enzymes (which are highly susceptible to

oxidation) from oxidation, thereby allowing even greater activity and more rapid protein degradation when calcium levels are adequate for full activity, as should be the case when calcium chloride is injected. It is possible that calpain activity was elevated to the level that all potential calpain-induced tenderization was accomplished by one day after injection with calcium chloride.

Implications

These data point to the conclusion that vitamin E supplementation may not only improve the color stability of fresh beef, but may also enhance the tenderization effect achieved when beef is injected with calcium chloride. Additionally since beef that is finished either solely on grass, or on pasture with some grain supplementation would also have elevated levels of vitamin E, it would be expected that beef from such animals would also respond much more rapidly to the tenderizing effects of calcium chloride.

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CATTLE HEALTH UPDATE: JOHNE'S DISEASE

J.G. Floyd, Jr., L.T. Hagood

What is Johne's Disease? Johne's (pronounced "YO-knees") Disease is an incurable condition of cattle, sheep, goats, deer, elk, and bison. It has been recognized for over 100 years as a chronic infection of the intestinal tract by the slow-growing bacterium *Mycobacterium paratuberculosis*. Johne's Disease is also referred to as paratuberculosis. The causative bacterium, *Mycobacterium paratuberculosis* (abbreviated *M. paratuberculosis*) is closely related to the bacteria which cause tuberculosis in cattle *Mycobacterium bovis,* and in humans, *Mycobacterium tuberculosis*.

What does an animal with Johne's Disease look like? Cattle usually become infected with paratuberculosis as young calves but take several years to develop outward clinical signs of the disease, which include watery diarrhea, weight loss, and death. There are four stages of the disease in cattle:

- Stage I - "Silent infection" in calves, young livestock, and adults. No clinical signs of sickness.
- Stage II- Subclinical disease, with carrier animals shedding *M. paratuberculosis* but not showing signs of sickness
- Stage III - Chronic, clinical disease (diarrhea, weight loss)
- Stage IV - Advanced clinical disease and death ("wasting away") - this may occur fairly rapidly.

Johne's Disease is often mistaken for parasitism in cattle. In such herds producers may unsuccessfully treat "wormy looking" cows numerous times with the many effective dewormers currently available. In such herds Johne's Disease is always a possibility and should be investigated with the help of a veterinarian.

Other species infected with *M. paratuberculosis* may show somewhat different signs from cattle. Johne's Disease in sheep, goats, llamas, and deer causes chronic weight loss and unthriftiness *without* diarrhea.

How is Johne's Disease spread? The disease-causing *M. paratuberculosis* bacteria are spread in the feces of infected animals, and can remain infective in some environments for almost a year. Infected animals may appear perfectly normal although they may be shedding millions of *M. paratuberculosis* organisms every day. For example, an infected cow may shed 10,000 *M. paratuberculosis* organisms in 1 gram (about 2/1000 ths of a pound) of its manure. A cow shedding 50 pounds of manure per day may be shedding 227 million *M. paratuberculosis* organisms per day. Cows with advanced clinical signs (Stages III and IV of the disease) may shed 1 to 2 billion bacteria per day.

Young calves are infected with *M. paratuberculosis* by ingesting fecally contaminated colostrum, milk, water, feed, dirt, or other environmental materials containing *M. paratuberculosis*. Older animals can be infected by larger amounts of the organism, but calves under 6 months are more at risk. This is because of calves' increased likelihood of contact with the organism and probably because fewer numbers of organisms are required to infect them compared to older animals.

During the time before the clinical signs develop, infected animals serve as sources of

infection for other, uninfected animals. **For every one animal showing clinical signs of disease, 15-25 other animals may be infected without showing signs.** The time between initial infection and development of clinical sign is lengthy, usually no less than 2 years and as long as 10 years. These characteristics make the disease very insidious and difficult to control. They also dictate that the disease is inherently a herd problem, not an individual animal disease. Control efforts which concentrate only on individual animals will insure that the herd as a whole remains infected.

In cattle, Johne's Disease may also be spread from an infected dam to her gestating fetus. It has been estimated that 20% to 40% of calves from dams with clinical signs (Stages III and IV) are infected during gestation, and therefore are born with the infection. Infected cows with no clinical signs (Stages I and II) are less likely to transmit the infection to their fetuses, with 8.6% of calves born to such cows being born infected in one survey.

The main route for introducing Johne's Disease into an uninfected herd is through the purchase of replacement breeding stock. Because heifers and young bulls may be infected but not showing clinical signs (Stages I and II), they may appear to be quite healthy. The same is true for the purchase of recipient heifers by pure bred operations for their on-farm embryo transfer programs. Unless the herd of origin is known to be free of Johne's Disease, these animals are a potential source of *M. paratuberculosis* introduction into a herd. Few beef herd owners in Alabama are aware of their Johne's Disease infection status at the point of this writing in November, 1998.

How much Johne's Disease is there in the cattle population? A national survey in the U.S. has estimated that 1.4% of the beef cattle and 2.6% of the dairy cattle are infected with *M. paratuberculosis*. Johne's Disease has for years been thought of as primarily a dairy cattle problem, but its frequency in beef cattle may be increasing. As reported in another survey in 1995, positive evidence of exposure to the causative organism was found in the blood of 13% of dairy cattle and 25% of beef cattle in Texas auction markets. This high percentage of auction market cattle may overstate the amount of Johne's Disease in the entire population. Many of the animals in this study were likely being culled for clinical signs associated with Johne's Disease, although their owners may not have been aware of the cause of their problems. Even if the number of culled animals with Johne's Disease in this survey is higher than the number in the overall population, the potential for infection that these numbers reveal is sobering. They underscore that purchasing animals of unknown disease history can potentially introduce serious disease problems into a herd.

What is the economic cost of Johne's Disease? In 1997 USDA estimated that a dairy with at least 10 percent of its cows infected with *M. paratuberculosis* was losing $227 per head annually, mainly from decreased milk production. The cost of Johne's Disease is more difficult to determine for beef operations, but is also significant because of cow losses, decreased calf production, and accelerated culling not based on performance criteria.

How is Johne's Disease Diagnosed? Diagnosing Johne's Disease can be challenging because currently available tests do not detect infection early in the course of the disease. The primary test being used is the ELISA blood test. This test is being used by the Alabama State Veterinary Diagnostic Laboratory at Auburn and is a good indicator that a test-positive animal is

infected; however, animals may be infected for long periods of time before they test positive. In a herd wishing to determine if Johne's Disease is present in the herd, this test would best be used on thin cows in poor body condition, with or without diarrhea. If some positive cows are detected, more aggressive testing can be conducted to better determine the extent of infection in the herd. The point to remember is that some animals can be infected in Stage I or II but will not test positive with the ELISA blood test until they reach Stage III or IV. This does not mean that the test is not a good one, but that it has some limitations for use as a quick screen of an entire herd.

The truly definitive test on a live animal is culture of its feces for the causative bacterium, which can take 2-4 months because *M. paratuberculosis* grows so slowly. A polymerase chain reaction (PCR) test on organisms isolated from fecal culture is now also available as a complimentary technique to positively identify the organism. Another definitive test which can be conducted after an animal's death is microscopic exam of tissues taken from its GI tract at necropsy.

Cattlemen and dairymen who feel that they may have Johne's, or any other disease in their herds, should contact their herd veterinarian and request a diagnostic visit. By using the diagnostic tools available and by working together, cattlemen and their veterinarians can devise a plan to deal with Johne's Disease. However, this is not an easy task. It may take as long as 7 to 10 years for some herds to become truly negative after an initial diagnosis of Johne's Disease. Herds which are not infected with Johne's Disease should carefully consider their sources of purchased replacements. Remember, infected replacements are the most likely source of Johne's Disease in most herds which become infected.

How can Johne's Disease be controlled in an infected herd? **There is no effective drug treatment, which only leaves management efforts for control.** Various therapies have been attempted, such as with drugs used in human tuberculosis. Some of these drugs may temporarily suppress disease signs, but are prohibitively expensive and will not eliminate the infection. Once such drug therapy is stopped, the disease progresses as before. Because of its chronic, contagious nature, the disease will increase in an infected herd if steps are not taken to control it.

For infected herds in which managers want to control the disease, the most basic control measure is to prevent exposure of the most susceptible animals, young calves, to infective manure. Calves should be born in a dry, clean area and kept away from manure of mature animals. Fecal contamination of feed bunks and water sources should be prevented. Such control measures may be easier to initiate in a dairy than in a beef herd, although some features are common to both situations.

For the herd owner desiring to eliminate Johne's Disease, a testing program should be initiated to identify infected animals. They and their calves should be removed from the herd and only sold through slaughter or feeder market channels. The current ELISA blood test can be used in such a testing program. Replacement animals should be purchased only from herds which are test-negative for Johne's Disease, although at this point there are few, if any, such documented sources.

There is no mandatory national control program for Johne's Disease in cattle, such as for Brucellosis ("Bangs") and tuberculosis. However, a National Johne's Disease Working

Group has published guidelines for use as a **voluntary** state program. Alabama had the first meeting of its state Johne's Disease Advisory Group in August, 1998. That group of cattlemen, dairymen, veterinarians, and Cooperative Extension agents and specialists discussed the possibility of developing a voluntary state management and control program which would provide a mechanism for individual herds to establish themselves as "Johne's Test Negative." Those herds could then serve as reliable sources of breeding replacement animals. That group requested that Dr. Kenny Brock of the Auburn University College of Veterinary Medicine conduct anonymous testing of blood samples taken at auction markets to better define the extent of Johne's Disease in the Alabama beef cattle population. At the present time those tests are being conducted.

Is there a vaccine for Johnes' Disease? Although there is a vaccine, it currently is not approved for use in Alabama. The vaccine does not prevent infection with *M. paratuberculosis,* but does decrease the amount of clinical signs and number of animals shedding organisms in a herd. However, vaccination interferes with testing for both tuberculosis and Johne's Disease, causing vaccinated cows to test positive for both. This makes differential diagnosis difficult and interferes with testing programs for both diseases. In states such as Wisconsin with a large number of dairies with paratuberculosis, vaccination is used to salvage heavily infected herds.

Are there human disease problems associated with Johne's Disease? A serious concern is the possibility that *M. paratuberculosis* may be associated with Crohn's Disease in humans. This is a disease of the bowel which affects 2-10 people for every 100,000 in the population. Crohn's Disease causes chronic diarrhea, hemorrhage, and abdominal pain in affected humans. Although a link between Johne's and Crohn's Diseases has not been proven, there is some evidence that *M. paratuberculosis* is the common cause of both. It may take years of research to prove or disprove this potential link.

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COMPARING TWO WINTER FEEDING SYSTEMS IN COASTAL ALABAMA

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SUMMARY

Two commonly used winter feeding systems and four castration-implant strategies were evaluated at the Gulf Coast substation (1993 to 1995). The two winter feeding systems were: 1) grazing prepared seedbed ryegrass forage (H) or 2) hay and supplement (L). Gelbvieh-sired male and female calves from the H system were 237 and 188 lbs. heavier ($P<.01$) at weaning, respectively, than calves from the L system. Calves castrated at 45 d were 61.3 lbs. lighter ($P<.01$) than uncastrated calves at weaning. Calves castrated and implanted at 45 d were 65.2 lbs. heavier ($P<.01$) at weaning than calves castrated and not implanted. Thus, implanting at 45 d negated the decrease in weaning weight due to castration. Economic comparisons from this study show a substantial economic return for the H system compared to the L system. However, producers should consider factors specific to their operation before making changes to their wintering system.

Introduction

Cattlemen in the coastal areas of Alabama are blessed with mild winters and plentiful rainfall. These climatic conditions are especially favorable for growing ryegrass. Ryegrass forage is high quality, but producing ryegrass on prepared seedbed is often considered a high input crop and not justified economically for grazing cows. The major objective of this study was to compare two wintering systems that are commonly used in the coastal region: 1) prepared seedbed ryegrass (H) or 2) hay and supplement (L). In addition, male calves were used to evaluate different castration and implant strategies.

Experimental Procedures

Ninety-six commercial cows were assigned randomly to a wintering program of 1) prepared seedbed ryegrass (H) or 2) hay and supplement (L). The genetic makeup of the cows consisted of varying percentages of Hereford, Holstein and Simmental. During the three years of the study, the two groups were managed as one herd on permanent pasture except from late fall to early spring. During winter and spring, cows in the H system were maintained on ryegrass pastures, while cows in the L system were fed hay and supplemented with grain to meet NRC requirements.

Heifers were mated to Angus and cows were mated to Gelbvieh. The calving season started at the end of September and was approximately 90 d. Male calves were assigned randomly to one of four treatments: 1) no castration or implant, 2) castration and implant 1 mo before weaning, 3) castration at 45 d and no implant, or 4) castration and implant at 45 d. The implant used was Calf-oid®. Calves were weaned at an average age of 274 d.

Birth weights, weights approximately 1 mo before weaning (WW1), and actual weaning heights (WH) and weights (WW) of the calves were recorded. Data recorded on cows included heights, weights, body condition scores and pregnancy status. In addition, data were recorded on the acreage needed for pasture, tons of hay, bushels of grain and hours of labor needed for the two wintering systems.

Data were analyzed using least-squares techniques employing a fixed effects model that included the effects of year, wintering system, age of dam and their two-way interactions. No adjustments for differences in calf ages were made because calf age differences were possible effects of wintering systems. Data from heifers and cows were analyzed separately because age of cow and service sire breed were totally confounded. In addition, data from male and female calves were analyzed separately because of the treatments imposed on the male calves. Contrasts among the four treatments assigned to the male calves were used to separate the effects of castration and implant.

Results and Discussion

Only data from the Gelbvieh-sired calves will be presented because of the small number of Angus-sired calves, but both groups exhibited similar trends for wintering system differences. Cows in the H system were heavier ($P<.01$), taller ($P<.01$), higher condition ($P<.01$) and gave birth to heavier calves than cows in the L system (Table 1). No significant differences in pregnancy rates were observed between the two systems probably because cows in the L system were maintained in adequate body condition during the breeding season. Cows in the H system gave birth to 10.3 lbs. heavier ($P<.01$) calves, but no differences in calving difficulty were noted between the two systems.

Both male and female calves produced in the H system had heavier ($P<.01$) weaning weights (WW1 and WW) and were taller ($P<.01$) at weaning (Table 2). The increase in the difference between the two systems from WW1 to WW probably indicates that lactational persistence of cows in the H system was greater than the cows in the L system because both sets of calves were on the same pasture during this time.

Table 1. Least squares means and standard errors of birth weights of Gelbvieh-sired calves and measures of cow size and condition by wintering system.

	Winter feeding system		
Variable	High	Low	System Diff.
Calf Wt., lbs	89.8 ± 1.69	79.5 ± 1.84	10.3**
Cow Wt., lbs	1349 ± 10.5	1134 ± 11.5	215**
Cow Ht, in	53.1 ± .14	51.8 ± .15	1.3**
Cow BCS	7.0 ± .06	6.0 ± .07	1.0**

**P<.01

Table 2. Least squares means and standard errors for weaning weights (lbs) and heights (in) of Gelbvieh-sired calves at two ages by winter feeding system and sex of calf.

	Winter feeding system		
Variable	High	Low	System Diff.
Male			
Early Wt.	711 ± 13.0	503 ± 14.2	208**
Wean Wt.	802 ± 12.1	565 ± 13.0	237**
Wean Ht.	53.1 ± .14	51.8 ± .15	1.3**
Female			
Early Wt.	637 ± 10.7	463 ± 10.7	174**
Wean Wt.	702 ± 10.6	514 ± 12.0	188**
Wean Ht.	47.5 ± .24	44.9 ± .27	2.6**

**P<.01

Effects of castration and implanting are presented in table 3. Calves castrated at 45 d and received no implant were 59.3 and 61.3 lbs. lighter ($P<.01$) for WW1 and WW, respectively, than uncastrated calves. Implanting at 45 d increased WW1 (46.3, $P<.10$) and WW (65.2, $P<.01$). These data indicate that

implanting at 45 d can negate the decreases in weaning weights due to castration at that time. No advantages due to implanting were observed ($P > .1$) when castration was delayed until 1 mo before weaning. These data clearly support the recommendation of early castration and implanting because castration at an early age is less stressful on the calf and the producer.

Table 3. Effects of castration and implanting with Calf-oid®

Variable	Castration[a]	Early Implant[b]	Late Implant[c]
Early Wt.	-59.3 ± 21.7**	46.3 ± 25.3*	
Wean Wt.	-61.3 ± 23.2**	65.2 ± 24.0**	-5.5 ± 25.2

**P < .01.
*P < .10.
[a]Difference between animals castrated at 45 d and uncastrated males.
[b]Difference between animals implanted at 45 d and castrated males that were not implanted.
[c]Difference between animals castrated and implanted 1 mo before weaning and those males castrated 1 mo before weaning and were not implanted.

Studies of this type lend themselves to economic analysis because of their comparative nature. Using the data collected as part of this study on inputs (acreage, labor, hay, and grain) and outputs (calf and cull animals weights), the economic comparison using prices received for outputs and costs incurred for inputs are presented in table 4. The comparison indicates a substantial economic gain from the H system ($26/cow) compared to the L system ($-127/cow). It would appear from these data that the recommendation for H system is warranted. However, several factors should be taken into account. The cows used in this study had the genetic abililty to use the improvement in nutrition and prices received and costs incurred are not constant across time. Producers should factor in their anticipated costs and prices and the genetic level of their cow herd before deciding the most economical winter feeding system.

In this study, hay was supplemented with grain (corn) to meet NRC requirements. Though the diet was balanced, supplementation of forage diets with grain can decrease the digestibility of the forage component. However, the level of grain supplementation that occurred in this study should not have had a significant negative impact on forage digestibility. The level of protein in the hay and corn supplement met NRC requirements.

Table 4. Economic comparison of the two winter feeding systems.

		Winter Feeding System	
Item	Unit	High	Low
Permanent Pasture	acre/cow	1.33	1.33
Ryegrass Pasture	acre/cow	3.03	0
Ryegrass Hay	ton/cow	.44	2.58
Grain	bushels/cow	95	9.87
Labor	hours/cow	9.19	12.17
Calf Production[a]	lbs/cow	679	465
Gross Receipts[b]	$/cow	429	314
Total Costs[c]	$/cow	403	440
Net Returns	$/cow	26	-127
Break-even Calf Price[d]	$/cwt	57	100

[a]Prices and costs are 1996 values.
[b]Includes heifers held for replacement.
[c]Includes sale of cull animals.
[d]Excludes land and labor costs.
[e]Holding value of cull animals constant.

FEEDING BY-PRODUCTS TO BEEF CATTLE

DARRELL L. RANKINS, JR.

SUMMARY

Five trials were conducted at various locations across the state. Each of the trials lasted for 112 days. Three of the trials evaluated the effects of quantity and quality of roughage being offered to stocker calves consuming broiler litter-based diets. Two of the trials were conducted to determine if soybean hulls could replace corn in a broiler litter-based diet. Results indicated that the fastest gains were observed when cattle were given free-choice access to good quality roughage. However, the most economical weight gains were produced by the lower quality roughages which were free of charge. Results from the soyhull studies indicated that soyhulls could replace all of the corn in a litter-based diet fed to stocker calves.

Introduction

Broiler litter has been used as a low-cost, by-product feed throughout the southeastern U.S. The majority of the litter is fed to brood cows, stocker steers and replacement heifers. The objectives of the studies described in this report were to: 1) evaluate various roughage sources for steers fed broiler litter-based diets and 2) evaluate the efficacy of replacing the corn in a litter/corn mix with soyhulls.

Experimental Procedures

Five trials were conducted at various locations across the state. All feeding trials were conducted for 112 days. In each trial, broiler litter was deep-stacked and covered for at least 21 days prior to feeding. All diets contained Bovatec at a level to provide approximately 200 mg/steer/day. Trial 1. Four diets were fed to 48 Angus x Charolais steers (440 lbs) at the Sand Mountain Substation. Diets were: 1) 50% broiler litter and 50% cracked corn, 2) diet 1 + daily hay at 3 lbs/steer, 3) diet 1 + hay fed twice per week to equal amount fed in diet 2 and 4) diet 1 + free-choice hay. The hay was primarily orchardgrass (80%) and some endophyte-free tall fescue (20%) and would be classified as a high-quality hay (12% CP and 55% NDF). Trial 2. Five diets were fed to 50 predominantly Brangus steers (597 lbs) at the Wiregrass substation. Diets were: 1) 50% broiler litter and 50% cracked corn, 2) diet 1 + daily hay at 3.2 lbs/steer, 3) 45% broiler litter, 45% cracked corn and 10% peanut hulls, 4) diet 1 + free-choice hay and 5) diet 1 + free-choice hulls. The hay was primarily bermudagrass and would be classified as a medium to high-quality hay (12% CP and 60% NDF). The peanut hulls would be classified as a low-quality (6% CP and 74% NDF) roughage source. Trial 3. Five diets were fed to 50 predominantly Brangus steers (609 lbs) at the Wiregrass substation. Diets were: 1) 50% broiler litter and 50% cracked corn + hay, 2) diet 1 + peanut hulls, 3) diet 1 + pelleted peanut hulls, 4) diet 1 + cotton mote and 5) diet 1 + gin trash. All diets and roughage sources were fed free-choice. The hay was primarily bermudagrass. Trial 4. Four diets were fed to 32 predominantly Angus steers (608 lbs) at the E.V. Smith Beef Unit. Diets were: 1) 50% broiler litter and 50% cracked corn, 2) 50% broiler litter, 37.5% corn and 12.5% soyhulls, 3) same as diet 2 and 4) 50% broiler litter, 25% cracked corn and 25%

soyhulls. Diets 1, 3 and 4 were supplemented daily with 3.4 lbs of bermudagrass hay per steer. Diet 2 received no hay. Trial 5. Five diets were fed to 60 crossbred heifers (425 lbs) at the Sand Mountain Substation. Diets were: 1) 50% broiler litter and 50% cracked corn, 2) 50% broiler litter, 37.5% corn and 12.5% soyhulls, 3) 50% broiler litter, 25% cracked corn and 25% soyhulls, 4) 50% broiler litter, 12.5% cracked corn and 37.5% soyhulls and 5) 50% broiler litter and 50% soyhulls. All diets were supplemented with hay at a rate of .5% of body weight per day.

Results

Table 1. Effects of hay feeding regimen on weight gains (lbs/day), daily intake (lbs/day) and feed efficiency of steers fed broiler litter-based diets.

Diet	ADG	Litter mix Intake	Hay Intake	Total Intake	Feed/gain	$/pound of gain
No Hay	1.94[a]	19.4[a]	0[a]	19.4[a]	10.0	.33
Daily Hay	2.68[b]	21.0[a]	3.0[b]	24.0[b]	9.0	.29
Twice/wk	2.11[a]	18.6[a]	3.0[b]	21.6[ab]	10.2	.33
Freechoice	2.86[b]	15.4[b]	9.7[c]	25.1[b]	8.8	.28

[ab]Values within a column with different superscripts differ $P<.05$.

Table 2. Effects of low and high quality roughages on weight gains (lbs/day), daily intake (lbs/day) and feed efficiency when fed to steers consuming broiler litter-based diets.

Diet[a]	ADG	Litter/corn Intake	Roughage Intake	Total Intake	Feed/gain	$/pound of gain
No Fiber	2.12[b]	23.2	0[b]	23.2[b]	10.9	.36
Limit Hay	2.70[d]	23.7	3.2[c]	26.9[c]	10.0	.33
LimitHulls	2.39[c]	23.4	2.6[c]	26.0[c]	10.9	.32
FC Hay	2.88[d]	21.8	8.2[d]	30.0[d]	10.4	.34
FC Hulls	2.58[cd]	23.4	6.8[d]	30.2[d]	11.7	.30

[a]Hulls = peanut hulls and FC = Free-choice.
[bcd]Values within a column with different superscripts differ $P<.05$.

Table 3. Effects of various roughage sources on weight gains (lbs/day), daily intake (lbs/day) and feed efficiency in steers fed broiler litter-based diets.

Diet	ADG	Litter/corn Intake	Roughage Intake	Total Intake	Feed/gain	$/pound of gain
Hay	3.23[a]	25.4	8.0[a]	33.4	10.3	.31
Hulls	3.02[ab]	26.6	7.5[a]	34.1	11.3	.26
Pelleted Hulls	2.50[c]	22.1	8.8[a]	30.9	12.4	.32
Cotton Mote	2.54[c]	27.6	3.7[b]	30.4	12.3	.33
Gin Trash	2.86[b]	24.5	5.9[ab]	31.3	10.6	.26

[ab]Values within a column with different superscripts differ $P<.05$.

Table 4. Effects of replacing corn with soyhulls on weight gains (lbs/day), daily intake (lbs/day) and feed efficiency in steers fed broiler litter-based diets.

Diet[a]	ADG	Litter mix Intake	Hay Intake	Total Intake	Feed/gain	$/pound of gain
1	2.38[b]	22.2	3.4[b]	25.6	10.8	.37
2	2.32[b]	23.8	0[c]	23.8	10.3	.33
3	2.65[c]	22.9	3.4[b]	26.3	9.9	.32
4	2.80[d]	23.0	3.4[b]	26.4	9.4	.28

[a]Diets: 1=50% litter & 50% corn, 2=50% litter, 37.5% corn & 12.5% soyhulls, 3=50% litter, 37.5% corn & 12.5% soyhulls, 4=50% litter, 25% corn & 25% soyhulls.
[bcd]Values within a column with different superscripts differ $P<.05$.

Table 5. Effects of varying levels of soyhulls in litter-based diets on weight gains (lbs/day), daily intake (lbs/day) and feed efficiency when fed to heifers.

Diet[a]	ADG	Litter/corn Intake	Hay Intake	Total Intake	Feed/gain	$/pound of gain
1	1.65	17.7	2.5	20.2	12.2	.35
2	1.60	16.7	2.5	19.2	12.0	.33
3	1.69	16.6	2.5	19.1	11.3	.30
4	1.61	16.8	2.5	19.3	12.0	.31
5	1.65	18.4	2.5	20.9	12.7	.31

[a]Diets: 1=50% litter & 50% corn, 2=50% litter, 37.5% corn & 12.5% soyhulls, 3=50% litter, 25% corn & 25% soyhulls, 4=50% litter, 12.5% corn & 37.5% soyhulls, 5=50% litter & 50% soyhulls.

Discussion

Overall: A point to note in each of these studies is that with the exception of trial 5 the daily gains are quite good. Most producers should expect daily gains of about 2 to 2.25 pounds per day. The reason for these differences is the fact that we receive the cattle and adapt them to the facilities for about 3 weeks prior to beginning the study, at this time we take our initial weight. If we calculated daily gains as pay-weight to pay-weight, they would be about 2 to 2.25 pounds per day.

Roughage Sources: Average daily gains were similar for trials 1 and 2. When using a high-quality hay, gains were increased by .2 to .3 pounds per day when the hay was offered free-choice versus a limit feeding. It is important to note that in these studies the free-choice hay was fed as square bales in a concrete feed bunk. As this information is applied to a field situation, one would assume that most hay would be offered free-choice in the form of a round bale, which would result in a considerable amount of the hay being wasted and would therefore increase the cost of this strategy. When comparing the high-quality roughage (hay) to the low-quality roughage (peanut hulls), daily gains were slower when the hulls were used, but as mentioned previously, the peanut hulls would be worth $27/ton if you assume that the hay is worth $60/ton. As you increase the price of hay, then the value of the peanut hulls would also increase.

Based on these results, the most economical gains will be produced by offering the roughage in a free-choice manner. A low-quality source of fiber may be used if the cost of that fiber source is low enough. Low-quality, in this case, refers to the amount of digestible nutrients in the fiber source. If the roughage is moldy or unpalatable, this would not necessarily be true.

Use of Soyhulls: When evaluating trial 4, as inclusion of soyhulls increased in the diet, average daily gain also increased. The fastest and most efficient gains were observed in the cattle being fed the diet containing the highest inclusion of soyhulls. The slowest gains were

observed for the cattle receiving no soyhulls. Similarly, the diet containing 12.5% soyhulls produced intermediate gains to the other two. Diet 2 (trial 4) contained 12.5% soyhulls but the cattle were not given any supplemental hay, this resulted in gains similar to cattle fed no soyhulls and supplemented with hay. No difference in feed intake were observed among the cattle fed varying levels of soyhulls. However, hay supplementation increased intake over the steers not being supplemented with hay. When feed costs are combined with the performance data there is an obvious advantage to using soyhulls.

Diet 2 (no hay) was included to determine if the soyhulls would replace the coarser fiber being provided by the grass hay. When comparing it to Diet 3 (same ingredients plus the hay supplement) it is apparent that a less digestible fiber source is more beneficial.

When trial 4 was initiated it was assumed that the highest percentage of soyhulls (25%) would be the maximum amount that could be used. However, 25% soyhulls was the best diet and the maximum was not reached. Therefore, trial 5 was conducted to evaluate higher concentrations of soyhulls. Results from this heifer trial indicated that all of the corn could be replaced with soyhulls. In trial 5, the daily gains were quite slow. This was a result of two factors: 1) heifers gain slower than steers and 2) the litter used in this study was of poor quality. Initially we started out with good quality broiler litter (<25% ash) but approximately one month into the study we exhausted this supply and had to obtain additional litter which was extremely high in ash content (33%).

Based on these results, soyhulls can replace half of the grain in a broiler litter/corn diet without compromising performance. In fact, performance was actually enhanced by substitution with soyhulls, presumably by effects on digestibility, making them a very economical alternative to corn in a litter-based diet. Even though the soyhulls are a digestible source of fiber, additional fiber (i.e., hay) should be offered for optimal performance.

Dietary Protein Considerations for Lactating Dairy Cows

K. A. Cummins

SUMMARY

Dietary crude protein between 9 and 18% of diet dry matter had an effect on milk production, with decreasing crude protein resulting in decreased milk, feed intake, and milk protein. Changes in skeletal muscle calpastatin content indicate that protein requirement for lactation may be between 1 and 15 % of diet dry matter.

Introduction

Dietary protein is the most expensive part of rations fed to dairy cattle, and has been steadily increasing in rations offered dairy cows in the last 20 years. It is not uncommon for cows to be fed diets of 20 percent crude protein or more. However, much of the effect of increased dietary protein is to increase dry matter, and thus energy, intake. In addition, environmental concerns about nitrogen runoff and ammonia release into the atmosphere apply pressure to reduce dietary crude protein offered. As part of on-going research at Auburn University, an experiment was conducted to evaluate the effect of reducing dietary protein on metabolism of protein in skeletal muscle of dairy cows in early lactation. This was done as part of an effort to evaluate dietary protein requirements by criteria other than milk production.

Experimental Procedures

Sixteen multiparous Holstein cows were assigned to one of four dietary treatments at calving. Treatments were either a 9, 12, 15, or 18 % CP diet starting at 30 DIM and continuing until 56 DIM (days in milk). All cows were fed an 18 % CP diet from calving to 29 DIM and from 57 to 84 DIM. Diets were based on corn silage, cracked corn, and soybean meal and were fed as a total mixed ration (Table 1). Muscle biopsies were taken at 49, 63, and 84 DIM from the semi-tendinosous muscle of the rear leg. Calpastatin, a peptide that controls muscle protein breakdown, was purified from the sample and quantified by Western blotting techniques using an antibody that binds bovine calpastatin.

Results and Discussion

During the pre-experimental period (0 to 29 DIM) there was no effect of dietary CP on feed intake, milk production, milk fat percentage, or milk protein percentage ($P > .1$). During the experimental period (30 to 56 DIM), dietary CP had an effect on feed intake, milk production, and milk protein content, which was reduced by lower dietary protein intakes(Table 2, $P < .05$).

Western blots show that at 84 DIM, after the experimental period was completed and all cows were consuming an 18 % CP diet, muscle calpastatin was affected by previous dietary protein intake. Dietary CP below 15% resulted in no detectable intact calpastatin in muscle tissue, but did not affect levels of the primary degradation product of calpastatin itself.

Table 1. Diet ingredients and nutrient composition[a].

	% CP			
	9	12	15	18
Corn Silage	53.0	49.6	47.0	44.5
Corn, cracked	43.0	37.1	34.0	28.2
SBM, 48%	0.0	9.9	15.9	24.6
Limestone	1.6	1.2	1.1	1.0
Dicalcium Phosphate	.43	.4	.38	.33
Salt	.46	.46	.50	.47
KCl	.3			
Dyna-Mate	.50	.60	.36	.10
Na Bicarb	.75	.75	.75	.75
NE_L	1.68	1.71	1.70	1.72
CP	9.4	12.3	15.2	18.5
ADF	19.9	19.0	20.8	19.1
Ca	.83	.86	.91	1.19
P	.42	.46	.48	.49
K	.87	.83	.99	.99
Mg	.39	.38	.39	.35

[a]All values are expressed as a percent except NE_L, which is Mcal/kg.

Table 2. Effect of dietary CP from 30 to 56 DIM on production and dry matter intake (DMI).

	% CP				
	9	12	15	18	SEM
DMI, kg/d	28.8[a]	31.9[ab]	32.0[ab]	32.9[b]	1.85
Milk, kg/d	25.7[a]	28.4[b]	27.5[b]	27.9[b]	1.32
Fat, %	3.70	4.40	3.71	4.09	.23
Prot., %	3.20[a]	3.27[ab]	3.34[ab]	3.41[b]	.13

[ab]Values without common superscripts differ $P < .05$.

Implications

Inadequate dietary CP intake during early lactation (30 to 56 DIM) appears to affect muscle protein metabolism even following a period of adequate CP intake. Altering dietary CP levels between 12 and 15 % of dry matter in early lactation may result in significant changes in protein metabolism. Results of this and previous studies at Auburn University indicate dietary protein requirement for lactating dairy cows may be approximately 14 to 15 % crude protein.

CORN, ALFALFA OR RYEGRASS SILAGE WITH OR WITHOUT COTTONSEED HULLS FOR MILK PRODUCTION.

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SUMMARY

The performance of mid-lactation cows fed corn , alfalfa or ryegrass silage was compared for 75-days when supplemented with cottonseed hulls. Corn silage was ensiled in an upright silo; alfalfa silage was ensiled in both an Ag-Bag and Vacuum-Bag system; ryegrass silage was ensiled in an Ag-Bag system. Cows fed corn silage without cottonseed hulls produced more milk (46.4 lb/d) than did cows fed the other three silages (37.6-39.4 lb/d). Cows fed ryegrass silage ate less feed (9.9-20.7 lb/d) than did cows fed the other three silages. No difference in milk production between Ag-Bag and Vacuum-Bag alfalfa silage was observed, indicating that the Vacuum-Bag ensiling process can be a satisfactory method of keeping silage. Inclusion of cottonseed hulls in alfalfa silage based diet increased dry matter intake, milk production and body weight but had no effect on milk fat or protein percentage.

Introduction

Dairy farmers continually seek out feeds and diet compositions which will allow economical production for healthy cows. The proper balance of forages and grains is not an easy task under favorable conditions but often becomes more difficult in Southeast U.S. This is because climatic conditions and crops in the Southeast U.S. create difficulty in growing and harvesting good quality hay. Harvesting and storing hay crops as silage are not affected as much by climatic conditions as are haying procedures. However, many farms are not properly equipped to store silage with conventional systems. Various approaches to ensiling crops have been developed during recent years. A vacuum process to extract air from the plastic-sealed silage crops has been used for 2-3 seasons under practical farm conditions at Alexandria, AL. However, crops ensiled with this procedure have not been adequately evaluated under controlled conditions. Inclusion of cottonseed hulls in diets has been beneficial under some conditions. However, milk yield responses to rations containing cottonseed hulls are variable. The objective of this investigation was to compare the effects of various silages and cottonseed hulls on milk yield and composition.

Experimental Procedures

Forty-eight mid-lactation (187 DIM) Holstein cows were fed one of eight dietary treatments for 75 days. Treatment diets consisted of a balanced grain mix with either corn silage (CS), Ag-bag pressed alfalfa silage (AgAL), vacuum-packed alfalfa silage (VAL), or Ag-bag pressed ryegrass silage (RG) supplemented with or without cottonseed hulls (CSH) at 7% of dietary dry matter. The corn silage was ensiled in August, 1997 in an upright concrete stave silo. The alfalfa and rye grass silages were ensiled in mid-May, 1998 after wilting for 24-48 hrs. Both alfalfa treatments were from adjoining areas within the same field but the AgAL was ensiled the day after the VAL treatment. Ryegrass and AgAL were ensiled

with accepted procedures for the Ag Bag system in nine feet diameter bags. For the VAL treatment, five vacuum system silage bags were filled. The silage was piled (~7' x 20') on top of plastic. Another sheet of plastic was placed over the top of the silage and connected to all four sides of the bottom sheet by rolling around a 2" PVC pipe. The plastic was secured to the PVC pipe with clamps and duct tape. A perforated PVC pipe was placed on the bottom sheet of plastic prior to filling and extended through the wrapped silo via a non-perforated PVC pipe. This pipe was coupled to a vacuum pump. This silage was evacuated immediately after ensiling and at daily intervals thereafter until opened for feeding.

Treatment diets were mixed and fed daily as a TMR for 75 d starting in mid June, 1998. Feed consumed was recorded for each cow, and treatment diets were sampled periodically. Silages were analyzed for DM at ensiling and sampled periodically throughout experiment for nutrient analyses. Diets were based on initial analyses.

Cows were housed in tie-stalls and milked twice daily at 0100 and 1300 h. Milk weights were recorded daily, and milk was sampled the first week of each month. Milk fat and protein were determined on individual milk samples by automated techniques at the Southeast DHIA lab (McDonough, GA). Cow body weights were taken on 2-3 consecutive days prior to the study, at 45 d and at the end of the study.

Results and Discussion

Nutrient composition of the silages (Table 1) are typical of good quality silage for the different crops. The Ag Bag alfalfa silage was much drier than the other silages but the nutrient content (DM basis) of the two alfalfa silages were very similar. Due to the wide variation of nutrient content of the silages and in an attempt to maximize the amount of silage used in the diets (Table 2), some variation existed in energy and protein content of the diets. Protein content of all diets were increased to that supplied by the RG treatment in order to minimize any possible protein differences. Energy content was greater in the CS diets but the energy supplied in other diets were considered adequate for the milk production at the start of the study. Differences in CP, fibers and minerals between the alfalfa, corn and ryegrass silages are consistent with known nutrient differences, relevant to stage of maturity at harvest between legume and grass silage.

Table 3 contains production results. Cows receiving VAL produced milk as well as those receiving AgAL. These results indicated that the vacuum method of ensiling is a satisfactory approach to ensiling crops. In our study, the first VAL silo was opened within 40 days of ensiling and the last at about 90 days after ensiling. The silage bags were vacuumed daily until the bag was opened. The silage within each bag was fed out within 2-3 weeks after opening with care to recover the bags after each day's feeding. All silage removed had a good visual appearance with a "normal silage" odor. The effect of longer storage and less frequent vacuuming on silage quality is not known. Additional laboratory tests on the silage are in progress to help evaluate the silage system. Intake was lowest ($P<0.05$) on ryegrass diets and greatest ($P<0.05$) on the AgAL diet. In contrast to earlier studies (Gu and Moss, 1997), CSH did not improve intakein CS or RG diets. However, intake was increased ($P<0.05$) with the inclusion of CSH in alfalfa diets. Also, in contrast to previous studies, CSH depressed milk production in the CS diets. Milk production was improved ($P<0.05$) by CSH in the alfalfa diets but did not affect production for cows on ryegrass. No differences in milk fat percentage

were observed among cows fed the various silages, although supplementing with CSH increased milk fat by 0.3-0.4 percentage units. Milk protein percentage was lower ($P<0.05$) for cows fed alfalfa silage or ryegrass silage with CSH compared with that of cows fed corn silage. This may have been due to the solubility of protein in the diets. The protein in grass and legume silage is very soluble. It is logical to conclude that such protein was absorbed from the rumen rapidly and not used to make as much milk protein. Cows gained weight on all diets with cows fed corn silage without the CSH supplement diet gaining the most ($P<0.05$).

Implications

Ensiling crops with a vacuum bag process may well provide as much milk production as when the crops are ensiled under more conventional methods. Additional information is needed on storing for extended times in these bags. Although alfalfa and ryegrass are high in protein, milk production may not be as good as with corn silage diets, probably due to usable energy. Use of cottonseed hulls may enhance production but results may not be consistent with different crops or seasons.

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Table 1. Nutrient composition of silages

Item	CS	Alfalfa AgAL	Alfalfa VAL	RG
Nutrient[a]				
DM	32.8	70.8	44.6	30.3
CP	12.4	22.6	23.4	18.3
ADF	22.0	31.0	31.0	32.0
NDF	51.0	46.0	40.0	48.0
Ca	.20	.67	1.00	.63
P	.18	.28	.34	.26
TDN	67.6	59.8	59.8	61.7
NE_L	.70	.61	.61	.64

[a]All nutrients are expressed as a percent of dry matter, except NE_L, which is Mcal/lb.

Table 2. Ingredient and nutrient composition of treatment diets.

	With cottonseed hulls				Without cottonseed hulls			
	Alfalfa				Alfalfa			
	CS	AgAL	VAL	RG	CS	AgAL	VAL	RG
Ingredients								
Corn Silage	51.3	0.0	0.0	0.0	58.8	0.0	0.0	0.0
Alfalfa Silage	0.0	50.0	45.8	0.0	0.0	58.3	59.0	0.0
Ryegrass Silage	0.0	0.0	0.0	46.1	0.0	0.0	0.0	61.4
Cottonseed Hulls	7.0	7.0	7.0	7.0	0.0	0.0	0.0	0.0
Cottonseed	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Corn, ground	0.0	15.5	5.7	10.0	0.0	5.6	0.0	0.0
Soybean Meal	14.7	0.4	0.0	5.3	14.4	0.0	0.0	2.4
Megalac®	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Soyhulls	10.0	10.0	25.0	24.3	10.0	19.2	25.1	19.0
Salt	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.1
AU Mineral	2.4	2.5	2.1	2.6	2.3	2.4	1.4	2.5
Dynamate®	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2
Content								
DM, %	47.8	79.6	61.8	47.6	44.8	78.1	56.5	41.1
CP, %	17.7	17.7	17.7	17.7	17.7	18.9	19.7	17.7
NE_L, Mcal/lb	0.78	0.75	0.75	0.75	0.80	0.75	0.75	0.75

Table 3. Intake, milk yield and composition and body weight changes for cows fed diets with different forage sources supplemented with or without cottonseed hulls

	With cottonseed hulls				Without cottonseed hulls			
		Alfalfa				Alfalfa		
	CS	AgAL	VAL	RG	CS	AgAL	VAL	RG
Intake								
DM, lb/d	34.5^{bc}	44.9^{a}	35.4^{bc}	26.6^{e}	34.1^{cd}	37.6^{b}	31.7^{d}	24.2^{e}
Energy, Mcal/d	26.9	33.7	26.6	20.0	27.3	28.2	23.8	18.2
Protein, lb/d	6.1	7.9	6.3	4.7	6.0	7.1	6.2	4.3
Milk Yield, lb/d	38.5^{cd}	42.0^{b}	40.9^{bc}	39.4^{cd}	46.4^{a}	37.6^{d}	39.4^{cd}	39.2^{cd}
Milk Composition								
Fat, %	4.1	3.85	3.7	4.10	3.7	3.7	3.8	3.8
CP, %	3.2^{a}	3.0^{b}	2.9^{b}	3.0^{b}	3.1^{ab}	2.9^{b}	3.1^{ab}	3.1^{ab}
Feed Efficiency								
Milk/DM	1.11	0.94	1.16	1.48	1.36	1.00	1.25	1.62
Body Weight								
Initial, lb	1336	1289	1313	1291	1325	1327	1376	1271
Final, lb	1406	1365	1362	1329	1426	1354	1399	1375
Change, lb/d	0.9^{ab}	1.0^{ab}	0.7^{ab}	0.5^{ab}	1.4^{a}	0.4^{b}	0.3^{b}	0.8^{ab}

^{abcd} Means in the same row with no common superscript differ ($P < 0.05$).

DAIRY HEIFER GROWTH ON DIETS CONTAINING BROILER LITTER

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SUMMARY

Thirty-two Holstein heifers were fed one of four diets for 84 days to evaluate broiler litter on feed intake and gain. Heifers were offered the following diets : 1) grass hay plus soybean meal; 2) grass hay plus broiler litter; 3) corn silage plus soybean meal; 4) corn silage plus broiler litter. Heifers consumed less feed when broiler litter was included with hay, broiler litter did not depress intake with corn silage. Wither height and heart girth were not affected by treatments. Average daily gain and body scores for heifers receiving broiler litter were satisfactory (1.43 and 1.94 lb/d) but less than for heifers receiving soybean meal (2.07 and 2.66 lb/d).

Introduction

Broiler litter is considered an economical source of nutrients for ruminants and is routinely fed to beef cattle in Alabama. A few producers are feeding litter to dairy heifers and seeking answers relative to growth and safety for heifers. However, information relative to feeding litter to dairy heifers is extremely sparse. A North Carolina study evaluated poultry litter for heifers, but included litter in corn silages at ensiling time. This is not a feasible approach with most producers. Mixing litter at ensiling is not feasible because it is not legal to add litter to feed for lactating cows and most producers who feed heifers with corn silage normally do not have the luxury of devoting a separate silo for heifer silage. Bunting et al. (1997 Louisiana Dairy Report) fed two sizes (280 or 380 lb) of Holstein calves diets containing 55% litter or a corn-soy concentration. However, the broiler litter diets also contained soy concentrate which could have masked the value of broiler litter. Patil et al. (1995: Prof. Anim. Sci. 11:100) compared growth rates of sixteen 348 lb Holstein heifers fed 0.5% of their body weight (BW) of bermuda grass hay, 1% of BW as ground corn and ad libitum amounts of additional bermuda grass hay, alfalfa hay or deep-stacked or composted broiler litter. Feed intakes did not significantly differ, but weight gains were less on broiler litter (1.08 and 0.90 lb/d) compared to bermuda grass hay (1.67 lb/d) or alfalfa hay (1.89 lb/d). Energy and protein concentration of the diets were not given, but digestibility was much lower for heifers receiving broiler litter than for those receiving either hays. Broiler litter may contain significant amounts of copper and the concentration of this nutrient has not been evaluated in dairy heifers. Recent episodes of intolerance of Jersey cattle to copper concentrations previously considered well within tolerance raises concern about the use of litter. A logical approach for feeding litter to heifers is feeding unensiled broiler litter-high energy feed mixtures with corn silage or grass hay.

The objectives of this study were to determine feed intake and growth of dairy heifers receiving diets based on conventional feeds (hays, grain, protein supplement) or broiler litter.

Experimental Procedures

Thirty-two Holstein heifers (average 450 lb) were placed in 16 pairs and then each pair was

assigned to one of four diets. Each pair was placed in a slotted-floor pen (~ 10' x 10') and received a diet based on (1) grass hay (chopped) and soybean meal (SBM), (2) grass hay (chopped) and broiler litter (BL), (3) corn silage and SBM, or (4) corn silage and BL. The amount of ground corn, soyhulls and forage varied to maintain similar energy and protein content in the different diets, and allow 25.9% broiler litter treatment diets (Table 1). The same source of feeds were fed throughout the 84 day study. Each dietary treatment contained minerals and vitamins to meet the National Research Council's (1989) recommendations for growth (Table 1).

The "concentrate" portion (ground corn, soyhulls, mineral/vitamin mix and SBM or BL) was mixed biweekly, mixed with the respective forages daily and fed as a total mixed ration (TMR). Each pen received a sufficient amount of the TMR to allow access for 24 hours and had automatic waterers. Feed not consumed was weighed back daily to provide consumption by the heifers in the pen. The pens were adjacent to each other in an open-sided barn. Diets were sampled weekly and stored for subsequent analyses. Samples were analyzed for nutrient content. Heifers were weighed prior to the study, at 8 weeks and at 12 weeks. Wither height and heart girth were measured also at these times. Body condition scores (visual appraisal) were taken prior to the study and at four week intervals during the study and at the end of the study. Blood samples were taken via jugular venipuncture once during the last week of the study for plasma urea nitrogen (PUN) determination. Growth data were analyzed as a completely randomized design using the GLM procedure of SAS (1988), with weights prior to the study used as a covariate.

Results and Discussion

Results are in Table 2. The heifers consumed less ($P<0.05$) of the grass hay diets containing BL than of the diets containing SBM, but the opposite occurred with the corn silage diets. Based on observations, the heifers were able to "sort out" the BL easier when mixed with grass hay than with silage, which could have affected palatability and thereby intake. However, due to the consistency of the grass mixtures, it was difficult to determine, either by analyses or visual appraisal, whether the "sorting out" of feed was consistent throughout the study. The heifers did not appear to adapt to BL as the intake of BL-containing diets were less between weeks 8-12 than between weeks 1-7. Conversely, intake on SBM-containing diets either was greater (grass based treatment) or similar (corn silage based treatments) during weeks 8-12 compared to weeks 1-7.

For grass hay containing diets, average daily gains followed the same pattern as that of feed intake with lower ($P<0.05$) gains on BL containing diets than those with SBM. However, in contrast to intake, gains were less ($P<0.05$) on corn silage diets with BL compared to that with SBM. Body condition scores followed the same trend as gains whereas there were no differences in wither height or heart girth. The length of study probably was insufficient to show differences in skeletal growth even if such differences might occur. Although growth on the BL treatments were less ($P<0.05$) than with SBM, the heifers on BL did have satisfactory weight gain of 1.43 to 1.94 lbs per day. This gain is greater than normally desired. However, these heifers were closely confined and had little opportunity for exercise.

Feed cost per day was less on the diets containing BL, but the cost per pound of gain was least on the corn silage diet with soybean meal (Table 2).

In summary, broiler litter gave satisfactory dairy heifer growth when used for 84 d, but growth on diets with broiler litter was less ($P < 0.05$) than with soybean meal. Additional studies are needed which will evaluate broiler litter in dairy heifer diets (1) over extended periods during the growing season and (2) the relationship to ultimate milk production.

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Table 1. Ingredient, nutrients composition and cost of heifer diets

	Grass Hay		Corn Silage	
Treatments	SBM	`BL	SBM	BL
Ingredient ($/ton)				
Bermudagrass hay (60)	40.3	24.2	0.0	0.0
Corn silage (25)	0.0	0.0	69.9	38.4
Soybean meal (180)	9.8	0.0	12.6	0.0
Broiler litter (25)	0.0	25.9	0.0	25.9
Ground corn (120)	18.4	19.2	0.0	5.0
Soyhulls (80)	30.0	30.0	16.0	30.0
AU Mineral (380)	1.5	0.0	1.5	0.0
Litter mix (300)	0.0	0.7	0.0	0.7
$/ton (as fed)	92.80	69.31	42.60	39.31
$/cwt (DM basis)	5.14	3.91	4.40	3.25
Content				
Dry matter, %	90.1	88.6	48.4	60.5
TDN, %	68.0	68.0	68.0	68.0
NE_g, Mcal/lb	.44	.43	.45	.44
CP, %	14.5	14.9	14.5	14.5
NDF, %	50.8	47.8	44.6	47.7
ADF, %	26.8	27.3	26.7	29.4

Table 2. Cost of feed, dry matter intake (DMI) and growth responses of Holstein heifers fed various forage and nitrogen sources.

	Grass hay		Corn silage		
Treatment	SBM	BL	SBM	BL	SE
DMI (lb/d)					
wk 1-7	21.3[b]	16.1[c]	20.6[b]	23.3[a]	0.37
wk 8-12	23.9[a]	15.1[d]	21.0[b]	19.8[c]	0.40
wk 1-12	22.4[a]	15.7[c]	20.7[b]	21.8[a]	0.29
$/day	1.15	0.62	0.91	0.71	
Daily Gain (lb/d)					
wk 1-7	1.96[ab]	1.17[b]	2.77[a]	2.09[ab]	0.33
wk 8-12	2.20	1.83	2.51	1.72	0.31
wk 1-12	2.07[ab]	1.43[b]	2.66[a]	1.94[b]	0.24
$/lb gain	0.56	0.43	0.34	0.37	
DMI/100 lb BW, %	2.35	1.75	2.12	2.35	
Wither ht increase (cm/d)					
wk 1-7	.02	.04	.04	.02	.01
wk 8-12	.08	.05	.06	.11	.02
wk 1-12	.05	.05	.05	.06	.01
Heart girth increase (cm/d)					
wk 1-7	.13[ab]	.08[b]	.20[a]	.19[a]	.03
wk 8-12	.16	.17	.11	.12	.04
wk 1-12	.14	.12	.16	.16	.02
Body Score					
wk 1-7	3.37[b]	3.35[b]	3.71[a]	3.42[b]	.10
wk 8-12	3.44	3.29	3.45	3.33	.09
wk 1-12	3.38[b]	3.20[b]	3.62[a]	3.30[b]	.11

Feeding Strategies During Hot Weather

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Introduction

The modern dairy cow with high genetic potential consumes and metabolizes a large quantity of nutrients. If the cow is to perform near her potential some heat abatement procedures are necessary to dissipate the large amount of metabolic heat produced. By minimizing the increase in body temperature that occurs with hot weather, cows have greater DMI and the efficiency of dietary nutrient use is improved. Reduced body temperature decreases sweating and panting which minimizes the loss of electrolytes via skin secretions and the disturbance of acid-base chemistry which occurs with heat stress. Modifying the environment by shading and cooling enhances the quantity of nutrients consumed by the cow but can also affect nutrient requirements.

The effects of heat stress on animal production are well documented. Pioneering research in Missouri established the relationship between high ambient temperature and increased rectal temperature of dairy cows (18), and the impact of high temperature on feed and energy intake and on milk yield (16). The effects of high environmental temperatures are magnified by high relative humidity (RH) and the combined effects of temperature and RH are calculated using a temperature-humidity index (THI). Heat stress affects high producing cows more than low producers (15), because high producers consume more nutrients and produce more metabolic heat. Modifying the environment to alleviate heat stress in cows is necessary if producers are to maintain dry matter intake (DMI) and milk yield during the summer months.

Discussion

Heat Stress Effects on DMI

Hot weather is costly in terms of milk yield, and the effects occur largely because of reduced DMI. The hot environment overwhelms the cow's cooling capacity and her body temperature rises. With the onset of hot weather, cows gradually adapt to the environmental conditions and DMI and milk yield stabilize at a level below that during cool weather. The NRC (24) predicts that the DMI for a 1323 lb cow producing 59.5 lb of milk will decline from 40.1 lb at 68°F to 36.8 lb at 95°F, and that maintenance costs will increase by 20% (Table 1). At 104°F maintenance increases by 32% and DMI falls to about 56% of that eaten by cows in thermoneutral conditions. Elevated body temperature apparently causes reduced DMI, and each 1°F increase in body temperature above 101.5°F resulted in 4 and 3 lb decreases in milk yield and TDN intake (16).

Cows often alter behavior in an attempt to maintain intake while avoiding stressful conditions. Changes in eating patterns from day to night feeding occur with hot days and cooler nights. Unfortunately the greater nighttime intake usually does not compensate fully for lost daytime intake. More frequent feeding encourages greater intake by providing fresh feeds and stimulating the cow's natural curiosity. Cooling systems which cool the cow at the feed

bunk also encourage intake. Minimizing handling and walking during hot weather can minimize heat stress. Body temperature for cows walked .6 mile prior to milking to simulate being brought from pasture increased by about 3.4°F and 2.9°F for Holsteins and Jerseys (6). Body temperature remained high for about 10 and 6 hours for the two breeds. Elevated body temperature can be minimized by not moving cows long distances from pastures, and by grazing cattle during cooler evening hours and providing cooling during hot daytime hours.

Feeding behavior changes during hot weather. Intake of concentrate and hay declined by 5% and 22% for lactating Holsteins as the temperature increased from 64 to 86°F (21). This may be related to the heat producing potential (heat increment) of the diet. Cows sorting and selecting feeds seriously impacts ration formulation and creates the potential for acidosis. Feeding total mixed rations (TMR) reduces the selection of feed ingredients, stabilizes rumen fermentation, and minimizes depressions in ruminal pH.

Water, The Forgotten Nutrient

Water is the most important nutrient for lactating cows subjected to heat stress. Milk contains about 87 percent water, and water is critical to the dissipation of excess body heat. There is a high correlation of water intake with milk yield and DMI (8). Generally cows consume 2 to 4 lb of water for each pound DMI, and rations high in salt or protein increase water intake (11). Water consumption increases sharply as environmental temperature increases (Table 1) because of water losses from sweating and from water vaporization from panting, both efforts aimed at increasing evaporative cooling for the cow.

Practical considerations are to supply unlimited quantities of clean water under shade within easy walking distance for the cow. Water in tanks placed long distances from the feeding area, especially if tanks are not shaded or the area between the feeding area and the tank is not shaded may force the cow to choose shade over water, limiting performance. Water should be available in holding pens, travel alleys and near feed bunks. A survey of drinking water tanks in west central Florida reported that average water temperature was 86°F, and ranged from 77 to 97°F (3). Shading lowered temperature from 87 to 81°F. Clean water which is free of algae and feed contamination is necessary. A good rule of thumb is, would you drink the water? If not, perhaps it is too dirty for the cows, too.

Several studies in Texas showed that cows offered well water (81 to 86°F) or chilled water (51°F) generally consumed more DM and yielded more milk when offered chilled water. Cows tended to consume less chilled water and when allowed to, would choose warm well water over chilled water. Research in Florida showed no benefit to offering chilled water compared with normal well water (3). However cows in the Florida field studies had access to fans and sprinklers (3) or cooling ponds (2). Being cooled may have negated any benefits from chilled water. At the very least, offering cool well water in a shaded environment will minimize the increase in water temperature due to direct sunlight and will encourage cows to go to water.

Heat Increment of Feedstuffs

Following a meal heat production increases. This increase is due to the heat increment of the feed, and consists of heat of fermentation (important in ruminants) and heat of nutrient metabolism (20). Feedstuffs have varying heat

increments, largely because the nutrients are used with different efficiencies or because of the heat of fermentation. In moderate to high producing dairy cows the heat increment of feeds may be about two-thirds of total heat production (4). Dietary fat has a low heat increment because of a high efficiency of utilization and heat production is lower. Fiber has a high heat increment relative to concentrates (1).

If heat increment can be exploited for hot weather feeding there is less heat to be dissipated and greater energy efficiency because energy is used for production and not lost to heat. Following is a discussion of heat increment of fats and fiber and the potential benefits during hot weather.

Fiber Feeding During Hot Weather

Fiber digestion may add to the cow's heat load and cows given a choice between hay and concentrate in hot weather consumed less hay (16). Beef heifers fed pelleted diets containing 75% concentrate (low fiber) had lower heat production compared with those fed pellets containing 75% alfalfa [high fiber] (27), suggesting that high fiber diets have the greater heat increment.

Cows fed high and low forage diets in hot weather, with the difference made up by concentrates, produced more fat-corrected milk, had lower body temperatures (.5 °F lower), and had fewer respirations (14.1 fewer breaths/min) for the low fiber diets (30). Intake of DM and milk yield were greater for cows fed diets containing 14 versus 17 or 21% ADF, and milk yield was less sensitive to changes in daily minimum temperature for cows fed the 14% ADF diet (7). However as daily minimum temperature increased, DMI declined more rapidly for the lower ADF diets. Important to remember is that total DMI was higher for the low fiber diets. Greater intake for cows fed the low fiber diets probably increased metabolic heat production, causing a more rapid intake decline with rising environmental temperatures.

Bermudagrass work at our station in Georgia has shown that Tifton 85 bermudagrass, which has higher yield and digestibility than older varieties such as Coastal, has the potential to be a forage source for lactating cows. However the high NDF content of the bermudagrasses may limit its use. Concerns about feeding high fiber levels led to a study in which cows were offered diets with no hay, and low, medium, and high levels of Tifton 85 bermudagrass hay. Cows had lower DMI as NDF level of the diet increased (Table 2, [33]). The DMI was lower with greater dietary NDF during both cool and hot weather. Lack of an interaction between hot weather intake and fiber levels suggests that heat increment of fiber in the diet was not a factor during heat stress. Results in this study, like those of Cummins (7), suggest that total DMI was a greater factor affecting heat stress response than was fiber content of the diet.

Feeding lower fiber diets during hot weather will improve DMI and milk yield and possibly reduce heat stress. However this must be balanced with the need for adequate fiber in ruminant diets. Attention to fiber quality for hot weather diets is critical, since lower heat production occurs with the fermentation of high quality forages when compared with lower quality forage. Feeding high quality fiber is preferred over very low fiber diets during hot weather. Maintaining adequate fiber (19 to 20% ADF) is recommended to maintain good rumen function and DMI. In addition, cows will reduce their forage intake more than their concentrate intake during hot weather if allowed to select. Total mixed rations help to minimize selection

and stabilize rumen fermentation. In addition, water added to a dry TMR improves palatability and binds feed particles together, reducing the cow's ability to sort ingredients.

Adding Fat to Hot Weather Diets

Fat increases the energy density of the diet which is of particular value when total intake is reduced. In addition, energy from fat is used with greater efficiency by the cow which may make it particularly valuable during hot weather. Research showed that early lactation cows were less subject to heat stress than mid-lactation cows, despite greater milk yield (19). These early lactation cows consumed less total feed than mid-lactation cows and relied heavily on body reserves (fat). Body fat is also used more efficiently than feed nutrients, and research shows that body tissue stores are used for milk production with an efficiency of 82.4%, compared with a 64.4% efficiency for metabolizable energy (22). This greater efficiency of energy use for fats, coupled with lower DMI during hot weather, may prove particularly useful when feeding the heat-stressed cow.

Addition of fat to the diet during hot weather does not consistently affect DMI, but can improve milk yield. Diets containing added fat and fed during hot weather improved fat-corrected milk yield (17, 29). In both studies fat was also fed during cool weather. In one study, no environment by diet interaction occurred (17), suggesting there were no added benefits from dietary fat during hot weather over those seen in cool temperatures; however Skaar et al. (29) reported dietary fat to be beneficial only to cows that calved during the warm season. In Arizona a prilled fat product fed during hot weather improved milk yield by 2.6 lb/day for cows that were cooled, but in another study increased milk yield by only 1.5 lb/day in cows that were not cooled (14). The Arizona results suggested less response from the added fat in heat-stressed than in cool cows, even though the researchers speculated that the added fat would reduce heat production, thus lowering heat stress (14). The data suggest that cooling the cow is necessary to achieve full benefits of dietary adjustments such as addition of dietary fat.

Although cows may not show signs of reduced heat stress in response to added dietary fat, cows benefit from greater energy density during periods of depressed intake. Practical applications are to add fat, not exceeding 5 to 7% total fat in the diet. Fat levels beyond these should be supplied using a rumen inert fat. As a general guideline, no more than 30 to 40% of total dietary fat should come from whole oilseeds (a source of unsaturated oils), 40 to 45% from other basal ingredients, and 15 to 30% ruminally inert fats. Another commonly used guideline is that 1/3 of dietary fat come from fats contained in the feedstuffs, from oilseeds, and from ruminally inert fats.

Crude Protein During Hot Weather

Protein intake declines as cows eat less during hot weather and cows often are protein deficient. It is necessary to increase the amount of crude protein (CP) in the diet to supply sufficient protein to sustain milk yield. Cows fed diets containing 14.3 or 20.8% CP during hot, humid weather consumed more DM (30.9 vs. 34.4 lb) and yielded more milk (39.2 vs. 41.9 lb) for the high CP diet (12). Even though the low CP diet was considered adequate for the level of production (25), greater intake occurred with the high protein diet. Cows fed high CP diets had lower respiratory rates and slightly lower rectal temperatures, possibly related to

improved digestion of the diet or altered metabolism.

Benefits from feeding more dietary CP during hot weather must be balanced with the increased energy needed to metabolize excess ammonia to urea. Excess protein fed to lactating cows decreased their energy balance by 7.2 kcal of metabolizable energy per gram of excess N (25). Cows offered diets of two protein solubilities (40 and 20%) during thermoneutral and heat-stress conditions had greater feed intake and milk yield for the less soluble protein diet for both environments (34) and milk yield declined from 54 to 50.9 lb when CP was increased from 19 to 23% of the diet (9). Calculations revealed that the energy cost of synthesizing and excreting urea accounted for the reduced milk output (26). Thus formulations with either inadequate or excess CP can reduce performance by lactating cows.

Protein degradability can influence performance during hot weather. Cows fed diets during hot weather with high and low CP (18.4 and 16.1% CP), with high and medium degradabilities (65.1 and 59.3% of CP) ate less DM and yielded less milk when fed the high CP, high degradability diet (13). Shading or evaporative cooling did not change intake for low or high protein degradabilities, but milk yield was greater for low degradability diets provided the protein was of high quality (31). When cows were either evaporatively cooled or shaded, milk yield was greatest for high quality protein diets and the response to protein quality was greater for evaporatively cooled cows compared with shaded cows (5; Table 3). A summary of this research (14) indicated that during heat stress the rumen degradable protein should not exceed 61% of total CP, and intake of rumen degradable protein should not exceed NRC (25) by 100 g N/day. Protein quality was an important factor, especially lysine content of the diet.

Mineral Supplementation

The requirement for mineral elements such as K and Na increases during heat stress because of losses through sweat and urine, and due to the high mineral content in milk. Intake was improved when dietary K exceeded NRC recommendations during hot weather (28, 32). Intake was also greater when diets contained .55 vs. .18% sodium during hot weather (28). Current ranges for mineral supplementation during heat stress include 1.3 to 1.6% K, .35 to .4% Na, and about .35% Mg.

A ratio or balance of K, Na and Cl may affect performance of the cow during hot weather. Escobosa et al. (10) were the first to evaluate diets fed to lactating cows during heat stress using the electrolyte or dietary cation-anion (DCAB) balance equation. They reported greater DMI for diets high in K and Na (alkaline) and lower for the high Cl (acidic). This suggested that an alkaline diet that is high in Na and K from buffers may be more important than the concentration of the individual elements for lactating cows. If so, this clouds the issue of the K content needed in diets fed during hot weather. Additional research is needed to define the desired DCAB for lactating dairy cows and to resolve the issue of K vs. Na supplementation. Note that the DCAB for lactating cows is highly positive, or alkaline, as opposed to the negative, or acidic, diets used for dry cow diets. The ideal means to increase DCAB for lactating cows is with a Na or K containing buffer. The diet cannot be made more alkaline by the use of salt (NaCl) or potassium chloride (KCl). Use of dietary buffers is a common practice, especially during hot weather, and DCAB may provide further justification for the use of buffers during

hot weather. Work with potassium carbonate as a source of supplemental K and dietary buffering showed positive results during heat stress (32).

Feed Additives for Heat Stress

In addition to formulating diets for adequate nutrient intake by the cow, a number of "non-nutritive" additives are available which may improve performance during hot weather. However an additive is only practical if it works in your herd, in your situation. Additives purchased to solve problems due to poor ration formulation are purchased for the wrong reasons. This brief discussion is not to be considered all inclusive, but mentions some feed additives that may have a place in hot weather feeding.

Sodium bicarbonate is particularly useful during hot weather. Because high concentrate, low forage rations are often fed to encourage DMI during hot weather and because cows may select against forage intake during hot weather, the potential for acidosis due to inadequate dietary fiber content is real. Buffers minimize pH fluctuations, usually enhance fiber digestion, and often encourage greater DMI.

The addition of fungal cultures to diets during heat stress was evaluated. Theoretically a more stable rumen environment should encourage greater feed intake, and possibly contribute to less heat production. The species for the heat stress research were strains of *Aspergillus oryzae* (AO). In several of the studies, rectal temperatures were lower in AO supplemented cows although there was no change in some studies. A number of studies also showed increased milk yield with AO use during heat stress. Ruminal effects associated with AO use include increased fiber digestion, greater numbers of cellulolytic bacteria, increased turnover rate of lactic acid, and less variation in rumen pH, ammonia, and VFA (14). Improved ruminal efficiency and reduced heat production could contribute to greater performance and reduced heat production. Any product which improves ruminal efficiency should contribute to improved performance during hot weather.

Niacin is a B vitamin that is involved with energy and fat metabolism. Cows in a commercial herd supplemented with 6 grams niacin per day during summer had about 2 lb greater milk yield (23). However when data for the cows producing more than 75 lb milk per day were analyzed, those cows yielded 5.3 lb more milk when fed niacin. These data illustrate that additives can benefit specific groups of cows, and that returns can be maximized when the additive is delivered only to those cows that need it.

Summary

The reduced milk yield that occurs during hot weather is primarily due to reduced feed intake. Greater maintenance costs for the cow during hot weather magnify her shortage of energy. Elevated body temperature of the heat-stressed cow is responsible for reduced performance, and protection from the ambient environment is the first step toward maintaining intake and milk yield during hot weather. Shading and cooling (using fans and sprinklers or evaporative cooling, depending on the climate) are effective ways to improve intake during hot weather. Other steps to enhance performance during hot weather include:

* Environmental modifications should be in place to maximize DMI by cows.
* Increase density of dietary energy, protein, and other nutrients to compensate for reduced total intake.

* Increase energy density by increasing content of concentrates in the diet, but avoid excessive fermentable carbohydrates which can lead to acidosis.
* Add fat to the diet as an energy source and to possibly improve efficiency.
* Make sure diets contain adequate fiber to maintain rumen function. Use high quality forage as a fiber source, emphasize forage quality and avoid very low fiber diets during hot weather.
* Formulate for proper rumen escape protein content and avoid excessive rumen degradable protein. Quality of protein is important during hot weather.
* Provide unlimited quantities of clean drinking water within easy access for the cow.
* Reformulate for proper mineral content of diets for hot weather feeding. Evaluate K, Na, and Mg contents.
* Use additives that have proven results and which can be beneficial in your herd situation.

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Table 1.
Changes in maintenance requirements and DMI for 1323 cows producing 59.5 lb of 3.7% fat milk at various temperatures.

Temperature (°F)	Required for 59.5 lb production: Maintenance (% of requirement at 50°F)	Required for 59.5 lb production: DMI needed (lb/d)	Expected: DMI (lb/d)	Expected: Milk (kg/d)	Water intake (gal/d)
-4	151	46.9	45.0	44.1	13.5
14	126	43.6	43.6	55.1	15.3
32	110	41.4	41.4	59.5	16.9
50	100	40.1	40.1	59.5	16.9
68	100	40.1	40.1	59.5	18.0
77	104	40.6	39.0	55.1	19.5
86	111	41.7	37.3	50.7	20.9
95	120	42.8	36.8	39.7	31.7
104	132	44.5	22.5	26.4	28.0

Adapted from NRC (1981).

Table 2.
Effect of increasing dietary NDF from bermudagrass on DMI of lactating cows subject to cool and hot, humid conditions.

		Added hay[1,2]				
Item	Environment	Control	Low	Medium	High	Effect
DMI, lb/d	Cool	51.4	48.1	45.4	41.9	L**
	Hot	40.3	39.2	38.4	36.1	L*
	Hot-adjusted	37.3	38.1	39.5	39.0	L×W**
Milk, lb/d	Cool	71.2	71.9	69.2	63.7	L†
	Hot	54.2	56.9	58.2	50.0	Q*
	Hot-adjusted	52.7	55.3	58.0	53.6	L×W*

[1]Bermudagrass hay added at 0, 7.6, 15.2, and 22.8% of diet DM yielding 30.2, 33.8, 37.7, and 42.0 % NDF for control, low, medium, and high diets, respectively.
West et al., 1995. J. Dairy Sci. 78(Suppl.1):208

Table 3.
Effect of protein quality and evaporative cooling performance of lactating cows.

	Treatment				
	Shaded		Evaporatively cooled		
Item	LQ[1]	HQ[2]	LQ[1]	HQ[2]	Effect
DMI, lb/d	50.0	52.7	53.6	56.2	C[3]
3.5% FCM, lb/d	53.8	60.0	58.6	66.6	P[4]**, C*
Rectal temp., °F	102.4		101.5		
Respiratory rate/min	82		64		

[1]Low quality protein - corn gluten meal.
[2]High quality protein - blood, fish, and soybean meals.
[3]Cooling effect.
[4]Protein effect.
Chen et al., 1993. J. Dairy Sci. 75:819.

PORK QUALITY IN THE GLOBAL MARKET

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SUMMARY

Pork quality is becoming increasingly important to customers and consumers worldwide. Product quality is defined as "the sum of all sensory, nutritional, hygienic/toxicological and technological properties of meat" (Hofmann, 1983). From this definition, it is evident that pork quality is important to further processors, export customers, food service, and retail customers. Therefore, it is important to packers and producers as well. Specifically, the pork quality issues of primary importance to the pork industry are pork color, water holding capacity (WHC) or drip loss, intramuscular fat (IM fat), and palatability (juiciness, tenderness, and flavor). The factors affecting pork quality are influenced by pork producers, truckers, packers, and others throughout the chain. Producer controlled factors include genetics, nutrition, and handling. The producer can affect quality through genetic inputs by breed selection, selection of sires within breed, eliminating the stress gene and the Napole gene, increasing IM fat, and using DNA technology. Nutritionally, producers can affect quality with vitamin and mineral supplementation, amino acid levels, fat sources and levels, repartitioning agents, and feed withdrawal. Pork quality is quickly becoming another factor in the value of pork and carcasses. To become the Meat of Choice, the industry focus on pork quality will grow in importance.

Introduction

'Pork quality' has become the new buzzword in the pork industry. Seminars, workshops, and indeed, entire conferences have been named with the pork quality title to attract audiences. In the process some have had little to do with actual pork quality. Therefore, it might first make sense to define pork quality. While pork quality can include concerns for packaging and adherence to specifications, this initiative is only addressing issues relating to lean composition and meat quality. Factors associated with meat quality can be segmented into technological, sensory, hygienic, or nutritive. The hygienic factors are associated with food safety and, as such, are not addressed here but rather are being handled by the NPPC pork safety department. Likewise, NPPC's consumer nutrition department addresses the nutritive qualities. The pork quality factors addressed here are those that the include the processing and eating qualities of the product.

The pork industry has come a long way in the past 40 years since the advent of the meat-type hog. In fact, the move has been geometric in that the progress during the past decade has been greater than the previous 30 years and the progress during the past year has been greater than the previous nine combined. However, during this time of giving emphasis to composition, we have done little to progress pork quality. We still have significant problems with PSE and juiciness, with flavor and tenderness seeming to have been compromised in the process. Moreover, we do not know of a way to measure these parameters in practical situations.

The entire industry is keenly aware of

these issues, which is certainly the first step in problem solving. However, we are well past the point of identification of the problem. Producers want to know how their pigs fare relative to pork quality considerations. Packers want to know how their raw material purchases measure up and furthermore, they wish to provide incentives or discounts to provide for improvements in the carcasses they buy. Processors wish, among other things, that the pork they utilize in the manufacture of their products would not drip and purge so badly. Consumers want a uniform, reddish-pink, fresh pork product with minimal purge and minimal visible fat, but they want that product to be tender, juicy and full of flavor. There is a categorical interest in finding a solution to these problems but everyone agrees that first we must be able to quantify the measurements. This requires development of technology to measure or predict these traits accurately at a high speed. Then we will be faced with finding the solutions to the problems measured whether they are genetic, nutritional, a result of handling prior to slaughter or the result of post slaughter handling.

A recent article written by Dr. Robert Kauffman states that the 1996 definable losses due to PSE and RSE (the condition of normal color but still poor texture and purge) are between 73 and 151 million dollars, depending upon perspective. These losses come from the costs of excess shrink, costs of sorting, costs of discounting loins, costs of research, and the costs of monitoring and studying quality by swine breeding companies. In reviewing the assumptions used to arrive at this number, it is clearly evident that this number is very conservative. The definable loss is probably much greater. The losses due to consumer rejection and its effects on demand would aggravate this number even more.

Some individuals have suggested that one of the major problems facing the industry in the pork quality arena is coming to an agreement on the levels of pork quality parameters. They say that no one agrees on what color, texture, firmness, water-holding capacity, marbling, etc. should be the ideal. But, the entire industry agrees that water-holding capacity values should be as low as possible with 2 ½ percent drip loss a goal. Every segment of the pork chain wants firm pork. No one in the world wants light-colored, low pH, watery, soft pork that is tough and dry. While there are slight differences in color preferences based upon geography and while we are still sorting out differences in intramuscular fat preferences, there are still many factors that we currently know as absolutes. The NPPC Pork Quality solutions Team recently published a fact sheet entitled "Pork Quality Targets." The purpose was to provide the industry with quantifiable measures at which to aim. These are as follows:

Attribute	***Target***	***Comment***
Color	3.0 to 5.0	utilizing a 6-point scale
pH	5.6 to 5.9	
Tenderness WBS	<7 lb	utilizing
	(3.2 kg)	at 7 days
Flavor	robust pork	(no off-flavor)
	flavor	
IM fat ("Marbling")	2 to 4%	
Drip Loss	not to exceed 2.5%	

There are sound reasons behind the interest in

finding solutions to the problems of pork quality and consistency. In addition, NPPC is the only organization which can pull together all the diverse activity on the subject into a national action plan.

Pork Quality Factors

Color: Product color of fresh pork is important to all segments of the pork chain. The Other White Meat campaign notwithstanding, consumers prefer their fresh pork to be reddish-pink in color. In fact, consumers who have purchased extremely light or white pork have expressed dissatisfaction with the flavor of the product. This pale pork has a low pH and therefore has a metallic, off-flavor 100% of the time. Conversely, extremely dark pork is high in pH and has a shorter shelf life than the normal, reddish-pink colored pork.

NPPC's visual color standards, developed in 1973, utilize a five-color standard that was subjectively divided based upon visual assessment. The technology now exists to divide these colors using objective approaches. In addition, every country in the world uses the six standard format developed by the Japanese. It has been decided that NPPC will shift to a six standard system with improvements to the Japanese approach. The system used will incrementally divide the color difference between the lightest and darkest into six equal increments with objective L^*, a^*, and b^* values. The color scores will then be used as a 'cheap' method to estimate the objectively measured color values.

The difficulty in measuring the color of fresh pork is not so much in developing the technology but rather in the fact that the problematic color patterns associated with PSE or DFD pork do not materialize in time to make an absolute judgement at the end of the slaughter line, 30-45 minutes after stunning. In addition, the only exposed meat surface available for non-invasive measurement of color is a medial surface of the ham. This muscle is the *gracilis* and is not nearly as susceptible to color variation as other ham or loin muscles. Many packers are measuring color of hams and loins during fabrication but the identification of the cuts directly to a producer is more difficult at this point in the process. In addition, it would require a change in the timing of payments to producers if the industry were to wait for the availability of this information to include in a payment program. In spite of the fact that color continues to develop for weeks, the extreme color problems are evident almost immediately post slaughter. Therefore, there should be a way to at least measure and quantify these extremes for the benefit of producers and packers.

Water-Holding Capacity

Water-holding capacity (WHC) is the ability of meat to retain its water during application of external forces such as cutting, heating, grinding, or pressing. It is important to all segments of the industry for several reasons, the most important of which has to do with loss of value. Water loss during chilling, fabrication, packaging, transport, or processing is a loss of weight that had been purchased by some segment in the chain. This drip loss can be as high as 10% or more in extreme cases. It is unsightly when it appears in the retail package visible to consumers. Often, pork with high drip loss will be drier (less juicy) in the cooked state. In addition, the product does not hold a cure as well, a fact troubling to processors.

Firmness, a component of PSE, is associated with WHC in that soft pork, categorically, has a higher drip loss than firm pork. While color is partially dependent upon WHC, neither firmness nor WHC are

particularly well correlated with color. We can see pale, firm product as well as normal colored, soft watery pork. pH is a good indicator of the extremes in WHC with genetic correlations of -0.92.

Intramuscular Fat (IM Fat)

Otherwise known as marbling, these flecks of fat in the muscle make up the percent lipid component of fresh meat. The U.S. pork industry has made so much progress taking the fat off of pigs that we are now approaching a time when pork may be too lean for consumers. Although the correlation between lean and IM fat is not very high (about -38%), it is such that with no selection pressure placed upon IM fat, selection for percent lean by selecting for backfat reduction has resulted in a dramatic reduction in IM fat. Consumers buying with their eyes show a preference for lean pork practically devoid of marbling. However, when consumers buy with their palates, their preference is for higher IM fat. In fact, the NPPC Consumer Preference Study demonstrated that the preference was linear up to the maximum fat content in the study of about six percent.

It is apparent that the industry needs to begin differentiating product destined for food service as opposed to that which is targeted for retail. Food service is generally willing to pay for quality while retail is more price-driven. Therefore, packer/processors who would characterize and sort product for these markets would likely reap the benefit from the food service side in improved quality that meets their specifications. When eating the product, consumers want a tasty, juicy product with at least a threshold level of IM fat. NPPC has gone on record stating that at least two percent IM fat is necessary for acceptable eating enjoyment. There are some branded products available on the market today which claim one percent fat or less (such as Smithfield's Lean Generation™ Pork). These products satisfy a niche market opportunity in which consumers demand an extremely lean, low fat product although juiciness and flavor may be compromised in the process. Also, enhancement of pork through pumping si another technology that has resulted in improvements in juiciness and flavor at relatively low levels of IM fat.

For at least twenty-five years, NPPC has had visual standards for IM fat. These have been widely used as subjective standards in the visual evaluation of fresh meat samples. Unfortunately, the standards are not necessarily tied to any chemical measure. To rectify that, NPPC is in the process of revamping the standards so that the marbling grades will correspond to percent lipid content. A number one marbling score will be an estimate of one percent IM fat, a two marbling score will be an estimate of two percent fat, and so on. In this way marbling score will be a 'cheap' method of estimating an objective measure, namely percent lipid content.

Palatability (tenderness, juiciness & flavor)

Tenderness of fresh pork is an issue that has received little attention but will become a major issue in the years ahead. There is a great deal of evidence, including NPPC's genetic evaluation work, that shows pork is tougher than we would like and certainly much more tough than poultry. There is a significant genetic component to tenderness as demonstrated most recently in the Terminal Line Study conducted by NPPC.

One of the problems is with quantifying tenderness. The scientific community uses such objective measures as Warner-Bratzler Shear Force and Instron pressure to quantify

tenderness. In addition, sensory evaluations of tenderness and chewiness by trained taste panels are subjective evaluations. None of these are very practical in industry settings.

Improvements in tenderness may come from a combination of genetic improvements or through post-harvest treatment of the product. Either way, increased sales of fresh pork will be dependent upon improving tenderness of the product as defined by consumers.

Consumer Preference for Pork Quality

NPPC has conducted numerous studies to measure consumer's abilities to detect differences in pork quality. Consumers in several different U.S. cities were asked to rate and select samples in a blind taste test. The samples were loin, fresh ham, or chicken. The outcome was that consumers could, indeed, recognize differences in pork quality. Their rating of the juiciness, tenderness, flavor, and overall acceptability of pork was highly correlated to lab measures of machine tenderness, pH, and lipid content. Consumers demonstrated a linear preference for increasing intramuscular fat, tenderness, and pH.

System for Assuring Pork Quality

	Opportunities for Intervention
QCP 1 Genetic Inputs	Choice of Breeds Choice of sires within breed (EPD's) Stress gene/Napole gene Loin intramuscular fat DNA marker technology (MAS)
QCP 2 Nutritional Inputs	Vitamin & mineral supplementation Amino acid levels pre-market Dietary fat sources and levels Dietary starch Nutritional repartitioning agents Feed withdrawal
QCP 3 On-Farm Hog Handling	Health/stress management Slaughter weight Facility construction
QCP 4 Handling Hogs During Transport	General Electric prods Truck/trailer type Load size Weather extremes

QCP 5 Pre-Slaughter Handling	Facility construction Water sprays Electric prods Rest times Pre-stun handling
QCP 6 Stun, Stick & Early Post-Mortem Handling of Carcasses	Stunning system Stun to stick interval Horizontal vs vertical sticking/bleeding Bleeding time Scald temp/time or skin time Time on buffer rails
QCP 7 Handling of Carcass During Evisceration	Evisceration time Splitting accuracy Fecal contamination Trimming Measuring composition Measuring quality
QCP 8 Chilling of Carcasses	Chilling system Chilling time/temperature
QCP 9 Fabrication of Pork Cuts	Workmanship Packaging Enhancement of fresh pork

Producer Factors Affecting Quality

Quality Control Point 1: Genetic Inputs

Breed Selection Recommendation: That all commercial hogs have at least some percentage of Durocs (and/or Berkshires) to help enhance their opportunity to produce higher quality products.

Sire Selection Recommendation: Commercial producers should request pork quality information and/or quality EPD status on all sire purchases from individuals or companies. Furthermore, the breeding stock companies and breed associations should begin to provide this type of pork quality information to their customers. Traits of interest are loin color, loin intramuscular fat, and drip loss. Ultimate loin pH (24-hr) is a predictor of quality that is also of interest.

Stress Gene Recommendation: The only logical position based upon the evidence is for producers to require that all breeding stock purchases be certified stress gene free. All commercial producers should certify that they do not or will not knowingly market hogs with the halothane gene.

Napole Gene Recommendation: Work should proceed to isolate this gene and further clarify its positive and negative impacts.

IM Fat Recommendation: Producers should continue to utilize breeds and sires that will contribute positively to marbling without increasing fat in other depots (subcutaneous, abdominal, and intermuscular).

DNA Technology Recommendation: The industry should utilize these valuable tools in traditional selection programs. As more DNA tests become more readily available, commercial producers should ask for assurance that their breeding stock suppliers are utilizing all the pork quality tools at their disposal.

Quality Control Point 2: Nutritional Inputs

Vitamin & Mineral Supplementation Recommendation: Producers should supplement swine diets with vitamin E (90 mg/lb) during the last 30 days before slaughter. Commercial producers should add magnesium aspartate to the diets of finishing hogs for five days prior to slaughter.

Amino Acid Recommendation: More work needs to be done on the effects of amino acids during late finishing on pork quality.

Dietary Fat Source Recommendation: Producers should moderate the use of fat in the diet controlling the amount of unsaturated fat added. Also, consideration should be given to the use of CLA when it becomes available commercially.

Ad-lib Feeding Recommendation: Producers should continue the U.S. practice of full feeding finishing hogs to maximize quality of the product.

Nutritional Repartitioning Agents Recommendation: None of these products are approved for use in the U.S. at this time, so no recommendation is apparent until more data supports a positive pork quality contribution of these compounds.

Feed Withdrawal Recommendation: Total feed withdrawal time from last consumption until stick should be between 12 and 18 hours with access to water.

Quality Control Point 3: Hog Handling on the Farm

Stress and Health Management Recommendation: Producers should be required to view the NPPC "Handling" videos; the use of electric prods should be eliminated or significantly curtailed; pigs should be accustomed to human activity during the finishing period; and health stressed pigs should be separated from healthy pigs.

Slaughter Weight Recommendation: Depending upon the genetic lines used, producers should carry finishing pigs to maximum practical weights to maximize product quality.

Facility Construction Recommendation: Attention should be given to providing facilities that offer the least resistance and stress for pigs during handling and loading. Dual ramp designs should be constructed into the loading facilities.

Quality Control Point 4: Transporting Hogs

General Recommendation: Producers take the responsibility for the proper handling of their hogs in transport to market even if the hauling is hired out. All transporters are required to watch the NPPC video on "Handling

for Transporters".

Electric Prods Recommendation: All use of electric prods should be eliminated for loading and unloading hogs.

Truck-Trailer Type Recommendation: Producers should only hire haulers who have flat-floor trailers. Commercial producers who do their own hauling should transition from potbelly trailers to flat-floor trailers to enhance pork quality and reduce the number of deads during transport.

Load Size Recommendation: Haul no more than 183 head in 48" x 102" standard flat-floor trailers.

Weather Extremes recommendation: Transporters should give special consideration to market hogs during times of weather extremes. Adjustments should be made to the transport vehicle to lessen the impact of the weather on the transport subjects.

Conclusions

Pork producers have made great strides in improving performance and reducing costs of production. Reproductive performance and feed conversion efficiency have shown steady improvements over the past few years. In addition, producers have made geometric improvements in carcass composition over the past couple of years. With all this improvement, little attention has been paid to the quality of the product. In fact some of the progress made in the other economically important areas probably has had a negative effect on quality. Certainly the use of the stress gene fits in this category.

This entire Pork Quality Initiative is a relatively new area of concentration for NPPC and for the rest of the industry as well. As the producer organization becomes more of an industry organization acting on behalf of the entire pork chain and all the various stakeholders, it is very appropriate that all aspects affecting our ability to promote the quality and wholesomeness of our product be considered. This Initiative is an early attempt to address some of these issues and bring out significant and lasting improvements in pork quality. These improvements will be invaluable to the industry as we strive to become "Pork-The Meat of Choice".

Amino Acid Restrictions and Pigs Selected for Lean Growth Efficiency

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Summary

An experiment was conducted to assess the effects of dietary amino acid restrictions during the grower phase on subsequent and overall growth performance and carcass traits of pigs. In general, genotype had no clear effects on the rate or efficiency of growth, but pigs selected for lean growth efficiency had a better carcass quality and utilized amino acids more efficiently for lean accretion than the control line pigs. There was an indication that select line pigs should be offered a grower diet containing an adequate amount of amino acids to optimize their overall growth performance. During the finisher and grower-finisher phase, pigs fed the low-amino acid grower and finisher diets sequence and high-amino acid grower and finisher diets sequence grew faster and more efficiently than those fed other diet combinations. They had, however, inferior carcass quality, indicating that improved growth performance was a result of an increased rate of fat rather than lean accretion rate. There was no evidence of compensatory weight gain in pigs previously subjected to amino acid restrictions during the finisher phase. On the other hand, they had a similar lean accretion rate as those fed the adequate diet. It is, therefore, possible that the compensatory response of lean tissue growth may have occurred at the expense of fatty tissue growth.

Introduction

Compensatory growth responses after a period of amino acid restrictions in young pigs have been reported (e.g., Chiba, 1994, 1995), indicating that the early nutritional status may have lesser importance in terms of overall rate and efficiency of growth. The effect of enhanced growth during the early phase of development on the overall growth performance is, however, still a matter of debate.

The pig's ability to engage in compensatory growth is likely to be influenced by diets offered in the subsequent phase. Furthermore, it is likely that the ability to exhibit compensatory growth is dependent on the pig's genetic potential for growth and protein accretion because of physiological and metabolical adaptations that are taking place in pigs selected for a specific trait.

A line of Duroc pigs (**SL**) was selected based on real-time ultrasound 10th rib backfat and feed conversion at this station. A contemporary, randomly selected, control line (**CL**) was also maintained. The experiment described herein was to investigate the effects of dietary amino acid restrictions during the grower phase on subsequent and overall growth performance and carcass traits of SL and CL pigs.

Experimental Procedures

Thirty-two SL and 32 CL pigs were selected based on their weight and assigned to 32 pens with two gilts or castrated males per pen. Pens of pigs were randomly assigned within the genetic line to two grower and two finisher diets

in a 2 x 2 x 2 factorial arrangement of treatments with four pens per treatment. When an average pen weight reached the target weight of 44 lb, pigs were offered one of the two grower diets. At an average pen weight of 110 lb, blood samples were collected for blood urea nitrogen (**BUN**) analysis, and backfat (**UBF**) was measured with a real-time ultrasound instrument before switching to one of the two finisher diets. At an average pen weight of 247 lb, blood samples were again collected from each pig before slaughter to assess carcass traits and to determine internal organ weights. Pigs were housed in pens with solid concrete floors in the two open-front buildings. The experiment was initiated in September and terminated in February. Pigs were allowed ad libitum access to feed and water.

Table 1. Dietary treatments[a]

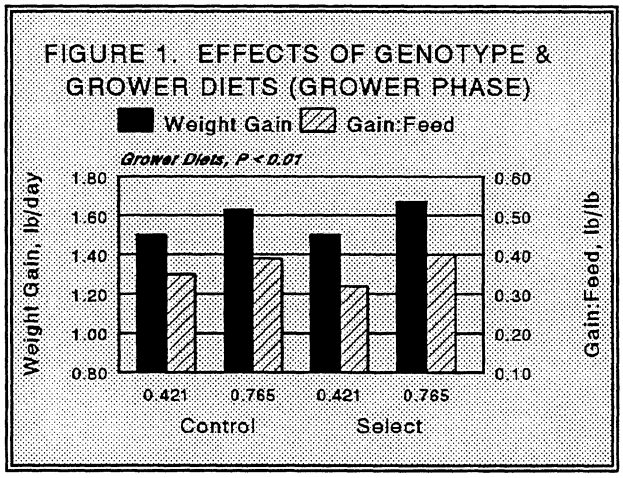
	Lysine:DE, g/MJ			
	Grower diet		Finisher diet	
Item	0.421	0.765	0.421	0.612
DE, MJ/kg	14.4	14.5	14.4	14.5
CP, %	13.3	20.4	13.3	17.2
Lysine, %	0.61	1.11	0.61	0.89

[a]DE = digestible energy (1 MJ = 0.239 Mcal); CP = crude protein.

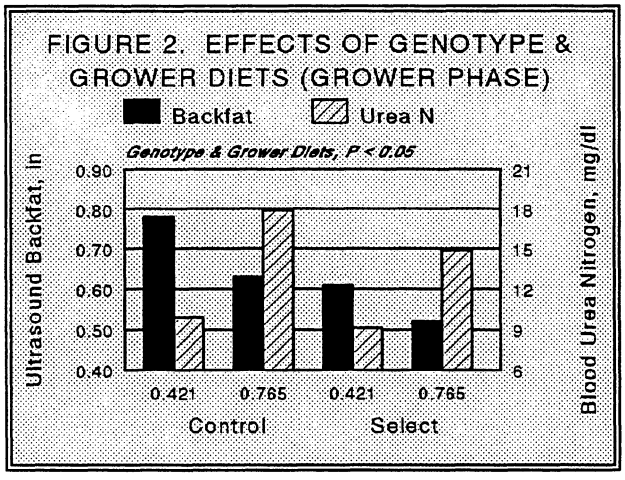
The two grower diets were designed to be either marginally deficient (0.421 g/MJ DE) or adequate in lysine (0.765 g/MJ DE; Table 1). The two finisher diets were designed to contain a lysine level recommended by the NRC (1988; 0.421 g/MJ DE) or 80% (0.612 g/MJ DE) of the grower diet containing 0.765 g/MJ DE. Corn and soybean meal were used as the only sources of energy and amino acids to formulate practical diets. All diets were formulated to contain adequate amounts of minerals and vitamins.

Results and Discussion

Genotype. Genotype had no effect on the rate or efficiency of weight gain during the grower (Figure 1) or finisher phase (Table 2). Overall, SL pigs fed the low-amino acid grower diet grew slower than other groups, and gain:feed in CL and SL pigs decreased and increased, respectively, as the amino acid content of the grower diet increased, which resulted in genotype x grower diet interactions (Table 3). These results imply that pigs selected for lean growth efficiency should be provided with a grower diet containing adequate amino acids to optimize their growth performance.



Although there were some interactions, in general, SL pigs had less UBF at the end of grower phase (Figure 2), and better carcass quality and heavier internal organs at the end of experiment than CL pigs (Table 4). In addition, SL pigs had lower BUN at the end of both grower phase (Figure 2) and finisher phase (though there was a trend for a three-way interaction; Table 2) than CL pigs. These results indicate that SL pigs deposited more lean, and utilized amino acids more efficiently for lean accretion than CL pigs.



Grower & Finisher Diets. Pigs fed the high-amino acid grower diet grew 9.8% faster and 17.5% more efficiently during the grower phase (Figure 1), and had 17.5% less UBF than those fed the low-amino acid diet (Figure 2). On the other hand, pigs fed the low-amino acid grower diet had lower BUN at the end of grower phase (Figure 2), implying that they utilized amino acids more efficiently for lean accretion than those fed the high-amino acid diet. The differences observed in growth performance of the two groups of pigs are in agreement with previous reports (e.g., Chiba, 1994, 1995), and the effort to depress the performance of one group of pigs during the grower phase through amino acid restrictions was, therefore, successful.

Low BUN at the end of the experiment in SL pigs fed the high-amino acid grower and low-amino acid finisher diet combination seemed to result in three-way and grower x finisher diet interactions (Table 2). In general, however, as in the grower phase, the lower BUN observed in pigs fed the low-amino acid finisher diet indicates that pigs are utilizing amino acids more efficiently for lean accretion than those fed the high-amino acid finisher diet. The results are consistent with an earlier report (Chiba et al., 1991).

During the finisher (Table 2) and grower-finisher (Table 3) phases, pigs fed the low-amino acid grower and finisher diet combination and high-amino acid grower and finisher diet combination grew faster and more efficiently than those fed other combinations, which resulted in grower x finisher diet interactions. These results imply that pigs fed a low-amino acid grower diet should be offered a low-amino acid finisher diet, whereas those previously fed a high-amino acid diet should be offered a high-amino acid finisher diet to optimize growth performance.

However, pigs fed the same diet combinations, low-amino acid grower and finisher diets and high-amino acid grower and finisher diets sequences, had higher 10th rib backfat, smaller longissimus muscle area, and lower proportion of carcass lean that those pigs fed the other diet sequences, resulting in grower x finisher diet interactions. These results indicate that improved growth performance of pigs fed the low-low or high-high diet combination was a result of an increased rate of fat rather than lean accretion rate.

Unlike previous research (Chiba, 1994, 1995), there was no evidence of compensatory weight gain during the finisher phase in pigs subjected to earlier dietary amino acid restrictions. On the other hand, there was no difference in the lean accretion rate between the two groups of pigs. It is, therefore, possible that the compensatory response of lean tissue growth may have occurred at the expense of fatty tissue growth.

Implications

If in fact pigs can achieve compensatory

growth despite their genetic potential for growth and protein accretion, it would have an impact on the overall productivity and efficiency. The results of the present research indicate that pigs selected for lean growth efficiency may need a grower diet adequate in amino acids for an optimum overall growth. Although there was no evidence of compensatory weight gain, pigs subjected to dietary amino acid restrictions during the grower phase had a similar lean accretion rate as those fed the high-amino acid grower diet. Depending on the market incentive to produce lean pigs, therefore, there might be an opportunity to reduce feed costs and improve overall efficiency of pig production by early dietary restrictions.

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Table 2. Effects of genotype, grower diets, and finisher diets on pigs during the finisher phase[a,b]

Genotype	Lysine:DE, g/MJ		Feed intake, lb/day	Weight gain, lb/day	Gain:feed, lb/lb	BUN, mg/dl
	Grower	Finisher				
Control	0.421	0.421	7.14	1.89	0.27	12.7
	0.421	0.612	6.28	1.59	0.26	15.9
	0.765	0.421	7.44	1.62	0.22	13.8
	0.765	0.612	7.24	1.87	0.26	18.5
Select	0.421	0.421	6.93	1.95	0.28	12.9
	0.421	0.612	6.56	1.65	0.25	14.9
	0.765	0.421	7.10	1.72	0.24	9.7
	0.765	0.612	7.22	1.86	0.26	18.4

[a]**BUN** = blood urea nitrogen, and **Grower** & **Finisher** = grower and finisher diets, respectively; Least squares means were based on four pens containing two gilts or two castrated males. [b]Genotype: BUN ($P = 0.067$); grower: feed intake ($P < 0.001$) & gain:feed ($P < 0.015$); finisher: feed intake ($P < 0.016$) & BUN ($P < 0.001$); grower x finisher: weight gain ($P < 0.002$), gain:feed ($P < 0.006$), & BUN ($P < 0.014$); genotype x grower x finisher: BUN ($P < 0.077$).

Table 3. Effects of genotype, grower diets, and finisher diets on pigs during the grower-finisher phase[a,b]

Genotype	Lysine:DE, g/MJ		Feed intake, lb/day	Weight gain, lb/day	Gain:feed, lb/lb
	Grower	Finisher			
Control	0.421	0.421	6.06	1.87	0.30
	0.421	0.612	5.56	1.60	0.29
	0.765	0.421	6.37	1.62	0.26
	0.765	0.612	6.15	1.77	0.29
Select	0.421	0.421	6.16	1.77	0.29
	0.421	0.612	5.83	1.45	0.25
	0.765	0.421	6.18	1.69	0.28
	0.765	0.612	5.97	1.81	0.30

[a]**Grower** & **Finisher** = grower and finisher diets, respectively; Least squares means were based on four pens containing two gilts or two castrated males. [b]Genotype: weight gain ($P < 0.090$); Grower: feed intake ($P < 0.031$) & weight gain ($P < 0.011$); Finisher: feed intake ($P < 0.010$) & weight gain ($P < 0.001$); Genotype x Grower: weight gain ($P < 0.001$) & gain:feed ($P < 0.019$; Grower x finisher: weight gain ($P < 0.001$) & gain:feed ($P < 0.006$).

Table 4. Effects of genotype, grower diet, and finisher diets on carcass traits and organ weights of pigs[a,b]

Genotype	Lysine:DE, g/MJ		10th rib backfat, in	LMA, in^2	Lean, %	Lean, lb/day	Heart, lb	Liver, lb
	Grower	Finisher						
Control	0.421	0.421	1.37	4.49	43.1	0.54	0.94	3.32
	0.421	0.612	1.10	4.77	46.6	0.52	0.94	3.31
	0.765	0.421	1.23	4.36	44.2	0.52	0.95	3.31
	0.765	0.612	1.27	4.49	44.2	0.55	0.90	3.68
Select	0.421	0.421	0.91	4.71	48.4	0.62	1.01	3.69
	0.421	0.612	0.80	5.22	50.9	0.55	1.01	4.19
	0.765	0.421	0.76	5.24	51.2	0.65	0.98	3.37
	0.765	0.612	1.04	4.43	46.7	0.60	1.03	3.96

[a]**LMA**= longissimus muscle area, **Grower** & **Finisher** = grower and finisher diets, respectively, and **Lean** = carcass lean containing 5% fat; Least squares means were based on four pens containing two gilts or two castrated males. [b]Genotype: 10th BF ($P < 0.001$), LMA ($P < 0.018$), Lean % ($P < 0.001$), Lean/day ($P < 0.002$), heart ($P < 0.020$), liver ($P < 0.001$), & kidney ($P < 0.017$); finisher: liver ($P < 0.001$) & kidney ($P < 0.002$); genotype x grower: liver ($P < 0.007$) & kidney ($P < 0.079$); genotype x finisher: lean/day ($P < 0.061$) & liver ($P < 0.031$); Grower x finisher: 10th BF ($P < 0.052$), LMA ($P < 0.073$), & lean % ($P < 0.039$); Genotype x grower x Finisher: LMA ($P < 0.087$).

SELECTION FOR LEAN GROWTH: EFFECTS ON PIG PERFORMANCE

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SUMMARY

In a selection experiment conducted for lean feed conversion in Duroc pigs, growth rate, backfat thickness and predicted feed conversion all improved, while feed intake did not change. In a second experiment with Landrace pigs, selection for increased loin eye area obtained from real-time ultrasound scans improved loin eye area and backfat thickness, but growth rates were reduced.

Introduction

Swine producers are in the meat production business. Their goal is to produce as much lean pork as possible in an efficient manner. Consumers of pork are looking for an economically priced, safe product that is low in fat, and high in quality. The genetic potential of the pigs for lean pork production is part of the answer that would provide a product the consumer desires and that the producer could produce rapidly and efficiently. Two Auburn University experiments were designed to study different methods and resulting side effects (correlated responses) in which the pigs were genetically selected for increased lean growth rate and efficiency.

Experimental Procedures

Experiment 1. Selection for Improved Lean feed Conversion. The first study was conducted with the Duroc breed. The boars and the sows from the original herd were divided into two groups (lines), a selected line and an unselected control line which was maintained along side of the selected line for comparison. All the boars and gilts in each generation were performance tested for growth (168-day weight) and real-time ultrasound backfat thickness measured at the 10th rib (a measure of carcass composition). A total of 1,579 animals were performance tested. These performance data were then used to estimate the breeding values (EBVs) of each pig for 168-day weight, ultrasound backfat thickness adjusted for the weight of the pig and a prediction of the feed conversion (pounds of feed required for each pound of gain) of the pig based, in part, on its growth and backfat thickness measurements. Then all of the pigs were ranked according to the following index:

$$\text{Index} = 50\% \text{ weight} \times EBV_{\text{Backfat thickness}} + 50\% \text{ weight} \times EBV_{\text{Feed Conversion}}$$

The index was an equal weighting of the EBVs for ultrasound backfat thickness and feed conversion, by considering both the economic value and varibility of each of the traits. Since reduced backfat thickness and less feed per pound of gain are desirable, increases in these traits have negative economic values. For the pigs in the selected line, eight boars and 25 gilts, 6-7 months of age, were selected with the largest index values and, and therefore, the most economic valuable for backfat thickness and feed conversion. This was repeated each year for 6 years (generations) with the newly selected boars and gilts completely replacing their parents. In the randomly selected control line, eight boars and 25 gilts each that had index values as nearest to zero as possible were retained for breeding in

each generation.

To ascertain whether the EBVs for feed conversion were effective in changing feed conversion, up to 40 randomly selected barrows from both lines in each generation were individually fed at the Wiregrass Substation to obtain information on feed intake, average daily gain and feed conversion. The pigs were started on the feeding test at about 70 pounds and removed from test after reaching 220 pounds. At the conclusion of the test the barrows were taken to the Auburn University Meats Laboratory to collect carcass information. After 24 hours of chilling, pig carcasses were evaluated for carcass length, 10th-rib backfat thickness, loin eye area, percent lean cuts, lean growth rate, and lean feed conversion.

Experiment 2. Selection for Increased Ultrasound Loin Eye Area. This study was conducted in the Landrace breed. As with the other selection experiment, the boars and the sows of the original herd were divided into two groups (lines), a selected line and an unselected control line which was maintained along side the selected line for comparison. All the boar and gilt pigs each (year) generation were performance tested for 168-day weight (WT), a real-time ultrasound backfat thickness measurement at the 10th rib (BF) and an real-ultrasound scan of the *longisimus* area at the 10th rib (loin eye area: LEA). A total of 1,406 animals were performance tested. These performance data were used to obtain estimated breeding values (EBVs) of each pig for 168-day weight, ultrasound backfat thickness adjusted for the weight of the pig and real-time ultrasound loin eye area. For the pigs in the selected line, eight boars and 25 gilts, 6-7 months of age, were selected with the largest EBVs for LEA. No attention was paid to the EBVs for 168-day weights or for backfat thickness in the selection of replacement boars and gilts. This was repeated each year for 5 years (generations) with the newly selected boars and gilts completely replacing their parents. In the randomly selected control line, eight boars and 25 gilts with EBV values as close to zero as possible were kept as replacements.

In each generation, up to 40 randomly chosen barrows from both lines, after reaching 220 pounds, were taken to the Auburn University Meats Laboratory for recording carcass information. After a 24 hour chill, the pig carcasses were evaluated for carcass length, average backfat thickness, 10th-rib backfat thickness, loin eye area, percent lean cuts, lean growth rate, and lean feed conversion.

Statisitical analyses. The statistical analyses for both experiments removed the effects of generation (year) and sex of the animals. The EBVs were calculated for each pig in the two data sets. These EBVs were averaged by line and generation to observe the genetic changes that occured due to selection in both studies. Analyses of carcass data included the effects of generation (year) and line. .

Results and Discussion

Experiment 1. Selection for Improved Lean feed Conversion. Based on the averages of the EBVs for ultrasound backfat thickness, feed conversion, daily feed intake and 168-day weight (Table 1), the select line pigs, after six generations (years) of selection, were.28 inches leaner, consumed 21 fewer pounds of feed per 100 pounds of gain, and were 12 pounds heavier than pigs from the control line. Daily feed intake was not different between the two genetic lines. With feed valued at 7 cents per pound, a saving of $2.25 per pig would result due to improved feed conversion. Select line pig carcasses were worth $3.64 than control line pig

carcasses because of reduced backfat thickness. So in total, pigs from the select line are worth $5.99 more than pigs from the control line.

Carcasses of barrows from the select line in the fifth generation were had -.50 inches less backfat thickness and had larger loin eye areas (.7 square inches) than carcasses from the control line (Table 2).

Experiment 2. Selection for Increased Ultrasound Loin Eye Area. Selection based on evaluation of real-time ultrasound scans was effective and resulted in a difference between the select and control line EBVs of 1.6 square inches in ultrasound loin eye area (Table 3). Although not selected for directly, pigs from the select line had .12 inches less 10th rib backfat, but weighed 4.1 pounds less than pigs from the control line. Estimates of heritabilities for 168-day weights, ultrasound backfat thickness and ultrasound loin eye area were .35, .56, and .47, respectively.

On average, carcasses from the selected line were 1.4 inches shorter, had -.15 inches less backfat thickness between the 10th and 11th ribs, and had loin eye areas which were 1.3 square inches larger than the control line pigs (Table 4).

Implications

The rate of response due to genetic selection for lean growth and efficiency depends on the definition used in the selection program. Selection based on an index of EBVs on real-time ultrasound measurements and feed conversion (predicted from growth and backfat thickness) resulted in improvement in both backfat thickness and feed conversion without a significiant reduction in daily feed intake. On the other hand, selection solely for *longissimus* area resulted in additional muscle area but the pigs grew more slowly.

Table 1. Average EBVs of Adjusted Backfat Thickness, Feed Conversion and 168-day Weights for Select and Control Lines in Duroc Pigs

		Line		
Trait	Generation	Select	Control	Difference
Backfat	3	-.20	.00	-.20
thickness,	4	-.23	.01	-.24
inches	5	-.26	.03	-.29
	6	-.28	.00	-.28
Feed	3	-.15	.00	-.15
conversion,	4	-.17	-.00	-.17
(feed/gain)	5	-.20	-.01	-.19
	6	-.22	.01	-.21
Daily feed	3	.02	.00	.02
intake,	4	.04	-.01	.05
pounds/day	5	.04	.00	.04
	6	.08	.01	.07
168-day	3	6.5	-.9	7.4
weight,	4	7.1	.7	6.4
pounds	5	9.1	1.3	7.8
	6	10.7	-1.3	12.0

Table 2. Carcass Performance Data for Pigs from Duroc Select and Control Lines

		Line		
Trait	Generation	Select	Control	Difference
Length,	3	30.7	30.8	-.1
inches	4	30.7	30.8	.0
	5	31.1	30.1	1.0
10th-rib	3	.87	1.36	-.49
backfat,	4	1.05	1.49	-.44
inches	5	.93	1.42	-.49
Loin eye	3	4.5	3.9	.6
area,	4	4.4	3.9	.5
square inches	5	4.8	4.1	.7

Table 3. Average EBVs of Real-Time Ultrasound Loin Eye Area, Adjusted Backfat Thickness, and 168-day Weights for Select and Control Lines in Landrace Pigs

Trait	Generation (Year)	Line		Difference
		Select	Control	
Loin eye	3	1.0	-.1	1.1
area,	4	1.4	-.1	1.5
square inches	5	1.6	.0	1.6
Backfat	3	-.06	-.01	-.05
thickness,	4	-.09	-.02	-.07
inches	5	-.12	.0	-.12
168-day	3	2.5	6.8	-4.3
weight,	4	5.8	11.8	-6.0
pounds	5	5.7	9.8	-4.1

Table 4. Carcass Performance Data for Pigs from Landrace Select and Control Lines

Trait	Generation (Year)	Line		Difference
		Select	Control	
Length,	3	31.8	32.0	-.2
inches	4	30.8	32.0	-1.2
	5	30.7	32.1	-1.4
10th-rib	3	1.11	1.32	-.21
backfat,	4	1.10	1.25	-.15
inches	5	1.02	1.17	-.15
Loin eye	3	4.9	4.1	.8
area,	4	5.3	4.1	1.2
square inches	5	5.5	4.2	1.3

GENETIC FACTORS INFLUENCING PORK QUALITY

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Summary

In order to study the effect of intensive selection for lean growth efficiency on pork quality, Duroc pigs that were genetically selected for increased 169-day weight and decreased backfat thickness at 230 lb. (lean growth efficiency) and pigs from a contemporary, non-selected stress-negative control line were used. Data that has been collected so far from this population of Duroc pigs shows that decreased pork quality in the Select line of Durocs has been manifested in several different ways. Both the longissimus dorsi from the loin and the semitendinosis from the ham have exhibited lower 24-hour pH values ($P < .05$), yet there was little difference in the rate of pH decline over the first 45 minutes between the Select and Control lines. The Select-line Durocs had significantly ($P < .01$) lower subjective firmness scores and a significant increase ($P < .01$) in the amount of moisture and protein lost as measurable drip. There were no differences in subjective color scores or in Hunter a and b values. Fewer differences were seen in processed product as compared to fresh product. This study indicates that selection for lean growth may have an impact on fresh pork quality.

Introduction

It has been well documented that the presence of the halothane (stress) gene has a detrimental effect on pork quality. Pigs that are homozygous recessive for the trait can be very lean and heavily muscled, but are more prone to shock, heatstroke and circulatory failure when exposed to stressful conditions. Once slaughtered, these stress-susceptible animals (and often the heterozygous carriers of the trait) exhibit exaggerated postmortem muscle metabolism, most commonly manifested as a very rapid glycolysis and concomitantly a rapid buildup of lactic acid in the muscle tissue. This rapid metabolism and buildup of lactic acid results in the meat having a significantly lower pH at 45 minutes postmortem (while the carcass is still hot) than meat from most stress-resistant animals at 45 minutes postmortem. It is important to note that in most cases, the ultimate pH of carcasses from stress-susceptible animals is not always significantly different from the ultimate pH of carcasses from normal animals (Lundstrom et al., 1989). Therefore, the rate of pH drop rather than the ultimate pH is the critical parameter associated with inferior meat from stress-susceptible animals. The combination of low pH (usually around 5.4-5.6) and high temperature (near body temperature) causes significant denaturation of muscle proteins leading to the development of poor quality pork. Meat from pork carcasses that has undergone this rapid decline in pH is pale in color, has reduced color stability, increased purge (moisture loss), reduced juiciness and lower processing yields.

Another quality concern that is associated with lower processing yields is manifested in carcasses from some Hampshires and Hampshire crossbred pigs. This condition has been referred to as the "Hampshire Effect" and is thought to be influenced by a dominant allele (referred to as the RN genotype) (LeRoy et al., 1990). Carcasses exhibiting the "Hampshire Effect" tend to have a normal rate of pH decline through the

first hour postmortem, but have significantly lower pH than normal (and some PSE) carcasses at 24 hours postmortem. This lower 24-hour pH has been hypothesized to be related to a greatly increased glycolytic potential when compared with other breeds. Product classified as exhibiting the "Hampshire Effect" can also be paler in color than is ideal (Monin and Sellier, 1985).

A unique line of Duroc hogs has been established at Auburn University by intensive selection for increased 168-day weight and reduced backfat thickness at 230 pounds (Kuhlers et al., 1996). The Select line of hogs exhibits a documented increase in lean growth efficiency, decreased backfat and increased percentage of lean cuts in the pork carcass when compared to a contemporary, randomly selected Control line of hogs. It is important to note that both the Select line of Durocs and the Control line of Durocs originated from the same base population of hogs at the beginning of the selection experiment. Interestingly, while this study has resulted in significant improvements in carcass composition and in lean growth efficiency, it has become apparent that this advantage in carcass composition has come at the expense of product quality. Poorer pork quality in the Select line is unexpected as the Duroc breed in general is not widely known for having substantial pork quality problems. Moreover, the Select line population has been genetically tested and has been found to be free of the halothane gene, the presence of which is widely known to adversely affect meat quality.

The objectives of the study were to characterize further the extent of the impact of selection on both fresh and processed meat quality in order to develop recommendations for intervention technologies to improve the quality and consistency of pork from halothane-negative hogs and to determine what factors in porcine muscle are being inadvertently selected for that cause this deterioration in quality.

Experimental Procedures

In order to accomplish the objectives, thirty-nine pigs, were randomly chosen from a stress-negative line of Duroc pigs that has been genetically selected for increased 169-day weight and decreased backfat thickness at 230 lb. (lean growth efficiency) and from a contemporary, non-selected stress-negative control line. These pigs were obtained from the fifth generation of the Auburn lean-growth efficiency Select and Control lines. Temperature and pH of the longissimus dorsi and the semitendinosus were monitored at 15, 30, 45 minutes and at 24 hours postmortem. Carcass data including average backfat thickness, 10th rib backfat thickness, loin eye area, carcass length and weights of trimmed lean cuts was obtained from the left side of all carcasses. Chops were obtained from the longissimus dorsi for evaluation by a trained panel for color, firmness and marbling according to the Wisconsin Standards. Color of the longissimus dorsi and the semitendinosus was monitored with the HunterLab Color Difference Meter. Drip loss was determined from samples of longissimus dorsi, semitendinosis, semimembranosus and biceps femoris after storage in a sealed bag under atmospheric pressure for 24, 48, 72 and 96 hours at 40°F. Two chops per muscle per animal were stored at 40°F for 120 hours and were then cooked to an internal temperature of 167°F. Cook loss was determined and these samples were also used to determine Warner-Bratzler shear forces as outlined by the guidelines of the American Meat Science Association. Relative protein solubility (an indicator of denaturation of sarcoplasmic and myofibrillar protein and a predictor of the

processing characteristics of the products) as outlined in Boles et al., (1992) was measured on 120 hour postmortem samples to obtain an indication of the functionality of specific classes of muscle proteins. To evaluate processing characterisitics, the longsissimus dorsi muscles from the loins from both select and control lines were injected up to 110 % (TRT1) or 150 % (TRT2) of initial weight with an appropriate curing brine, allowed to equilibrate and cooked to an internal temperature of 158 °F. The semitendinosis muscle from the ham from both select and control lines were injected up to 110 % of initial weight with a curing brine, tumbled to improve brine uptake, and cooked to an internal temperature of 158°F. Samples were packaged and stored in vacuum package bags. Purge was measured 28 days after processing. Hunter color values were evaluated at 1, 14 and 28 days post processing. The select line LD samples in TRT1 had higher percent purge lost ($P < .1$), lower Hunter L values at days 1, 14, and 28 and a and b values at day one post processing ($P < .05$) than the control line longissimus dorsi samples.

Results and Discussion

All pigs in the study tested negative for the presence of the halothane gene. The select line loin eye area and percent lean cuts were significantly greater than control line. The 10th rib fat thickness was less in the select line than the control line. Meat quality traits in the longissimus dorsi (LD), semitendinosus (ST), biceps femoris (BF) and semimembranosus (SM) were documented. There were no selection line effects on LD subjective color and marbling scores, Hunter L, a, b values or protein solubility. The pH values at 15, 30 and 45 minutes postmortem were lower ($P < .05$) in the select line than in the control line LD and ST muscles. The select line LD pH was lower at 24 hours than the control line ($P < .1$). The ST pH at 24 h was lower ($P < .05$) and had lower protein solubility than C line ST chops ($P < .05$). Selection had no effect on calpastatin activity in the LD or ST. Warner-Bratzler shear values were higher in the select line LD ($P < .05$) and ST ($P < .10$) chops than control line chops. Drip loss was greater in the select line LD, ST and SM chops than the control line after 24, 48, 72 and 96 h storage. There was no difference in driploss in the BF between lines. The data imply that the selection strategy has been successful in improving carcass composition. However, consideration must be given to pork quality when developing selection approaches to improve lean growth efficiency even with the absence of the halothane gene.

Fewer differences were seen in the processed products. The select line longissimus dorsi samples in TRT2 had lower Hunter L values at one day post processing ($P < .05$). The select line semitendinosis samples in TRT1 had lower Hunter b values at 28 days post processing ($P < .1$). No selection line differences in percent purge lost were observed in longissimus dorsi TRT2 or semitendinosis TRT1. These data indicate that, though selection for lean growth had a large impact on fresh pork quality, fewer effects on cured products characteristics were observed.

Taken collectively, these data demonstrate that pork quality in the Select-line is adversely affected by a mechanism much different than the mechanism at work in carcasses from stress-susceptible pigs (Huff-Lonergan et al., 1997). This research points out that elimination of the Halothane gene will solve some, but not all of the pork quality problems faced by the industry. Selection for some economically important traits such as feed

efficiency or increased lean growth in the absence of the Halothane gene may still compromise pork quality.

Research efforts need to be focused toward efficient production of a very consistent high quality product. Researchers in pork quality are working to help the industry attain that goal.

Implications

This line of research should lead to means for developing specific intervention strategies to improve pork quality from non-stress susceptible animals and to the development of molecular markers to use as selection tools in breeding systems to efficiently produce lean pigs that yield high quality meat.

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CONSTRUCTED WETLANDS FOR ANIMAL MANURE TREATMENT AND ODOR CONTROL

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SUMMARY

A one- acre constructed wetland was evaluated for 57 months for the treatment of secondary lagoon wastewater from a 500 farrow-to-finish swine operation. The system successfully met USDA/NRCS effluent guidelines for constructed wetlands treating animal manures but failed to consistently meet effluent criteria for ammonia, phosphorous and fecal coliform bacteria required for effluents from wetlands treating municipal sewage. This is not expected to be a deterrent to the use of wetlands because discharge of wetland effluent, regardless of analyte levels, requires a discharge permit. It would be in the best interest of the livestock producer to recycle the treated water rather than to discharge it. Constructed wetlands is an economical and highly efficient method of treating animal manures that is perceived by the public to be sustainable and environmentally friendly.

Introduction

Liquid manure management systems associated with confined animal operations typically use lagoons as temporary wastewater storage structures. Objectionable odors and water contamination are potential weaknesses of these systems. Lagoons eventually fill and require the wastewater to be irrigated onto pasture or cropland to prevent the lagoons from overflowing. Odors associated with irrigation of lagoon wastewater are offensive to nearby homeowners, and some livestock producers have been forced to use alternative methods of managing lagoon effluent to avoid offending their neighbors. Constructed wetlands are being explored as secondary treatment systems to reduce the impact of livestock wastewater on the environment. The technology has been proven to be highly successful for treatment of municipal wastewater, and this has stimulated interest to adopt this technology for the treatment of lagooned manures. Constructed wetlands are shallow earthen detention ponds planted with emergent aquatic plants, such as cattail and bulrush, that serve as physical barriers and attachment sites for microorganisms that aid in wastewater treatment.

Experimental Procedures

A free surface flow wetland was constructed at the Sand Mountain Agricultural Station (SMSS), Crossville, Alabama, in 1988 to evaluate the efficiency of constructed wetlands to treat the waste generated by a 500 pig/year (farrow to finish) operation. On a daily basis this amounts to the BOD_5 loading contributed by 160, 200 lb pigs; 40, 1000 lb dairy cows or 4,390, 4 lb layer hens. A two-stage anaerobic lagoon system serves as a temporary wastewater storage structure. The effluent from the secondary lagoon flows continuously through a shallow mixing pond and then into a two-tiered constructed wetland consisting of five upper cells and five lower cells. Each cell is 26 x 164 ft

(0.1 acre) with an operating wastewater depth of 0.5 ft and a bottom slope of less than 1% grade. The total treatment area of the wetland cells including both upper and lower tiers is 1 acre. The wetland was operated at a loading rate of 5.3 lbs BOD_5 (biochemical oxygen demand) and 5.0 lbs of total Kjeldahl nitrogen (TKN) per acre per day. The theoretical hydraulic detention time including both tiers was approximately 18 days.

Results and Discussion

Data collected over a 57-month period indicate that the constructed wetlands are highly efficient for treating lagoon effluent. The TKN of the wetland inflow was reduced from 74 to 12 mg/L after treatment, an 84% reduction (Table 1). Total ammonia-nitrogen (TAN) was reduced 85%. Total phosphorus (TP), BOD_5, chemical oxygen demand (COD) and total suspended solids (TSS) were reduced 76%, 90%, 80% and 89%, respectively. After treatment the wetland effluent contained the following concentrations of analytes (mg/L) TP, 6.8; BOD_5, 7.9; COD, 64.2; TSS, 15.5; TKN, 12.2; TAN, 8.6 and NO_3-N <1 (Table 1). The upper tier of cells alone provided sufficient treatment to meet the USDA/NRCS wetland effluent criteria for BOD_5 and TSS (<30 mg/L), but both the upper and lower tier of cells were required to meet the recommended effluent criterion for TAN (<10 mg/L). After 5 years of continuous operation, the SMSS wetland has met or exceeded the suggested USDA/NRCS (1991) wetland effluent criteria (mg/L) for BOD_5 <30, TAN <10 and TSS <30 (Table 2). However, TAN exceeded the 5 mg/L and TP exceeded the 2 mg/L guidelines approved for discharge of effluents from constructed wetlands treating municipal wastewater. The fecal coliform count for the SMSS wetland effluent was reduced 95% of the influent count but the effluent count of 6500/100 ml was about 33 times higher than the EPA criterion for full body contact water (<200/100 ml) (Table 1). Additional treatment would be required to meet fecal coliform limitations of most streams and lakes. Although TAN, TP and fecal coliform bacterial count of the final wetland effluent exceeded the discharge limits approved for wetlands treating municipal wastewater, it is anticipated this would not create a problem because it would be in the best interest of the livestock producer to not discharge the final effluent but rather recycle the water for cleaning livestock production facilities or to apply the effluent to land. Odors were not measured directly, however criteria such as the blackish-green color of wastewater associated with odorous lagoon wastewater were used as a crude measure. The lagoon water entering the wetlands was blackish and odorous, and after treatment the wetland effluent was odorless and nearly colorless. To ensure no discharge of the wetland effluent, a detention pond was constructed. The treated wastewater in the detention pond was pumped as required to a storage pond located upgrade of the constructed wetland system. The recycle water has been used to flush manure from the animal production facilities. The analyte concentrations of the recycle water were determined at two-week interval for one year and contained the following concentrations of analytes (mg/L) TKN, 6.5; TAN, 1.6; BOD_5, 12.0; TSS, 24.9; TP, 6.2 and fecal coliform count of 312/100 mL. The analyte concen|rations met the USDA/NRCS minimum guidelines of BOD_5, TAN and TSS for treating animal lagoon wastewater and also the criteria for effluent from wetlands treating municipal sewage (Table 2). However, the fecal coliform count for the recycle water (312/100 mL) exceeded the EPA criterion for full body contact (<200/100 mL).

Implications

The constructed wetland technology for wastewater treatment is accepted by many state governments and by the EPA. Many small communities that cannot afford expensive sewage treatment systems are using constructed wetlands with approved discharge of the treated sewage to streams. Since the technology is approved for treatment of municipal sewage, the use of wetlands for the treatment of animal manures appears to also have gained the approval of the public and of government agencies. In some states serious thought is being given to the abandonment of lagoons for temporary storage of animal manure because of serious odor and water pollution problems. Constructed wetlands offers a solution to these problems that is acceptable to the public and to government water quality agencies.

Table 1. Mean concentrations of wastewater analytes and treatment efficiencies for constructed wetlands treating lagoon effluent[1]

	Wetland Upper Tier			Wetland Lower Tier		Overall
	Influent	Effluent	Reduction	Effluent	Reduction	Reduction
	mg/L	mg/L	%	mg/L	%	%
TKN	73.7	27.1	63.2	12.2	55.0	84.0
TAN	55.6	20.7	62.8	8.6	58.5	84.5
NO_3-N	<1	<1	-	<1	-	-
BOD_5	76.6	16.8	78.1	7.9	53.0	89.7
COD	319.9	107.7	66.3	64.2	40.4	80.0
TP	28.4	12.7	55.3	6.8	46.5	76.1
TSS	135.7	19.1	85.9	15.5	18.8	88.6
FCB[2]	$1.2X10^5$	$1.3X10^4$	89.2	$6.5X10^3$	50.0	94.6

[1] Triplicate analyses were conducted at 2-week intervals for 57 consecutive months.
[2] Fecal coliform bacteria per 100 ml of water.

Table 2. Comparisons of effluent quality from wetlands treating animal and municipal wastewaters

Components	Constructed Wetland Effluent					
	Animal Waste			Municipal Sewage		Rain Water Field Runoff[6]
	57-Month Study SMSS[1]	NRCS Criteria[2]	Poultry Processor Plant[3]	Georgia Criteria[4]	Danish Criteria[5]	
BOD_5, mg/L	7.9	30	5-15	20	15-20	11
TAN, mg/L	8.6	10	1-5	5	-	2
TP, mg/L	6.8	-	-	-	1.5	1
TSS, mg/L	15.5	30	15-30	30	-	-
FCB (#/100 mL)	6,500[7]	-	-	-	-	11

[1] Mean final analyte concentrations for wetlands treating lagoon wastewater over 57-month at the Auburn University, Sand Mountain Substation.
[2] USDA/NRCS minimum effluent guidelines for wetlands treating animal lagoon wastewater.
[3] Texas state discharge regulations for poultry processor.
[4] Georgia Department of Natural Resources criteria for effluent from wetland treating municipal sewage.
[5] Danish discharge criteria for sewage treatment by constructed wetlands.
[6] Mean analyte concentration of rainfall runoff from non-manured field over a two- year period.
[7] Fecal coliform becteria criterion for "full body contact" water classification is 200/100 mL.

MANURE TREATMENT TO ELIMINATE *E. COLI 0157:H7* AND *SALMONELLA*

Thomas A. McCaskey, Sidath V. Panangala, and Allison K. Witherow

SUMMARY

A constructed wetland system for treatment of lagoon swine manure was demonstrated to be effective in eliminating enteric bacterial pathogens such as *E.coli* O157:H7 and *Salmonella* in swine manure. Because these pathogens have been involved in foodborne disease outbreaks and even deaths associated with the consumption of animal- derived protein foods, current mandated federal rules require all meat processors to meet more stringent criteria for meat safety. Controlling these pathogens on the farm is one of many strategies been pursued to ensure the safety of foods.

Introduction

Foodborne bacterial pathogens such as *E. coli 0157:H7* and *Salmonella* are the focus of much attention by government agencies and by the public. There have been numerous conferences, workshops, senate hearings and public forums to discuss strategies on how to control these bacteria in foods especially fresh meats. Illness and even death resulting from the consumption of meats contaminated with *E. coli 0157:H7* or *Salmonella* and the sporadic occurrence of these bacteria on fresh meats make meat processors wary. Even the most modern and sanitary processing plants are not exempt from these bacteria. Because the bacteria are enteric bacteria, which means their habitat is the gastrointestinal tract of all warm-blooded animals and man, strategies to control these bacteria usually focus on sanitary practices of animal slaughter and meat processing. Feces of animals and humans contaminated with these bacteria is the source of the bacteria in foods. Meat processors have taken much of the criticism relative to *E. coli 0157:H7* because fresh ground meat has been involved in foodborne disease outbreaks and therefore much of the publicity about the bacteria has focused on fresh meats. Because state-of-the-art slaughter and highly monitored meat processing facilities are no deterrent to the entry of *E. coli 0157:H7* into a meat plant, intervention strategies appear to be focusing more on animal husbandry practices at the farm. If the incidence of *E. coli 0157:H7* and *Salmonella* can be reduced in animals and in the environment where the animals are reared, perhaps the incidence of these bacteria in meats also can be reduced or even eliminated.

Because animal manure management practices are likely to come under more scrutiny in the future relative to enteric diseases that can be contracted from food-producing animals, a study was conducted to determine the fate of *E. coli 0157:H7* and *Salmonella* in a liquid swine manure system. A USDA study of fecal samples from 4229 swine from the top 16 swine producing states revealed no detections of *E. coli 0157:H7*. However, until the mechanism whereby non-pathogenic *E. coli* acquires the pathogenic traits of *E. coli 0157:H7*, it is highly likely that all *E. coli* regardless of their animal hosts can become pathogenic. *E. coli* is the same whether its animal host is cattle, swine, sheep, poultry or humans. The liquid swine manure system that was evaluated relative to the fate of *E. coli 0157:H7* and *Salmonella* is a

constructed wetland which is treating the effluent from a two-stage lagoon system. The swine manure treatment system has been evaluated at the Sand Mountain Substation Crossville, Alabama for the past seven years. The treatment system has operated remarkably successfully achieving effluent criteria required for discharge of effluent from constructed wetlands treating municipal sewage.

Experimental Procedures

E. coli 0157:H7 and *Salmonella* were not detected on four attempts to isolate the bacteria from the liquid manure treatment system. Therefore, it was necessary to inoculate the bacteria into the manure to ensure that they were present in the manure at relatively high population levels. It was not practical nor safe to inoculate the bacteria into the waste treatment system at the swine farm, therefore a practical approach was to collect wastewater samples from four stages of the swine manure treatment system. Wastewater samples were collected from the primary lagoon, secondary lagoon, the detention pond which stores the water after it has been treated through the wetlands, and the recycle water which is the final treated water that is used to flush manure from the swine houses.

Each sample was mixed and a 400 ml aliquot was poured into a 500 ml Erlenmeyer flask. The sample was inoculated with 1 ml of a 24-hour broth culture of *E. coli 0157:H7* or *S. typhimurium* to attain about 1 million viable bacteria per ml of each wastewater sample. Each of the four wastewater samples inoculated with each bacterium was replicated twice for each trial and four trials were conducted. The inoculated samples were held at 92°F and viable bacterial counts were determined at Day 0, and at 2-day intervals for 10 days. For each trial 12 microbial analyses were performed. Each bacterium was made tolerant to 200 ppm of nalidixic acid which was added to the media used to recover the bacterium from the inoculated samples of wastewater. At each sampling time dilutions of the inoculated samples were made and plated on Eosin Methylene Blue (EMB) agar with 200 ppm of nalidixic acid for *E. coli 0157:H7*, and XLT-4 agar with 200 ppm nalidixic acid for *S. typhimurium*. After 2 days incubation at 99° F the colonies were counted and two of the colonies were tested further using the API-20E system and specific antisera to verify that the colonies counted were *E. coli* or *S. typhimurium* with the same characteristics as the cultures inoculated into the wastewater samples.

Results and Discussion

E. coli. 0157:H7 and *S. typhimurium* population levels declined more rapidly in the primary lagoon and secondary lagoon water samples and reached lower populations than in the detention pond and recycle pond water samples. The lagoon samples represent highly polluted waters with much higher ammonia concentrations and higher competitive microbial populations which are believed to limit the growth and survival of enteric pathogens. Water from the detention pond is lagoon water that has been treated by passing it through the constructed wetland system then capturing the treated water in a pond for temporary storage. The recycle pond water is detention pond water that has been pumped to a pond of higher elevation from where the treated wastewater can flow by gravity back to the swine houses for cleaning the facilities. The primary lagoon wastewater is most polluted and the recycle pond water is the least polluted. Studies with both of the pathogenic bacteria showed that survival of the pathogens is curtailed more in the two lagoon

water samples than in the water after wetland treatment. In the primary lagoon wastewater *E. coli 0157:H7* declined from 740 thousand per ml to 62 per ml during 10 days with an average decimal reduction value (time for the bacterial count to decrease 90%) of 2.45 days (Table 1). Each 2.45 days the viable bacterial count decreased 90% or 1 log value. Assuming that there were 1 million viable *E. coli 0157:H7* per ml of the lagoon water, after 8 log reductions requiring 19.6 days, the *E. coli 0157:H7* count would decrease to 1/100 ml of water. However it is not likely that lagoon wastewater initially will contain 1 million *E. coli 0157:H7* per ml because the population is continuously declining in the lagoons. The count in the lagoon water during the first two days of the 10 day study trial decreased over 99%. Therefore, the 19.6 days required to achieve an 8 log value reduction of *E. coli 0157:H7* has a considerable margin of safety. Furthermore, animal manure lagoons are constructed to provide at least three months storage capacity.

E. coli 0157:H7 survived longer in the primary lagoon water than *S. typhimurium* (2.45 days vs 1.85 days to achieve a 1 log reduction of bacteria) (Table 1). This trend was apparent for all four of the wastewater samples. About 20 days would be required for treatment of wastewater to achieve an 8 log reduction for *E. coli 0157:H7*, whereas 18 days would be required for *S. typhimurium*. To eliminate both pathogens the wastewater should be stored in the lagoons and/or treated in the wetlands for a combined period of 20 days. Any combination of treatment schemes that results in a total of 20 days of treatment would be satisfactory to eliminate both bacteria, e.g. primary lagoon 8 days, secondary lagoon 5 days, detention pond 2 days and recycle pond 5 days. There is a considerable margin of safety that the treated water from the liquid swine manure treatment system will be safe from *E. coli 0157:H7* and *Salmonella*. Manure treated with a lagoon/wetland system that has at least a 20-day detention time can be recycled to use the water to clean livestock facilities or the water can be applied to land without the risk of spreading enteric infection to animals or humans.

Implications

Government agencies are focusing attention on animal management and manure practices as a strategy to reduce the incidence of enteric bacterial pathogens in food producing animals. This strategy is being instigated to control the incidence of enteric bacterial diseases in humans associated with consumption of animal derived protein foods. Treatment of lagoon swine manure by constructing wetlands has been demonstrated to eliminate *E.coli* O157:H7 and *Salmonella* when these bacteria are inoculated at high concentrations into swine manure wastewater. Detention of the inoculated wastewater for 20 days eliminates the pathogens, thus eliminating health risks that might be involved with recycling the treated wastewater for cleaning manure from animal production facilities.

Table 1. Decline of *E. coli* O157:H7 and *S. typhimurium* in wastewater

	Time to achieve 1 and 8 log reductions of bacterial counts			
	E. coli 0157:H7		*S. typhimurium*	
	1 log[a)]	8 log[b)]	1 log	8 log
	Days		Days	
Primary Lagoon	2.45	19.6	1.85	14.8
Secondary Lagoon	1.94	15.5	1.81	14.5
Detention Pond	2.28	18.2	1.94	15.5
Recycle Pond	2.44	19.5	2.25	18.0

a) Days required for bacterial count to decline 1 log or 90%.
b) Days for count to decline from 1 million bacteria/ml to 1/100 ml.

COMPOSTING FOR SWINE MORTALITY DISPOSAL

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SUMMARY

Burial pits are no longer permitted for the routine disposal of animal mortalities in Alabama. The disposal method that has gained wide acceptance is the composting method. Studies have demonstrated that swine mortalities can be composted into a humus like product with no noxious odors in about 60 days. About 22% of the mass and about 22% of the volume of the initial composting mixture will be reduced during the 60-day composting period. The finished compost contains about 35% moisture, it has no noxious odors, and has a fertilizer value of about $47 per wet ton. The high temperature generated during the composting process kills most pathogenic microorganisms.

Introduction

The disposal of swine mortalities is a task that all swine producers must face. There are several methods of disposal and the selection of a method must weigh heavily in favor of a method which has minimum impact on the environment. Disposal methods available to producers include burial pits, incineration, transporting mortalities to rendering plants and composting. Composting has become widely accepted by poultry producers and by environmental agencies as a feasible, environmentally acceptable method for disposal of poultry mortalities. Composting also might be a feasible method for disposal of swine mortalities, but swine are larger than poultry and composting of swine might be less efficient. Also, its impact on the environment especially, odor control is questionable.

Composting is a complex degradative process by which organic wastes are converted into safe, stable humus by microorganisms. There are four elements required for efficient composting:

1) The material to be composted must be organic in nature, such as farm animal mortalities, animal manures, food wastes, etc.
2) Because microorganisms are responsible for the composting process, the material to be composted should be blended with materials to achieve a carbon-to-nitrogen (C:N) ratio of the compost mixture of about 15:1. Higher C:N ratios (about 20:1) are recommended but the higher ratios reduce the quantity of mortalities that can be incorporated into the compost mix. Proteinaceous wastes such as swine mortalities are low in carbon relative to nitrogen and require a carbon supplement such as chopped hay or straw to increase the C:N ratio.
3) Moisture of the compost mixture should be adjusted to about 40% for best composting. Microorganisms do not grow well below 30% moisture, and much above 50% moisture the compost is saturated with moisture that prevents air from penetrating the compost pile. Air is essential for the compost process.
4) In addition to the carbon amendment to the compost mixture, a bulking agent such as poultry litter or recycled compost is recommended to be added to the mixture to prevent compacting of the

compost pile. The bulking agent decreases the bulk density of the compost which allows air to penetrate the compost and makes the compost degrade faster and generate heat. The heat kills pathogenic bacteria.

Experimental Procedures

To determine whether the composting process can be used efficiently to dispose of swine mortalities, composting trials were conducted at the Lower Coastal Plain Agricultural Substation at Camden, Alabama. The composting ingredients consisted of recycled compost generated from previous composting studies, which was used as a bulking agent, swine mortalities less than 15 lbs each, chopped hay as a carbon source and added water. These were added in the wet weight ratio of 3:1:0.3:0.5, respectively (Table 1). Based on this ingredient ratio, swine mortalities made up 20.8% of the compost weight, and the compost mixture had a C:N ratio of 15:1. Composting was conducted in wooden bins 4x4 feet at the base and 5 feet high. A six-inch layer of recycled compost was placed in the bottom of the bin, followed by a layer of swine mortalities, a layer of chopped hay, and water was added to the top of the layers. Each time swine mortalities were added to the bin, the process was repeated until the bin was filled, about 1/2 ton. Finally a six inch cap of recycled compost was added to the top of the bin to control odors and vermin. As the layers of ingredients were placed into the compost bin, temperature probes were placed in the compost at four sites to monitor heat generated in the compost. As a rule, the compost temperature should reach at least 122°F and remain above 122°F for at least 5 days to eliminate any enteric pathogenic bacteria. After about 30 days, the compost was removed from the bins, mixed to aerate the compost and returned to the bins to undergo a second 30-day composting process. After the composting process, samples were collected for N-P-K analyses. All analyses were conducted on a dry weight basis and performed in triplicate.

Results and Discussion

Four composting trials were conducted, and all compost mixtures had the same ingredients in the same ratio. After first stage composting the mass (weight) of the compost mixture decreased an average of 13.5% and the volume decreased 16.9% (Table 2). After combined first and second stage composting, the mass and volume decreased a total of 22.1% and 21.8%, respectively. Most of the total decrease occurred during first stage composting amounting to 61% for mass and 78% for volume. Mass and volume decreases are due in part to moisture loss and to volatilization of carbon dioxide and ammonia which are by-product gases from the degradation of organic matter. When the composting process is complete, mass and volume will stabilize. Based on the compost ingredient ratio of 3:1:0.3:0.5 (recycled compost: mortalities: chopped hay: water), the recycled compost (bulking agent) made up 62.5% of the compost mixture. During two-stage, static pile composting, the compost mass decreased 22%. If the finished compost is recycled as bulking agent, 80% of the compost weight generated in one compost bin can be used as an ingredient to compost another bin of mortalities. This leaves 20% excess compost generated during each composting cycle. The finished compost contains about 35% moisture, it has no noxious odors, and contains on a wet ton basis about 50 lbs of nitrogen, 100 lbs super-phosphate and 61 lbs of potash (Table 3). Based on commercial fertilizer costs, the fertilizer value of a wet ton of the swine mortality

compost was determined to be $47.

Implications

Composting is a feasible, economical and environmentally sound method of disposing of farm animal mortalities. The process is natural and does not require the addition of chemicals or microorganisms to carry out the process. Mortalities could easily be degraded without using the composting process but odors, flies and other vermin potentially could transmit disease and cause pollution problems. By using organic materials, such as chopped hay and poultry litter to cover the mortalities in layers, a biological filter is created which virtually eliminates odors and vermin problems. When swine mortalities compost is spread on land, there are no odors to attract vultures nor odors to incite public criticism. The composting method is approved by the state veterinarian as an acceptable method for disposal of farm animal mortalities.

Table 1. Compost Ingredients and Quantities

	Ratio	lbs	%
Recycled Compost	3.0	625	62.5
Swine Mortalities	1.0	208	20.8
Chopped Hay	0.3	63	6.3
Water	0.5	104	10.4
Total	4.8	1000	100

Table 2. Performance of Swine Mortality Composting Process

Composting Trials	1st Stage		1st and 2nd Stages		Temperature (°F) of Compost	
	Mass	Volume	Mass	Volume		
	--- % Decrease ---		--- % Decrease ---		Max.	Days > 122
1	14.9	9.3	23.9	14.7	128	9
2	11.4	19.3	23.0	24.9	133	9
3	13.7	21.4	19.8	29.8	130	19
4	14.0	17.6	21.7	17.7	131	16
AVG.	13.5	16.9	22.1	21.8	131	13

Table 3. Fertilizer Value of Second Stage Swine Mortality Compost

Composting Trials	Pounds/wet ton N	P_2O_5	K_2O	$ Value/wet ton
1	52.1	91.8	58.3	45.10
2	46.2	89.7	54.0	42.10
3	50.7	110.7	66.2	50.07
4	49.1	108.8	65.7	49.11
Average	49.5	100.3	61.1	46.60

Fertilizer value calculated on pound basis as N = $0.29, P_2O_5 = $0.23 and K_2O = $0.15

FACTORS AFFECTING UTERINE CAPACITY AND LITTER SIZE IN SWINE: AN OVERVIEW[1]

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SUMMARY

Embryo mortality is a major factor limiting litter size in pigs. Simply increasing embryo numbers, by whatever means, is not a solution to increasing litter size. The capacity of uterine tissues to support embryos under conditions that will optimize their survival and growth may be determined, in part, by the success of events that support the organization and maturation of the uterine lining or endometrium during early neonatal life. Therefore, research here is focused on identification of developmental determinants of adult uterine capacity in the pig. To date, results indicate that estrogen receptor (ER) -dependent, estrogen-sensitive mechanisms regulating endometrial maturation between birth and postnatal day 14 are potentially critical determinants of adult uterine capacity.

Introduction

Pigs are litter-bearing mammals. Increasing litter size, the number of pigs born per litter, would increase both efficiency and profitability of swine production. Many factors

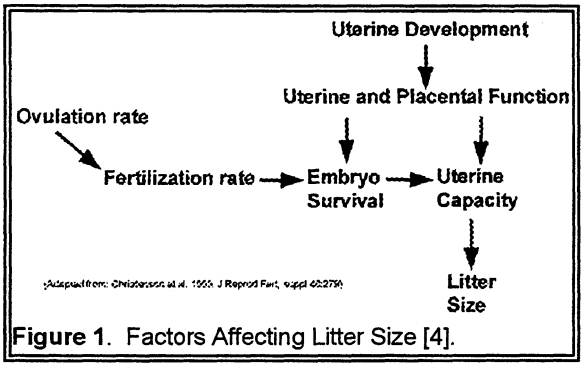

Figure 1. Factors Affecting Litter Size [4].

can affect litter size (Figure 1). The ability of pigs to give birth to litters reflects the fact that a normal, cyclic gilt or sow can release as many as two dozen ova or eggs with each ovulatory cycle or ovulation. Ovulation rate is defined as the number of ova released at each ovulation. When breeding is managed well, fertilization rate, the number of ovulated eggs fertilized at each breeding period, is also very high in pigs, and the majority of fertilized eggs have the potential to develop normally to term. Generally, neither ovulation rate nor fertilization rate are traits that limit litter size. Indeed, increasing the number of ova or embryos through: (i) genetic selection for increased ovulation rate; (ii) drug-induced superovulation; or (iii) transfer of inordinately large numbers of embryos into an appropriately synchronized uterine environment can increase the absolute number of potentially viable embryos found in the uterus on or before day 30 of pregnancy. However, "extra" embryos die thereafter [4,5]. In fact, 20-30% of all porcine embryos die prior to day 30 and another 10-20% of fetuses die between gestational day 40 and term [5]. Interestingly, embryo losses are reduced in naturally hyperprolific Chinese Meishan pigs which, in comparison with White crossbred pigs, have significantly larger litters at a given rate of ovulation throughout gestation [4]. Patterns of uterine development differ between neonatal Meishan and occidental gilts at both structural and biochemical levels [3]. Thus,

events supporting neonatal uterine organization may affect the ability of adult uterine tissues to provide an optimal environment for embryo development.

Available data can be interpreted to indicate that: (i) embryo mortality is a major problem in pigs; (ii) simply increasing embryo numbers, by whatever means, is not the solution to increasing litter size; (iii) uterine capacity - the maximum number of embryos that a pregnant gilt or sow can sustain at any given stage of gestation - constitutes a major constraint to litter size; and that, while limits of uterine capacity may be defined genetically, (iv) functional uterine capacity can reflect the relative success of developmental mechanisms regulating the organization of uterine tissues. Therefore, research in this laboratory is focused on identification of developmental determinants of uterine capacity in the pig. Particular attention is given to the endometrium, the tissue that lines the inside of the uterus and provides direct support to developing embryos.

Objectives of ongoing research are to: (i) characterize events associated with normal development of the porcine endometrium between birth (postnatal day = PND 0) and PND 120; (ii) determine the extent to which ovarian factors are required to support endometrial maturation during this period; (iii) determine whether normal postnatal development of endometrial glands requires expression and activation of a functional estrogen receptor (ER) system; (iv) establish the utility of estradiol-17β valerate (EV) as a tool with which to disrupt the normal program of endometrial development in the neonatal pig; and (v) determine whether EV-induced disruption of endometrial development during the first few weeks of postnatal life affects subsequent uterine capacity.

Materials and Methods

Uteri were obtained on specific postnatal days from: (i) normal, ovary-intact gilts or gilts ovariectomized at birth; and (ii) gilts treated with either corn-oil vehicle (CO), EV (50μg/kg bw/day), an equimolar dose of the antiestrogen ICI 182,780 (ICI; 125μg/kg bw/day), or the combination of ICI + EV (IE), for specific intervals prior to surgical uterine collection. In all cases, uteri were obtained using aseptic technique, from gilts under halothane anesthesia. Procedures involving animals were approved by the Auburn University Institutional Animal Care and Use Committee. Experimental and analytical details, results and detailed discussions are published elsewhere [1,2,3,6,7,8,9].

Results and Discussion

In the pig, as in other domestic animals including cattle and sheep, uterine development begins during fetal life (prenatally), but is completed after birth (postnatally) [1,2]. Ovariectomy of gilts at birth does not affect patterns of uterine growth, as reflected by patterns of change in uterine wet weight (Figure 2), or development of normal endometrial

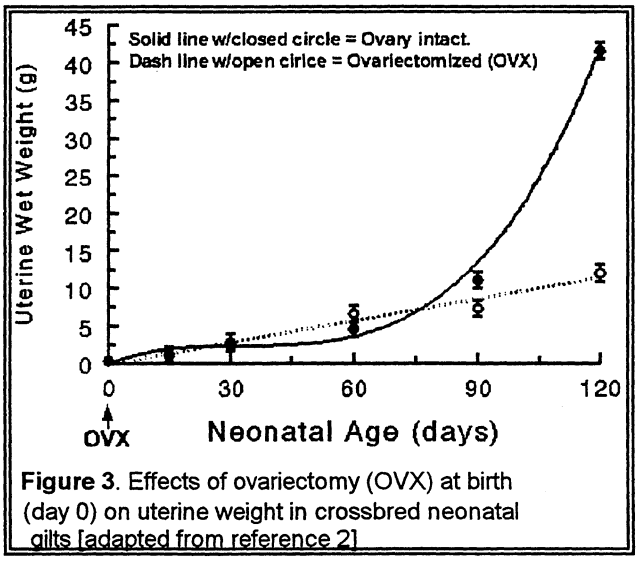

Figure 3. Effects of ovariectomy (OVX) at birth (day 0) on uterine weight in crossbred neonatal gilts [adapted from reference 2]

architecture until after about PND 60, when ovarian factors begin to influence uterine growth positively. Endometrial glands are absent or rudimentary at birth, but proliferate rapidly during the first few weeks of postnatal life [2].

Cells that express functional ER can respond directly to estrogen and display enhanced responsiveness to other factors that affect cell behaviors necessary for tissue maturation. The porcine endometrium is ER-negative (ER^-) at birth [8]. However, appearance of uterine glands between birth and PND 15 is associated with expression of ER-positive (ER+) character by newly developed glandular epithelium (GE) and the stromal (St) cells that surround them and support luminal epithelial cells. Luminal epithelium (LE) lines the inside of the uterus and remains ER-negative (ER^-) until approximately PND 30, by which time all major endometrial cells display ER+ character (Figure 3). Development of ER+ character by cells of the neonatal porcine endometrium does not require ovarian support [8].

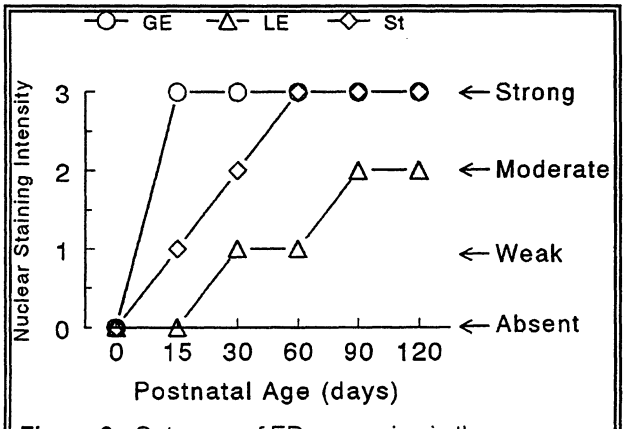

Figure 3. Ontogeny of ER expression in the neonatal porcine endometrium [8]

The normal course of endometrial development in the neonatal pig can be disrupted if gilts are exposed to estrogens or antiestrogens [2,6,7,8,9]. Generally, effects of estrogen on patterns of uterine development in the porcine neonate are uterotrophic, specific to the period when exposure occurs, and become more pronounced with increasing age from birth, in association with expression of ER+ character by the developing endometrium. Estrogen stimulates growth and development of the neonatal endometrium, as reflected by increased DNA synthesis in new GE, proliferation of uterine glands, and precocious development of endometrial folds [6,7,9]. In contrast, ICI, a "pure" antiestrogen that inhibits ER function, is antiuterotrophic in the neonatal pig. Given from birth, ICI inhibits expansion of endometrial stroma and prevents development of uterine glands [7,9]. Thus, normal endometrial development and gland proliferation in the neonatal porcine uterus requires expression and activation of a functional ER system. Never the less, hyper-activation of this developing ER system has negative consequences for embryo survival in adults.

Compared to vehicle-treated controls, adult gilts exposed to EV from birth through PND 13 cycled normally, displayed equivalent ovulation rates and conceived to natural service. However, when evaluated on gestational day 45, embryo mortality was increased 22% ($p < .05$) in neonatally EV-exposed gilts [2]. Data can be interpreted to suggest that transient hyperactivation of the uterine ER system during the first two weeks of neonatal life alters critical developmental events in specific endometrial cell compartments that affect the capacity of adult uterine tissues to support embryo development. The extent to which such reduced uterine capacity may be due to lasting effects of neonatal estrogen exposure on adult endometrial responsiveness to steroid and conceptus signals

that are essential for establishment and maintenance of pregnancy is the subject of ongoing research.

To date, studies of uterine development in the pig have provided important insights into organizational events and mechanisms that can affect uterine capacity and litter size. Information generated from this work can be used to refine husbandry guidelines associated with development of reproductively sound females in the national pig herd.

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POTENTIAL FOR ALTERING EMBRYONIC MUSCLE DEVELOPMENT AND LIVESTOCK PRODUCTIVITY[1]

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SUMMARY

Phenotypic and genotypic variation in muscle growth and meat quality in meat animals is indeed extensive. Increased efficient lean growth and meat endproducts with high consumer acceptance is desired by the livestock industry. At the tissue level, the goal may be achieved through combined alterations in hyperplasia (myofiber number=MFN), predominately an embryonic process, and hypertrophy, predominating postnatally. In particular, MFN has a positive relationship to rate, composition, lean quality and efficiency of growth in the pig. To conceptulize opportunities for exploiting features of muscle differentiation prenatally which subsequently influence the extent of muscle deposition and growth postnatally in agriculturally-important mammals such as the pig, my goals in this overview are to: (i) highlight the practical benefits of altering muscle fiber number, (ii) examine a contemporary model of myogenesis, (iii) identify critical periods of myogenesis in developing embryos, (iv) feature some dynamics of the peri-implantation intrauterine environment as related to embryo development, and (v) present documented evidence for beneficial effects of pharmacologic or nutritional treatments during gestation on muscle growth, myofiber number and/or subsequent postnatal performance of progeny. Differentiative events in muscle have been shown to be sensitive to a wide array of growth factors as they interact with developmental genes, including myogenic regulatory factors (MRF's). MRF's function at critical points within an intracrine circuitry controlling mutually exclusive events of proliferation and differentiation. Results from work at Auburn on porcine and bovine species revealed a temporal MRF mRNA expression pattern of: myf, myoD, myogenin, and mrf4. Embryonic expression of MRF and a differentiation inhibitor gene (ID) was altered ($P<.05$) in a manner consistent with conceptual hypotheses for increased myofiber number by exogenous treatment of the maternal unit. The periimplantation period is dynamic in terms of both intrauterine (changes in histotroph composition, vascularization, etc.) and embryonic events. MFN eventually form in successive waves during "windows of sensitivity". While small data sets exist to enable a suggestion that MFN may be increased through gestational treatment, mechanisms remain unknown. Nevertheless, it appears that postnatal growth can be altered through nutritional and pharmacological treatments during gestation. A more complete understanding of the controls for muscle formation at the molecular level along with the interrelationships between intrauterine environments and embryo development are needed and should lead to more precise regulation of muscularity in pigs and other species.

Introduction

Why is myofiber number and size important? The first determinant of the muscle mass of an animal is the number of mature muscle cells or myofibers and the second is the size or diameter of the myofiber. The number of

myofibers is unaffected postnatally and as will be discussed, any influence on this determinant must occur during gestational development of the embryo and fetus. With emphasis on increasing myofiber number, the average myofiber size will likely tend to decrease. Myofiber size is determined primarily by the amount of protein accumulated inside the cell and while numerous factors can influence hypertrophy after birth, there are limits for maximal or optimal myofiber size. Emphasis on increasing myofiber size through selection or nutritional manipulation results in a decline in muscle quality in pigs. A collective examination of the literature indicates that increasing myofiber number is of significant importance for performance and quality. Figure 1 summarizes results of experiments by Dwyer et al. (1) which examined growth, feed efficiency and myofiber number in pigs from 50 to 180 lbs. These graphs illustrate a positive relationship between increasing myofiber number to improved ADG and F:G.

A Contemporary Model of Myogenesis. In order to optimize a biological system, a thorough understanding of the players involved and interaction is needed. As illustrated in figure 2, cells found in specialized structures called somites will give rise to the lineages for all the muscle in an animals body. Myogenesis first involves a proliferation phase to increase numbers within the lineages and then a differentiation phase where cells become different from other cells, fuse with each other and begin to take on the appearance and function of muscle. The first myofibers to form are called primary myofibers and these cells serve as a seedbed for formation of another type of myofiber called secondary myofibers (figure 3). In the histochemical characterization of pig muscle, one can see each primary surrounded by a rosette of up to 20 secondaries. While the numbers of primary myofibers seem to be more genetically determined, the secondary myofibers have been increased through domestication. The myogenic circuitry involves interaction between many players which exert positive and negative control all within the context of critical developmental windows of time. Most significant players include cell cycle genes, protooncogenes, homeobox genes (Pax-3), differentiation inhibitor (ID), retinoblastoma protein, myogenic regulatory factors (MRFs: myf5, myogenin, MyoD, MRF4), MEF's, Meso-1 and numerous growth factors (GFs: IGF-I & II, TGF-B, FGF, PDGF, HGF and more) which operate like local hormones (2,3). Expression of the MRFs will lead to differentiation and their expression is controlled by GFs. Work at Auburn has shown these genes to be controlled by IGF-I and II in developing bovine muscle (3,4). A newly discovered group of proteins, growth and differentiation factors (GDFs) are also involved in muscle formation (5). In fact, GDF-8 or myostatin, is clearly involved in determining cell number as reduction of myostatin protein can increase myofiber number 2 to 3-fold and is believed to be the gene responsible for double muscling in cattle (5). In summary, in order to control the number of myofibers in livestock, we must focus on regulating the expression of MRFs, myostatin and myostatin-like genes, and will be obligated to regulate these during early embryogenesis.

Critical Periods of Myogenesis / Embryogenesis in Pigs. Interestingly, if one considers the time from birth to market relative to the gestation lengths of livestock, over 50% of the life of modern livestock are spent in utero and reinforces the importance of events during this period, as many of the desirable economic traits are determined prior to birth. Prior to recognition of pregnancy, the morphologic

changes of the embryo and uterine tissues are profound. It is a time of apposition and early placentation. During this dynamic period, cells in the embryo and uterus are proliferating, making commitments to lineages, differentiating and migrating. From day 13 to 14, the spherical porcine embryo progresses from a disk of cells to an embryo with a visible neural tube yet no somites. At day 15, several pairs of somites have appeared (rate of 0.3 somites/h) and by day 18, limb buds have appeared, the brain developed and vital organs are apparent (6,7). The embryo has become a secretory unit and secretions communicate to the uterine endometrium (8). It is through this communication that the endometrium secretes a protein-laden secretion called histotroph that bathes the peri-implantation, pre-placental embryo. The expression of GFs are temporally and coordinately regulated in the embryo, endometrium and luminal fluid (8). It appears that from day 15-22 of the porcine embryo, there is extensive somitogenesis, primary myogenesis and proliferation of the progenitor population for secondaries; day 36-50 captures extensive proliferation of secondaries; and from day 50-70, primaries are at maximal number and total MFN is maximal by day 70 (9). During post-placental fetal stages, nutritional influences are likely mediated through placenta mechanisms. Factoring all of this information, our hypotheses have been that alteration of the maternal endocrine millieu could influence the uterine environment thus, favorably affecting programming of embryos. In order to study these interactions more carefully, a culture system for day 15 porcine embryos was recently developed (6,7) to complement in vivo studies.

Outcomes of Nutritional and Pharmacological Treatments during Gestation. The following discussion will highlight evidence that nutritional and pharmacological treatments during gestation can lead to altered muscle cell number and performance of progeny after birth. The concept of embryonic "programming" is based on a presumption that nutritional and non-nutritional factors ellicit different effects at different windows and effects are in cell number, organ structure, hormonal axes and metabolic set-points.

Progeny of sows fed increased intakes during gestation had a 10 and 8% improvement in ADG and F:G from 70 to 130 days postnatally (10). Compared to progeny of sows fed normally during gestation, pigs also had an increased ratio of secondary to primary myofibers (10). These data provide evidence to support the hypothesis for programming through nutritional manipulation.

In the early 1990's, we began to explore the potential for use of porcine somatotropin (pST) administration during early gestation of gilts to alter MRF gene expression, myofiber number and postnatal performance of progeny. A sequence of experiments performed at Auburn University are summarized in Figure 4. Results will be briefly highlighted. The first experiment utilized pituitary derived pST administered at 30 ug/kg from day 28-40 of gestation (11,12). Observations were made on embryos at day 41 plus neonatal and market weight progeny. Results showed that embryo survival and growth were improved plus expression of MRFs were altered by treatment. Treatment progeny slaughtered at 220 lb had reduced backfat and overall improved lean growth rate (11,12).

A subsequent experiment involved treatment with 0, 30 and 60 ug/kg of rpST from day 28-40 (13). Most significant was the observed improvement in carcass traits and semitendinosus weight. Embryonic observations of improved survival, growth and expression of

MRFs were consistent with the previous experiment. A third experiment involved a comparison of performance and carcass traits of progeny treated with 0 or 60 ug/kg/d of rpST from day 15-30 (14). Carcass traits were improved and lean growth rate clearly favored progeny of treated litters. A fourth experiment (unpublished) focused on the temporal expression of the MRF genes and in response to treatment of litters sired by average or heavy muscle sires. These data showed that the pattern of expression occured in pulses and pST particularly reduced myf5 expression in embryos of light muscled litters. Furthermore, the higher the pulse of myogenin at day 20 the lower the expression of a differentiation inhibitor gene ID and the higher the expression of myf5 at day 22 and 24 (unpublished data). Collectively, the MRFs expression patterns support in vitro evidence for increasing cell numbers when MRFs expression is affected in a similar fashion.

We recently reported that treatment of gilts from day 15-30 of gestation with pST or a growth hormone releasing peptide, Rismorelin, resulted in heavier semitendinosus and peroneus muscles in newborn progeny (15,16). Additionally, periimplantation embryos harvested from non-pST-treated gilts, cultured in serum from pST treated gilts or in the presence of pST directly, had increased rates of somitogenesis and development compared to non-treated embryos (7). These data support a hypothesis that myogenesis can be influenced by pharmacologic treatment of the gilt.

Work by Rehfeldt et al. (17) has shown that pST treatment of sows from day 10-24 increased myofiber number by more than 27% supporting the potential for altering myofiber number in utero.

In summary, at least three approaches for experimentally altering myofiber number have been reported yet additional work is needed.

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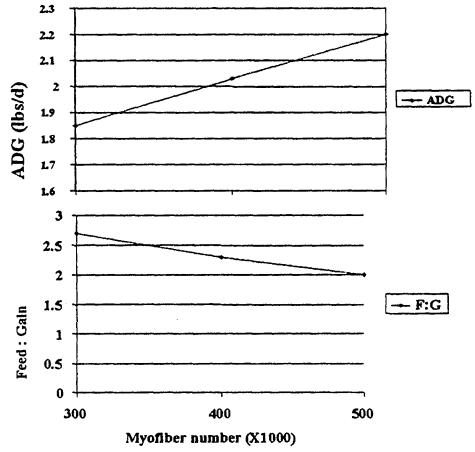


Figure 1. Association of myofiber number to ADG and F:G (ref 1)

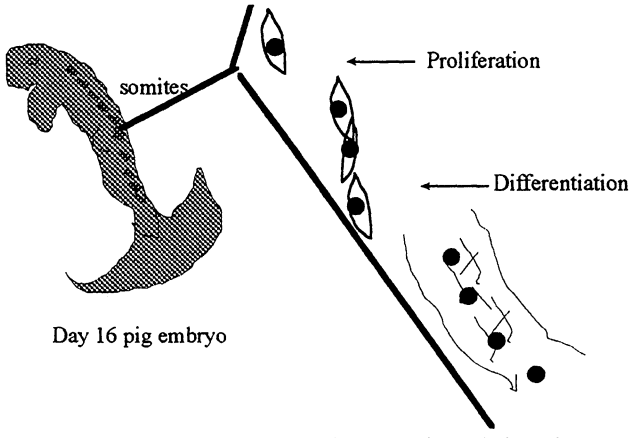
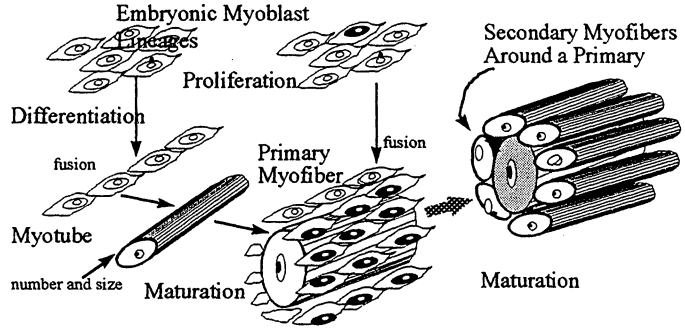


Figure 2. Schematic of proliferation and differentiation of muscle cells.

Figure 3. Schematic of Myogenesis: Primary and Secondary Myofiber Formation



Seedbed for secondary myotube formation

Figure 4. Administration of pST to Pregnant Gilts

1992	1993	1994-95	1996
•0 vs 30 ugkg •pit pST •d 28-40 •18 litters	•0, 30 & 60 ug/kg •rpST •d28-40 •54 litters	•0 vs 60 ug/kg •rpST •d15-30 •55 litters	•0 vs 8.4 mg •rpST •d 14-28 •84 gilts •Hvy vs Avg muscle •embryos
RESULTS:			
•inc lean growth •MRF genes •Inc neonate [IGF-I]	•inc carcass traits •ST muscle wt	•inc carcass traits •lean growth inc.	•MRF genes altered

EQUINE LEARNING ABILITIES - WHAT DO WE KNOW?

C.A. McCall

SUMMARY

Horses have good discriminative abilities and simple discrimination tasks often are used to investigate equine learning abilities. However, equine performance on complex discrimination learning tasks may not be related to performance on tasks required of the riding animal. Horses may have trouble reversing complex discriminations once they are learned, emphasizing the need for trainers to maintain accuracy in the horse's initial learning experiences. Correct responses of the horse can be reinforced with either positive or negative reinforcers, and horses respond to different reinforcement schedules in response patterns typical of most animals. Horses learn more efficiently when a moderate number of learning trials are given in fewer learning sessions per week. It is unclear how early handling experiences influence later equine learning abilities, but research suggests the existence of a critical handling period that enhances later learning ability. Although the extent of equine learning abilities still merits investigation, future research emphasis in this field should shift to methods of favorably influencing equine learning abilities through better management and training practices.

Introduction

Horses learn through stimulus-response-reinforcement chains which are commonly known as "trial and error learning". In this type of learning, the horse perceives some stimulus, or cue, and makes a random response to that stimulus. Reinforcement (reward) tells the horse when it has made the right response and strengthens the connection between a specific stimulus and a specific response. In an ideal training situation, the trainer would present a stimulus and the horse would make a random response. The trainer would keep repeating the stimulus until the horse makes the desired response and then the trainer would reinforce the response. Through repeated reinforced pairings of the stimulus and desired response the horse learns to give a specific response to a specific stimulus. However in a less than ideal world, horse trainers must remember that anything perceived by the horse can be a stimulus (such as a backfiring truck) and any action by the trainer (such as an accidental fall off the horse) could influence the association the horse makes between the stimulus and the response.

Discriminative Abilities

To learn through a stimulus-response-reinforcement chain, the horse must be able to discriminate the learning stimulus from all other stimuli in the horse's environment. Horses are capable of discriminating very fine stimuli. In the early 1900's a horse named Kluge Hans (Pfungst, 1907) seemed to possess the ability to solve mathematical and spelling questions. However, a scientific investigation revealed that the horse could give the correct answer only when the handler knew the correct answer. The handler unintentionally was cuing the horse to make the correct answer by tensing and relaxing his facial muscles. Although the investigation exposed the problem-solving horse as a fraud, it also illustrated that horses could perceive and respond to very subtle stimuli.

Stimulus discrimination may involve any of the horse's senses. Auditory, visual and tactile discriminative stimuli utilized separately (Yeates, 1976) or combined (Mackenzie et al., 1987) result in high rates of learning for simple tasks, such as lever pressing. However, more complex tasks such as discrimination reversals (the formerly correct stimulus becomes incorrect and the formerly incorrect becomes correct) may be influenced by the sensory system used in the discrimination. Visual discrimination reversals are harder for horses to learn than spatial reversals (Voith, 1975), and success at visual discrimination reversals is not correlated with successful performance on detour tasks which are related to riding performance, such as crossing a bridge and a small jump (Sappington et al., 1997). Similarly, Wolff and Hausberger (1996) reported that horses that were successful in an instrumental task (opening a box to get feed) were not necessarily successful in an spatial task (finding a feed compartment entrance in a circular maze).

Horses easily learn daily reversals in discriminative stimuli when only one relevant stimulus (e.g. bucket color) is important in discrimination (Voith, 1975; Fiske and Potter, 1979). However, reversals in which a relevant stimulus (bucket color) is paired with an ambiguous stimulus (spatial position) are more difficult for horses indicating that horses may have difficulty reversing initial learning of more complex tasks (Sappington et al., 1997).

Because horses are so adept at discriminating stimuli, trainers must be specific and consistent with their presentation of cues. If a specific cue is not similar in presentation method and timing each time it is used, the horse must generalize (respond to a stimulus that approximates the original discriminative stimulus) to continue responding to the cue. Horses learn to generalize readily to tactile (Dougherty and Lewis, 1993) and visual stimuli (Dougherty and Lewis, 1991). However, continued generalization to nonspecific stimuli can result in a horse which needs stronger and more obvious stimuli to perform at its initial level of responsiveness.

Responses

Once the horse has responded to a stimulus, the trainer must be able to recognize that the horse has made the correct response, or at least an approximation of the correct response. It is important to realize that all major maneuvers performed by horses are just chains of small responses connected together. For example, a major maneuver such as a rollback is learned in small segments. First the horse learns to bend the body, then shift its weight to its hindquarters, then cross over the front legs, etc. A successful trainer must be able to break up major maneuvers into these small parts and must successively teach the horse each small response before connecting the responses together. By shaping the horse's behavior one response at a time, trainers can have the horse performing major maneuvers correctly with minimal training sessions.

Reinforcements

Reinforcements are the glue that connects a specific stimulus to a certain response. Correct timing of reinforcements is essential to successful training. To make a good association the reinforcement must closely follow the response in time. All reinforcements should be given immediately after the horse gives the desired response. Also reinforcements must be contingent upon the correct response to be effective, e.g. reinforcements should not be given in the absence of any appropriate response.

Trainers must decide what the correct response is and reinforce the horse only when that response is given. However, it should be remembered that the response does not have to be a finished major maneuver before it is reinforced.

It is recommended that horse trainers reinforce every correct response when the horse initially is learning a new response. However, horses will respond to various fixed ratio (reinforcement delivered after a fixed number of correct responses) and fixed interval (reinforcement delivered after a fixed amount of time regardless of the number of correct responses) reinforcement schedules with stable rates of responses which resemble those of other animals under similar reinforcement schedules (Myers and Mesker, 1960). These reinforcement schedules produce scalloped response patterns in which the horse responds at a higher rate as reinforcement delivery approaches. Because trainers want horses to consistently respond to each stimulus presentation, horses should be put on an intermittent schedule of reinforcement delivery after the response acquisition phase. Animals work harder to obtain reinforcements when the reinforcement is not on a predictable or continuous schedule.

Reinforcers in horse training can be classified in the broad categories of positive (giving the horse sometime it likes) or negative (removing something the horse does not like). Both of these reinforcement situations have the same end result - increasing the probability that a specific stimulus will produce a specific response in the horse. Most horse trainers utilize a combination of positive and negative reinforcements, and equine learning abilities are similar under both types of reinforcers (Haag et al., 1980). Trainers also utilize secondary (learned) reinforcements in horse training. Examples of positive, secondary reinforcers are a pat on the neck or verbal phrase. Although horses seem to respond to secondary reinforcers in training situations, McCall and Burgin (1997) could not demonstrate experimentally that a secondary reinforcer (buzzer) can prolong the expression of a learned response in the absence of a primary reinforcer (food). However, it did appear that the secondary reinforcer might facilitate learning a new task.

Other Factors Influencing Learning

Miscellaneous factors can influence the effectiveness of the stimulus-response-reinforcement chain in the horse. Amount of handling received by the horse prior to the learning test may influence the horse's learning performance. Heird et al. (1986) reported that horses receiving handling early in life perform better on later learning tests than horses with little handling. In contrast, Mal et al. (1994) could not show that preweaning handling of foals influenced their learning ability or manageability after weaning. Variations in results from these studies implies there may be a critical handling period for horses, which probably occurs during the first 42 days of life (Mal and McCall, 1996).

Temporal distribution of learning sessions influences equine learning ability, with fewer learning sessions per week resulting in more efficient learning (Rubin et al., 1980). However, during each learning session there must be enough learning trials (repetitions) for the horse to learn the task (McCall et al., 1993). So even though learning efficiency in horses is decreased when the same task is worked on every training session, there must be a moderate repetition of training trials on the days the task is presented for efficient learning to occur.

Many trainers assume that horses can learn habits from each other. However, published studies (Baer et al.,1983; Baker and

Crawford, 1986) have indicated that horses do not learn readily by observing another horse perform a task. Clarke et al. (1996) did report that observer horses approached a feed area and ate significantly faster on their first trial than control horses after watching an trained horse demonstrate a discrimination task, however they also reported that the observer horses were no more likely to select the demonstrated bucket than control horses.

Horses have good memories and can form a general solution to a discrimination problem that makes subsequent problems easier to solve (Dixon, 1970). Some (but not all) horses form and use a concept (e.g. a triangular shape is correct in a pair of visual patterns) in solving discrimination problems (Sappington and Goldman,1994).

Implications

The recent research in equine learning abilities indicates that horses have good discriminative ability, respond to a wide variety of stimuli, and can form general solutions to learning problems. Horses respond well to both positive and negative reinforcers and can learn under a variety of reinforcement schedules. However, horses which excel in experimental learning tasks may not necessarily be good at performance tasks. This may be due to differing stimuli utilized in the tasks, differing complexities of the tasks, differing reinforcers and the additional influences of human interaction and equine athletic ability in performance tasks.

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IMPORTANT LESSONS FROM FREE-RUNNING EQUIDS

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The behavior of equids at liberty, either in pastures or under semi-wild conditions, can raise provocative questions and teach us a great deal about reproduction in our domestic horses. This presentation proposes examples of important lessons learned from critically comparing the behavior of free-running equids with the behavior and problem behavior of horses in more closely managed or confined domestic conditions. The lessons in some cases suggest changes in reproductive management of horses from currently accepted practice in some parts of the world. Application of the concepts will likely save time, effort, and money, and can rescue the breeding career of certain individual animals.

The harem stallion and his mares interact almost continuously. Mares and stallions at liberty that eventually breed interact almost continually throughout the cycle of the mare. The mare is a far more important player in mate location and stimulation of the male than we have assumed in domestic breeding programs.

The stallion rarely has to "dismount" as we know it in hand-breeding. At liberty, in the moments immediately following ejaculation, the stallion need only relax on the back of the mare. The mare then typically steps forward, easing the stallion's chest down over her hind quarters. In contrast, hte hand-bred stallion is typically required to lift himself up while backs off the mare or dummy mount. Some stallion handlers tend to rush the stallion to dismount immediately after ejaculation, before the horse has a chance to collect himself. For some stallions, particularly old or lame stallions, this dismounting represents an apparently aversive or difficult experience. Ejaculatory failure sometime ensues, possibly in association with anticipation of dismount.

At liberty stallions breed and breed and breed. Most stallions exhibit greater sexual endurance and fertility at liberty than when hand-bred. Stallions at pasture breed as often as every 1 to 2 hours day and night, with good fertility. In contrast, for many hand-bred stallions both sexual interest and fertility diminish with schedules exceeding one or two covers per day.

There are harem stallions and there are bachelor stallions. In all equid breeding systems, some stallions gain access to a harem and some remain "bachelors". We now know that harem status imparts an upgrading of reproductive function, including changes in hormone levels, sexual and aggresive behavior, accessory sex gland size, testicular size, and semen quality. Bachelor status imparts changes in the opposite direction. Domestic housinf may impose bachelor social status on breeding stallions. Stallions kept in barns with other stallions appear to have suppressed reproductive function compared to those kept as the only stallion in a barn with mares.

Spontaneous erection and "masturbation" are normal and maybe necessary. Free-running equid stallions, regardless of age, (newborn to aged), bachelor or harem status, or species, exhibit spontaneous erections and penile movements at the rate of about one episode every ninety minutes. The rate is the same for domestic stallions, regardless of the type of breed , type and level of work, housing arrangement, breeding status, androgen levels, libido, or fertility. This appears to be a normal and probably necessary behavior, that becomes problematic only when people try to stop it.

Donkeys are not horses. There are at least two distinct types of equid social organization. Domestic horses, Przewalski wild horses, and some zebra breed in harem groups of one stallion to several mares. In contrast, domestic donkeys, most wild asses, and some zebra are territorial breeders, a system in which each breeding male guards a territory and thereby has breeding access to the females passing or residing within the territory. There are notable differences in mate location and precopulatory behavior between horses and donkeys reflecting harem and territorial and harem type social organization. For example, jennes in estrus form a sexually active group which lingers a short distance from the jack. These jennes, like cows, tease and mount one another. This activity appears to stimualte the interest and sexual response of the jack. The jack doesn't herd and guard the jennes as a horse stallion does, but rather stands off in seemingly disinterested manner waiting for the sexually active group to approach. In contrast to stallions, jacks achieve erection at a distance from the jennes, often in association with a rolling and marking sequence and while gazing away from the jennes. Approach and mount immediately follows erection. Actual copulatory behavior including insertion latency, number of thrusts, and total time mounted is similar between horses and donkeys (and all equids).

STEREOTYPIES IN HORSES

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Introduction

Stereotypies remain one of the most perplexing animal behavior problems. Most of our understanding and clinical approach hasn't improved for decades. Current increased attention to stereotypies in human mental illness, in production animal species, and as a general animal welfare issue is beginning to "stir the pot" at least. There are some interesting new findings and issues.

Definition

Stereotypies are repetitive, highly stylized, seemingly functionless motor responses and sequences. They occur in all captive wild and domestic species. In humans, stereotypies occur in normal as well as psychopathological states. They are a key component of autism, Tourette's Syndrome, Lesh Nyan Syndrome, and obsessive-compulsive disorder. The classic equine stereotypies are listed in Table 1. In addition, horses can develop a wide variety of other stereotypical movements. Stereotypies are sometimes included in the category of misbehaviors called "stable vices," which also includes other annoying habits such as wood-chewing, water-tipping, blanket pulling, or resistance to being caught. The term stable vices has fallen out of favor, particularly for stereotypies, because of the connotation of intent.

It is important to recognize that pawing, circling, flank nipping, kicking, head tossing, and other movements are common during acute stress or pain. If pain or stress is resolved quickly, these movements do not usually become a long-term stereotypy.

Prevalence

Estimates of the prevalence of stereotypies among domestic horses have ranged considerably, from as low as 1% to as high as 26%. Considerable variation among subpopulations of domestic horses is well recognized. In captive wild equids, the incidence of stereotypies is much higher (greater than 40% of animals). The severity of stereotypy varies considerably among animals and within an individual over time.

Current Understanding of Etiology

It is not clear whether stereotypies should be viewed as abnormal behavior, misbehavior, or whether they represent a normal "coping" behavior which reduces stress. There also remains considerable controversy about the factors involved in stereotypies in horses as well as in other species. Management conditions (housing, social, exercise, nutrition) and genetic predisposition are considered important factors. The view that all stereotypies are abnormal and the result of boredom or frustration of stable life

is now known to be too narrow. Certainly there can be medical causes, yet for a large percentage of the cases one cannot be identified. In many of these the behavior may appear genuine, as opposed to a simple attention getting or "boredom" activity. In some individuals, no matter what the root cause, the stereotypy clearly appears exacerbated by social, nutrition, and exercise factors.

Table 1 Equine Stereotypies

Oral
Cribbing
Tongue movements
Lip movements
Locomotor
Head movements (bobbing, tossing, shaking, swinging, nodding)
Throat rubbing
Pacing
Weaving
Fence or box walking
Circling
Stomping, kicking
Pawing, digging
Self-mutilation
Self-biting (flank, chest, shoulder)
Wall-kicking
Lungeing into objects

Several laboratories have confirmed that endogenous opiates rise during the performance of a stereotypy in horses. In horses that perform a stereotypy in the absence of an obvious physical, medical, or apparent environmental cause, the assumption is made that the behavior likely initially had a tangible cause, but has now become a habit maintained by the reward of opiate release.

The trend in clinical veterinary behavior has been to call stereotypies "obsessive-compulsive disorder." This label implies a much more complex cognitive component to stereotypies than we can assume is the case with animals.

A consistent observation is that some horses appear much more likely to perform a stereotypy than others, and that the predisposition may run in families. Marsden and coworkers in Edinburgh (1) recently surveyed the history of stereotypies among captive Przewalski horses for which breeding histories are well documented. They concluded that genetics is an important factor.

Evaluation and Treatment Approaches

Key traditional methods for treating stereotypies include physical and social environmental manipulation, nutritional changes, physical restraint, and aversive conditioning. These have been reviewed in detail elsewhere (2). Pharmacologic aids which in some cases have appeared helpful include long-acting tranquilizers and serotonin enhancing agents (tricyclic anti-depressants, l-tryptophan).

Acupuncture and acupressure methods are under development for treatment of behavioral problems in horses. Auriculotherapy in the form of acupuncture, acupressure, or surgical stapling of the ears is now a popular treatment option for cribbing. The same procedures that are used to relieve estrus cycle and ovarian problems are used for stereotypies (3). In a limited number of cases, the long-term outcome has *not* been satisfactory

Treatment of equine stereotypies is also becoming quite a controversial topic. If a stereotypy is a normal coping mechanism, should you try to eliminate it in any way other than eliminating the cause? So anti-cribbing surgery,

aversive conditioning, physical restraint and pharmacologic treatments are being seriously questioned, particularly in some parts of the world. Systematic behavior evaluation including detailed study of 24-hour videotaped samples of the horse's behavior can usually provide considerable information about the possible causes and exacerbating factors that can lead to a individualized management and treatment program.

Recent Findings

Photic headshaking. Madigan and coworkers in California (4) have found that some headshaking in horses appears to be light-or sound-induced trigeminal-mediated nasal irritation similar to the photic sneeze syndrome in humans. The type of headshaking in such cases is a more violent and irregular, snorting toss, compared to the more rhythmic traditional head bobbing or nodding seen as a classic stereotypy. The horse may appear to be trying to scratch its nose on a foreleg or even on the ground as it snorts, even going along at a trot or canter. This form of headshaking almost always worsens under work, and immediately subsides as the animal is returned to the barn or rest, so is easily misinterpreted as a purely behavioral problem. In most cases, photic headshaking is seasonal, and will stop immediately when the eyes are covered or the area is darkened. Dark goggles or sun-blocking face masks may be all that is needed for some individuals. Cyproheptadene (0.3 mg/kg b.i.d. orally) can effectively relieve most cases.

Cribbers don't swallow the air. McGreevy and coworkers in Bristol, England (5), have used endoscopy and fluoroscopy to evaluate the process of cribbing. They concluded that cribbers don't actually swallow air to the stomach. Rather a bolus of air is formed in the esophagus and then expelled. The characteristic grunt occurs as incoming air passes through the cricopharynx.

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EVALUATION AND COMPARISON OF REACTIVITY TESTS IN HORSES

C.A. McCall and S. Hall

SUMMARY

Four methods of ranking horses on reactivity were evaluated and compared: the isolation stall (IS), novel stimulus (NS) and runway (RW) tests, and subjective emotionality scores (SE). Forty horses performed each test daily on three different days in a switchback design and were randomly assigned a daily test sequence which was maintained throughout the study. Horses also were randomly assigned to either drug-vehicle-drug or vehicle-drug-vehicle treatment with injections of tranquilizer or vehicle on corresponding days. In all tests heart rates were recorded and behavior was videotaped. To be a valid test of reactivity, at least one heart rate and one behavioral measurement in the test had to show a significant difference due to tranquilization, and behavioral measures had to be displayed in at least 75% of the trials. No significant differences in heart rate values were detected in the RW test, and it was rejected as a valid test of reactivity. Both NS and IS were valid tests. The NS test showed higher correlations between heart rates and behavioral variables than the IS and therefore was considered more accurate. The SE scores were moderately correlated ($r_s < .47$) with variables from the NS and IS tests. The NS test was the most accurate method tested for measuring reactivity in horses. Combining physiological and behavioral measurements or using more than one behavioral measurement in reactivity tests may better reflect the reactivity of the horse than a single behavioral measurement.

Introduction

Reactivity, or emotionality, in the horse has been correlated to equine learning abilities (Fiske and Potter, 1979: Heird et al., 1981; Mal et al., 1994) and used to assess effects of nutritional supplements on equine behavior (Bagshaw et al., 1994 and Holland et al., 1996). Various methods of assessing reactivity in horses have been utilized in these studies, but none have been validated to determine if they accurately reflect reactivity. Also there is little continuity among these reports. For example, even though two research reports utilize a particular reactivity test, the researchers may be measuring different variables within this test.

Reactivity in horses has both behavioral (fright and escape responses, vocalizations, defecations, etc.) and physiological components (changes in heart rate, blood pressure, hormones, respiration rate, etc.). In an accurate test of emotionality, the behavioral responses utilized to assess reactivity should be observable in the majority of the animals and should correspond to physiological changes in the animal. Also, an accurate test should show a reduction in behavioral and physiological responses of the horse when the horse is tranquilized with a drug which depresses the central nervous system.

This study was developed to identify a test which would quantitatively and objectively measure reactivity in horses. The commonly utilized methods of assessing reactivity in horses (IS, NS and SE) and one new test developed for use in this study (RW) were evaluated and compared.

Procedures

Forty horses of various ages, sexes and breeds were used in this study. Before the study, each horse was assigned a SE score by two independent observers who were familiar with the horses and blind to treatment. Emotionality scores ranged from: 1 (bold and calm) to 5 (very shy and reactive). The final SE score for each horse was the average of the scores from the two observers.

Each horse performed three different tests (the NS, IS and RW) on each of three test days. Horses were randomly assigned a daily test order and remained on the same test order on all three test days. Each horse was randomly assigned to one of two treatment sequences: 1) drug-vehicle-drug or 2) vehicle-drug-vehicle, and received 2 mg/100 lb body weight intramuscularly of either the drug, acepromazine maleate, or .9% saline solution accordingly on the test days. Test days were separated by at least 3 days to allow complete clearance of the drug from the horse's body between test days, and horses were given a 30 minute washout period between tests to reduce possible effects of one test on the next. The horses' heart rates were recorded at 5 sec intervals in each test, and minimum, maximum, mean, range and mode (most common) heart rates were calculated. Behavior was videotaped in each test, and number of steps at each gait, number and type of vocalizations, incidences of defecating, urinating, bucking, rearing and pawing were calculated.

A rectangular pen measuring 62 by 47 feet was used in the NS test. A bright blue and orange plastic child's tricycle served as the novel stimulus. During testing horses were released into the pen and behavior and heart rate was recorded for 15 minutes.

A 12 by 12 foot stall with solid wood walls 8 feet high was used in the IS test. During testing the behavior and heart rates of the horse in the stall were recorded for 15 minutes.

The RW test took place in a runway measuring 143 by 12 feet. All horses were trained to negotiate the runway to reach food and herd mates prior to testing and traveled through the runway consistently without a human handler. During testing a blue plastic tarp which covered the width of the runway was placed on the ground 27 feet from the finish area of the runway. Heart rate and behavior were recorded.

The effect of the tranquilizer on the heart rate and behavioral variables was analyzed in a switchback design as described by Sanders and Gaynor (1987), and significant differences ($P < .05$) in behavior and heart rate variables during tranquilized and non-tranquilized tests were the criteria for a test to be considered a valid test for reactivity. Spearman's rank correlation coefficients (Daniel, 1978) were used to evaluate relationships among heart rate and behavioral variables within and between tests.

Results and Discussion

In the IS test, tranquilization decreased ($P < .01$) the mean, minimum and modal heart rates of the horses, and these values were all highly correlated ($r_s > .72$, $P < .01$) indicating that any one value would rank the horses similarly in the IS. Because the mean heart rate had the highest correlation with the other heart rate measurements, it was selected as the most informative heart rate value for this test. Behavioral variables in the IS test that changed during tranquilization were frequency of urination, defecation, snorting, calling and head tossing ($P < .05$). However, urination, calling and head tossing were of little value in ranking the horses' reactiveness because they were displayed by only a few horses in the study.

Defecation was observed in 75% of the IS trials and occurred less frequently ($P < .05$) in tranquilized horses. Therefore defecation rate was the behavioral variable considered the most indicative of reactivity in the IS test. Because defecation rate is increased in stressful situations in horses (Waring, 1983) and rats (Candland et al., 1967) and is decreased when the animal's sympathetic nervous system is depressed with acepromazine, this variable seems like a valid indication of reactivity. A high correlation ($r_s = .55$, $P < .01$) between defecation frequency and mean heart rate in the IS test further confirmed that the behavioral and heart rate variables ranked the horses similarly. The IS test fit the requirements for a valid test of reactivity in horses, and results indicate that mean heart rate and defecation rate are informative variables to measure during this test.

The NS test also was a valid test of reactivity in horses. Heart rate measurements in the NS test were sensitive to tranquilization effects with the maximum, range and mean heart rates decreased ($P < .01$) in tranquilized horses. These heart rate measures were highly correlated ($r_s > .67$, $P < .01$) indicating that any one value would rank the horses similarly. As in the IS test, the mean heart rate was chosen as the most accurate ranking tool because it had the highest correlations with the other heart rate values. Walking, calling and trotting were decreased ($P < .05$) in tranquilized horses, however calling and trotting were not exhibited in a large percentage of trials. Walking was exhibited in all trials and was highly correlated to mean heart rate ($r_s = .66$, $P < .01$). A higher heart rate would be expected with either increased activity or increased reactivity. However, because flight is a major component of a horse's usual reaction to frightening stimuli, it is not really necessary to separate these two variables.

The RW test did not detect any significant differences in heart rate variables between tranquilized and normal horses. Additionally the two behavioral components which were significantly different in tranquilized and non-tranquilized horses, number of trot steps and number of snorts, only occurred in 29.4% and 52.1% of the trials, respectively. Consequently it was determined that the RW test was not a valid test of reactivity in these horses.

The SE scores assigned to each horse varied from 1 to 3.5. This method of evaluating reactivity was moderately correlated to mean heart rates in the IS and NS tests ($r_s = .33$ and .40 respectively, $P < .05$). The SE score was moderately correlated to the walk in the NS test ($r_s = .47$, $P < .05$) but not to defecation frequency in the IS test ($r_s = .26$, $P > .10$). These data indicate that experienced horsemen were only moderately successful in predicting reactivity, as expressed by both behavioral and physiological changes, in the horses in this study. Because of its subjective nature, the SE scoring system requires that the scorer be blind to treatment, familiar with the horses used in the experiment and impartial to factors such as utilization, breed or pedigree of the horse for accurate assignment. An additional problem with this method is that there is no standard SE scoring system for horses. Each researcher usually develops his own scoring criteria.

The IS and NS tests determine reactivity based on more quantitative information than SE scores and based on these data would give a more accurate evaluation of the reactivity of the horse than SE scores. Mean heart rate measurements were highly correlated ($r_s = .79$, $P < .01$) between IS and NS tests, meaning the same horses had high heart rates on both tests. However the behavioral measures, defecation in the IS and walking in the NS test, were not

highly correlated (r_s = .27, P<.10), suggesting these behavioral variables may be measuring different aspects of reactivity. Although both the IS and NS test isolate the horse from its herd mates, the degree of isolation is different. In the IS the horse cannot see out of the stall, while in the NS test horses could see distant herd mates. Additionally there is a novel stimulus to occupy the horse's attention in the NS test, and the horse has more freedom to move because the test area is larger. The IS test may be indicative of reactivity due to confinement and isolation, while the NS test results are based on reaction to confinement, isolation and a novel stimulus. How each of these contributes to the total arousal of the horse is difficult to determine and probably varies among horses. However, training and handling situations often involve novel stimuli so the NS test may more accurately reflect the horse's reactivity when it is not in the test environment.

Implications

Based on the correlation between the SE scores and behavioral and physiological variables used in this study, SE scores are not good predictors of reactivity in horses. Both the NS and the IS tests were objective tests of reactivity. The physiological measurement used in these tests ranked horses similarly in both tests and correlated well with the significant behavioral measurement in each individual test. However, the behavioral measurements alone did not rank the horses similarly on these tests. This indicates that the behavioral measurements used for the IS and NS tests in this study may not be an accurate representation of the true reactivity of the horse. Combining behavioral and physiological data or using more than one behavioral measure in reactivity tests may better reflect the reactivity of the horse than using a single behavioral measurement.

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TEACHING YOUR HORSE TO LOVE VETERINARY PROCEDURES

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Many of the every day minor, though frustrating, "behavior problems" of horses with their veterinarian can be inexpensively and quickly eliminated with simple behavior modification. With minimal knowledge and experience the you can correct almost any of the many simple aversions to veterinary procedures. You can also effectively teach your horse to enjoy almost any routine veterinary procedure, including injections, nasogastric tubing, or manipulation of any body part including ears, eyes, legs, nose, mouth, or genitals.

Consistent application of simple behavior modification principles invariably produces positive results. Most amazing is how little time it actually takes to get your horse to appear to enjoy these procedures. The principles are the same that work in Skinner boxes with rats, with our kids, with a circus elephant, with our pet dogs, or with our horses for other types of training. There are some species specific techniques that take advantage of varying innate behavioral characteristics, size, and domestic behavioral expectations. These general principles and equine specific techniques can be effectively applied by just about anyone competent to care for a horse.

There are some "tricks" to getting people to actually do what they need to do. The horse behavior fad of the moment is the "horse whisperer" or super guru horse trainer. What these people actually do from the horse's perspective is remarkably the same—they apply the principles of behavior modification. Often the equine specific techniques are also very similar. Where the various guru trainers differ is in the explanation given to owners of how and why their method work, and in specific tricks to get people to actually comply with their particular method.

The Simple Principles and General Procedures

Gaining compliance with a non-painful procedure. Probably the most common theme to behavior problems with horses is non-compliance with a necessary procedure--injections, worming, picking up feet, handling ears or mouth, washing the penis before breeding, etc. All horses can learn to tolerate and even to "enjoy" just about any normal non-painful veterinary, grooming, or handling procedure. For gaining compliance with any procedure or manipulation, there are three basic concepts for the horse to grasp:

1. The procedure doesn't really hurt (that much).
2. Tolerance of the manipulation can actually lead to a reward.
3. No ordinary resistance or reaction will stop the procedure.

To get these concepts across to the horse, the procedure (or successive tolerable approximations of the procedure) is patiently repeated under as completely calm and positive conditions as can be creatively designed. Initially each increment in compliance is rewarded. Any decrements are **not** punished. (Strong voice tones, over-restraint, or explosive wrecks can represent inadvertent punishment sending the message that this really is a nasty procedure.)

Should you use a twitch?

A twitch applies pressure to the sensitive nerve endings in the nose. This inflicts pain, which initially distracts the horse from either noticing or responding to an unpleasant procedure. It usually particularly inhibits movement and kicking. That's why it is used often used to restrain mares for breeding. The pain causes a release of natural analgesic chemicals in the brain, known as endogenous opiates or endorphins, which then likely mask both the pain at the nose and any discomfort elsewhere. You will see that after a few minutes the horse may get a droopy lip and drowsy, glazed looking eyes. This drowsyness corresponds to high levels of endorphins in the blood. After about 10-15 minutes on the twitch, most horses become agitated. Some seem to explode or "blow the twitch." This behavior corresponds to lowering blood levels of endorphins, perhaps because the brain has temporarily depleted its supply.

Some horses seem to get to dislike the twitch, while others don't. This may be related to whether or not the twitch was removed during the relaxed drowsy (positive) state or whether they reached the obviously unpleasant point of "blowing the twitch."

So for mildly painful, brief procedures, a twitch will give your veterinarian some added security. Just as for any other procedure, you may want to accustom your horse to the twitch in practice sessions. These sessions will allow you to more effectively learn how to apply the twitch smoothly, as well as to learn your horse's typical behavioral response and the duration of twitch tolerance. Practice sessions will allow you and horse to remain calm and unhurried, which will maximize the possibility that it becomes a tolerable emergency procedure.

GERIATRIC NUTRITION IN THE DOG

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SUMMARY

Canine aging is characterized by progressive and probably irreversible changes in multiple body systems. Decreased metabolic rate and inactivity which typically occur result in decreased maintenance energy requirements. Commercially prepared geriatric diets contain reduced calories for prevention of obesity. These diets are also low in protein for prevention of renal dysfunction. However, little information is available concerning the protein requirement of geriatric dogs. Some research has suggested that geriatric dogs require 50% more protein than younger adult dogs. To further study dietary protein needs in geriatric dogs, 36 geriatric and young-adult dogs were fed diets containing 16, 24, or 32% protein. Whole-body protein turnover increased as dietary protein intake increased. However, N balance was not different regardless of protein intake. Excess dietary protein had no adverse effect on kidney function. Results of this study indicated that a 16% protein diet was adequate for maintaining N balance in these dogs. While excess protein did not affect renal function, additional protein may not be needed in geriatric canine diets. Nutritional management for geriatric dogs should include individual animal assessment before making specific dietary recommendations.

Introduction

Over 40% of dogs in the United States are 6 or more years of age, and approximately one-third of these dogs are eleven years of age or older. While many pets remain healthy and youthful well into their teen years, most dogs begin to slow down and show signs of aging as early as 5 to 6 years of age (LaFlamme, 1997). Aging dogs are considered classified as "geriatric" when they have reached the last 25% of their expected life span. This age classification is related to size or breed, as well as the care received during the dog's lifetime. Small breed dogs are considered to be geriatric when they reach the age of 12 years, while medium breed dogs are classed as geriatric when they reach at 10 years of age. Large and giant breed dogs are considered geriatric at the ages of 9 and 7 years, respectively (Anonymous, 1997).

Aging dogs seldom have single body system disorders. Rather, canine aging is characterized by progressive and possibly irreversible changes of multiple body systems, including the skin and hair coat, and the cardiovascular, respiratory, digestive, urinary, and musculoskeletal systems (Hoskins, 1996; Goldston, 1989). Some of the signs of aging include: decreased metabolic rate, lack of activity, increased body fat, dull and lusterless hair coat, decreased muscle, bone, and cartilage mass, periodontal disease resulting in bad breath and tooth loss, decreased saliva production, reduced gastrointestinal motility, decreased pancreatic enzyme secretion, and decreased kidney weight and glomerular filtration weight (Mosier, 1989).

Aging is an extension of the physiologic state known as adult maintenance (Sheffy et al., 1985). While geriatric dogs need the same nutrients as in earlier life, the quantities of these

nutrients per unit of metabolic body size may differ, and feeding management to deliver these nutrients may need to be changed (Hoskins, 1996). Several factors must be considered in the feeding management of geriatric dogs. The decreased metabolic rate, combined with reduced physical activity that typically occurs in older dogs, results in a lower caloric requirement for these dogs. Additionally, canine geriatric diets should be highly palatable and digestible due to changes in smell, taste, teeth, and digestive system function. An adequate intake of unsaturated fatty acids and zinc are important for ensuring proper skin health and hair coat. Finally, increasing the fiber in the geriatric dog's diet is recommended to aid caloric restriction and also to enhance intestinal function (Hoskins, 1996).

Maintenance energy requirements (MERs) are the energy needs required for the normal healthy animal to survive with minimal activity. Individual MERs, especially in inactive animals, are controlled by the basal metabolic rate, which varies depending on the genetic potential, health status, and whether the animal is sexually active or neutered (LaFlamme, 1997). The decreased metabolic rate and increased inactivity of geriatric dogs results in reduced MERs which may lead to obesity if not compensated for dietarily (Markham and Hodgkins, 1989). Therefore, canine geriatric diets contain reduced amounts of dietary fat and calories and may have added dietary fiber to further restrict calories. While obesity can be a problem, a large number of geriatric dogs remain highly active and are underweight. Feeding management of the geriatric dog will vary depending upon the condition of the individual dog, and it is important to individually assess these dogs to determine their nutritional needs.

In addition to energy needs, protein requirements are another concern in dietary recommendations for geriatric dogs. This aspect of canine geriatric nutritional management has been a much debated topic in recent years. Although little information is available concerning the dietary protein requirements of geriatric dogs, veterinarians have historically recommended low protein diets for their canine geriatric patients. Their rationale for using low protein diets in elderly dogs is to preserve renal function and to prevent possible renal problems. It has been presumed that many "well" geriatric dogs have a reduced ability to metabolize and excrete excess dietary protein waste, but the capacity of reduced protein diets to prevent renal failure remains controversial (Markham and Hodgkins, 1989). In fact, it has been shown that excess dietary protein had no effect on renal function in geriatric dogs. In a study conducted with uninephrectomized geriatric dogs fed either a low protein diet (18%) or a high protein diet (34%), renal function was not impaired in the dogs fed the high protein diets (Finco et al., 1989). Some current reviews of geriatric protein needs have emphasized results of a classic study of the protein requirements of old and young dogs (Wannemacher and McCoy, 1966). Results of this study indicated that geriatric dogs require up to 50% more protein than young dogs to maintain nitrogen balance and body protein stores. Even though the protein debate continues, most commercial diets for geriatric dogs are low in protein (16 to 18%).

It is well-established that lean body mass declines with age due to the loss of skeletal muscle protein resulting from decreased muscle protein synthesis. Perhaps the low protein diets currently fed to geriatric dogs may intensify the loss of lean body mass and the aging process. It has been hypothesized that decreased lean body mass in aging individuals is due to a reduction in

growth hormone (GH). It is also known that insulin-like growth factor-I (IGF-I) mediates many of the anabolic effects of GH in various tissues such as muscle and bone (Florini et al., 1996). It has been demonstrated in growing animals that increasing the level of dietary protein increased hepatic IGF-I gene expression and circulating concentrations of IGF-I (Davenport et al., 1995; Hays et al., 1995). The relationships that exist between protein intake, IGF-I, and body composition suggest that increasing the dietary protein intake of geriatric dogs may delay the effects of aging by maintaining lean body mass. Therefore, a study was conducted to assess the effects of increasing levels of dietary protein on endocrine controlled regulation of whole-body protein turnover in geriatric and young-adult dogs (Williams, 1998).

Experimental Procedure

Thirty-six adult female Beagles averaging 2 years of age (young-adult) or over 8 years of age (geriatric) were fed one of three isocaloric diets containing 16, 24, or 32% crude protein (CP). The study consisted of a 2-week cage acclimation period, a 7-week dietary adaptation period, and a 1-week excreta collection period. Venous blood samples were collected prior to daily feeding on days 0 and 28 of the adaptation period and on days 4 and 7 of the collection period for analysis of IGF-I (Davenport et al., 1993) and biochemical profiles (Labcorp, Birmingham, AL).

Nitrogen balance was determined using Kjeldahl N concentrations in feed, feces, and urine samples that were quantitatively collected each day of the collection period. Whole-body N flux was estimated by administering a priming dose of ^{15}N-glycine (250 mg) contained in a gelatin capsule to each dog on day 4 of the collection period. The priming dose was followed by a constant oral administration of ^{15}N-glycine (50 mg) every 4 hours for 48 hours (Picou and Taylor-Roberts, 1969). Enrichment of ^{15}N (atom % excess) in urine samples collected 36 hours after dosing was determined using direct combustion of the sample and mass spectroscopy (Isotope Services, Inc., Los Alamos, NM). Whole-body N flux and rates of protein synthesis and degradation were calculated using urinary enrichment values and N balance (Assimon and Stein, 1992).

Data were analyzed as a 3 x 2 factorial arrangement of treatments using the GLM procedure of SAS (1989). Means were separated using the PDIFF option of the least squares procedure when significance of $P < .10$ was observed. Orthogonal polynomials were used to test for linear and quadratic responses associated with increased levels of dietary protein.

Results and Discussion

Feeding increasing levels of dietary protein to geriatric and young-adult dogs increased nitrogen flux through the metabolic pool (Table 1). Consequently, rates of whole-body protein synthesis and degradation increased with higher levels of dietary protein (Table 1). However, N balance was similar for all dogs regardless of dietary protein intake (Table 1) indicating that the protein requirement of these dogs may not have exceeded 16%.

Reduced protein diets are currently recommended to prevent the onset of renal insufficiency in aging dogs. However, serum and urinary chemical profiles were normal in the geriatric dogs used in this study indicating that increased protein consumption had no adverse effects on renal functionality in these dogs.

Hormone analyses demonstrated that dietary protein had no effect on circulating concentrations of IGF-I in these dogs (Table 2).

Surprisingly, IGF-I concentrations were higher in all geriatric dogs regardless of protein intake. The age-related increase in IGF-I was not expected base on previous research in other animal species. Information on the GH/IGF-I axis in aging dogs is limited. As a result, more research is needed in this area to gain a better understanding of the role of GH and IGF-I during canine aging.

Implications

Physiologic changes associated with canine aging may warrant dietary adjustments. Reduced metabolic rate and decreased physical activity result in the need to reduce the caloric content in the diets of most geriatric dogs in order to prevent obesity. However, not all geriatric dogs are inactive or overweight, so these animals do not need reduced calorie diets. Limited information is available concerning the protein requirement of geriatric dogs. Most commercial geriatric dog foods are low in protein for prevention of renal dysfunction. However, research has shown that excess dietary protein does not adversely affect kidney function. While some research has indicated that older dogs may require higher levels of protein than younger adult dogs, our research indicated that excess dietary protein may not be necessary. Therefore, in making recommendations for geriatric nutritional management, it is important to assess the individual condition of these senior dogs.

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Table 1. Nitrogen balance and whole-body protein turnover in young-adult (YA) and geriatric (G) dogs fed 16, 24, or 32% protein.

	Dietary Protein				Age		
Item	16%	24%	32%	SEM	YA	G	SEM
N BALANCE							
N Intake (g/d)[a]	3.6	5.3	7.5	0.2	5.5	5.4	0.1
N balance (g/d)	-0.4	-0.6	-0.3	0.1	-0.4	-0.4	0.1
WHOLE BODY PROTEIN TURNOVER							
N Flux (g/d)[b]	9.5	13.8	26.1	1.8	15.2	17.5	1.5
CP, g/kg/d							
Synthesis[b]	3.5	4.9	11.4	1.1	6.0	7.3	0.9
Degradation[b]	3.8	5.3	11.6	1.1	6.2	7.6	0.9

[a] Protein: linear, $P < .10$ [b]Protein: quadratic, $P < .10$

Table 2. Endocrine Response of young-adult (YA) and geriatric (G) dogs fed 16, 24, or 32% protein.

	Dietary Protein						
	16%		24%		32%		
	YA	G	YA	G	YA	G	SEM
IGF-I, ng/ml[a]	146.7	241.4	181.2	239.2	176.3	226.7	20.7

[a]Age: $P < .10$

PERFORMANCE NUTRITION FOR THE HUNTING DOG

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SUMMARY

The purpose of this study was to evaluate the effects of dietary fat and physical conditioning on body temperature, olfactory acuity, and body composition of canine athletes subjected to treadmill exercise. Eighteen male English Pointers were allotted to three dietary and two physical conditioning treatment groups to evaluate the effect of level and source of dietary fat on the olfactory acuity of canine athletes subjected to treadmill exercise. Diet groups (6 dogs / diet) consisted of commercially-prepared diets (minimum of 26% crude protein) containing 12% fat as beef tallow (A, 4,085 kcal/kg), 16% fat comprised of 8% beef tallow and 8 % corn oil (B, 4,322 kcal/kg), or 16% fat comprised of 8% beef tallow and 8% coconut oil (C, 4,321 kcal/kg). One-half of the dogs within each dietary group were subjected to treadmill exercise 3 times per week for 30 min (8.05 km/h, 0% grade) for 12 weeks. All dogs were subjected to an exercise stress test (8.05 km/h ,10% slope for 60 minutes) every four weeks beginning at week 0. Olfactory acuity was measured utilizing behavioral olfactometry before and after each physical stress test. Non-conditioned (NON) dogs displayed a greater decrease ($P < .05$) in olfactory acuity, while physically conditioned (EXE) dogs did not show a change from pre-test values. A diet by treatment interaction ($P < .10$) was detected over the course of the study. Additionally, these data indicate that utilization of a moderate physical conditioning program can assist canine athletes in maintaining olfactory acuity during periods of intense exercise.

Introduction

It is well known that diet and exercise affect the general fitness and body composition of various species, including dogs. Research involving the changes in physiological parameters of canine athletes have been limited primarily to Greyhounds that are subjected to a brief, intense period of exercise (Pieschl et al., 1992) or sled dogs subjected to prolonged periods of physical exertion (Hinchcliff et al., 1993; Burr et al., 1996). Metabolic responses are altered in inactive dogs subjected to treadmill exercise (Nazar, et al., 1992; Pohaska, 1979). In addition, Crispin et al. (1992) reported significant differences in plasma lipids and lipoprotein profiles of working border collies compared with non-working border collies. Diet composition may influence the physical performance of the working dog. Ingestion of high fat diets by exercising dogs increased body temperature which may affect their endurance and performance during hot and humid weather (Kaciuba-Uscilko, et al., 1989). However, trained sled dogs utilized dietary fat more efficiently than carbohydrates during prolonged periods of exercise (Reynolds, et al., 1994). Although environmental conditions affect the dog's response to dietary fat, it is not known if the fatty acid composition affects the physiological responses of the canine athlete.

Experimental Procedures

Animals. Eighteen healthy, male pointers (2 to 4 years of age, 23.94 ± 0.54 kg body weight) were selected from performance kennels from across the Southeast region of the United States. All dogs received complete physical examinations by the project clinician and pronounced in normal health prior to entering the study. All dogs successfully completed this study.

Diets and feeding regimes. All dogs were given free access to fresh water and fed a complete and balanced dry diet (Diet A, control) containing a minimum of 26% crude protein and 12% crude fat (comprised of beef tallow), during a four week acclimation period prior to the initiation of the study. Following the initial exercise stress test, dogs were allotted to one of three diet groups (6 dogs / diet group). The diets were formulated based on AAFCO nutrient requirements for adult dogs (1996) and fed as an extruded product manufactured by Ralston-Purina Company, St. Louis, Missouri. Diet B contained a minimum of 26% crude protein and a minimum of 16% crude fat (comprised of 8% beef tallow and 8% corn oil). Diet C contained a minimum of 26% crude protein and a minimum of 16% crude fat (comprised of 8% beef tallow and 8% coconut oil). Diet formalization resulted in diet B containing predominately saturated fatty acids, while diet C contained predominately saturated fatty acids.

Physical Conditioning Program. Dogs from each diet group were allotted to one of two treatment groups (physically conditioned and non-conditioned). Physically conditioned dogs (EXE) were exercised three times weekly on a motorized treadmills (Parker Treadmills, Auburn, AL) at a rate of 8.05 km/h (0% slope) for 30 minutes per day on non-consecutive days. Non-conditioned dogs (NON) were exercised at 8.05 km/h (0% slope) for 10 minutes per day one day per week to ensure familiarity with the treadmill. Duration of the physical conditioning program was 12 weeks. Additionally, all dogs were subjected to an exercise stress test on weeks 0, 4, 8 and 12 of the study. During two-stage test, dogs were initially exercised at a rate of 8.05 km/h (5% slope) for 15 minutes, and then at a rate of 8.05 km/h (10% slope) for 45 minutes. The physical test was concluded at 60 minutes or when the dog refused to continue.

Response Criterion. Olfactory acuity is measured as the lowest concentration of a selected odorant which is detectable by an organism. Olfactory thresholds were determined for all dogs prior to the initiation of this study by behavioral olfactometry, were utilized to determined odorant-detecting thresholds 30 minutes prior to treadmill exercise and 30 minutes post-treadmill exercise. Body temperatures were obtained rectally at initiation and termination of exercise, and immediately following thirty minutes of recovery.

Statistical Analysis. Dogs were allotted randomly to diet and treatment groups in a 3 x 2 factorial arrangement. Data were analyzed by analysis of variance (ANOVA) as a double spit plot over time design. Initial olfactory estimates collected at week 0 were utilized as covariates to assess changes in olfactory acuity during the experimental period. The general linear model (GLM) procedure of SAS (Statistical Analysis Systems Version 6.12, SAS Institute, Cary, NC) was utilized for statistical analyses. Differences among treatment least squares means were separated utilizing the PDIFF option of SAS when protected by a significant ($P < .10$) F-test.

Results

In this experiment, physical conditioning affected olfactory acuity ($P < .05$) with dogs receiving physical conditioning three days per week having greater odorant-detecting

capabilities compared with NON dogs following one hour of physical exertion. NON dogs had a 64% reduction in olfactory acuity following the physical stress test based on pre and post exercise values. In contrast, pre and post-exercise values for EXE dogs were similar ($P > .10$).

TABLE 1. Olfactory acuity of canine athletes pre and post treadmill exercise [1]

Treatment [2]	NON	EXE
No. of dogs	9	9
Pre-stress test	10.7 ± 1.3^{ac}	7.8 ± 1.4^{ac}
Post stress test	3.9 ± 1.4^{bc}	8.1 ± 1.2^{ad}
Percent change (%) [3]	- 64.2 %	***

[1] LSMeans±SEM. Values represent the negative log of the minimum eugenol concentration that elicited a behavioral response.
[2]Treatment: NON, non-conditioned ; EXE, physically conditioned.
[3] Percent change in olfactory acuity between pre-stress test values and post stress test values.
[ab] Indicate differences within treatment group. Means within the same treatment group lacking a common letter differ ($P < .05$)
[cd] Indicate differences within time period. Means within the same time period lacking a common letter differ ($P < .05$)

Body Temperature. Physically conditioned dogs fed diet B had lower ($P < .10$) resting body temperatures compared with non-conditioned dogs fed the same diet and EXE dogs fed diet A and C (Figure 1). Likewise, EXE dogs fed diet B had lower ($P < .10$) mean body temperatures following treadmill exercise compared with all non-conditioned dogs and EXE dogs fed diet A (Figure 1).

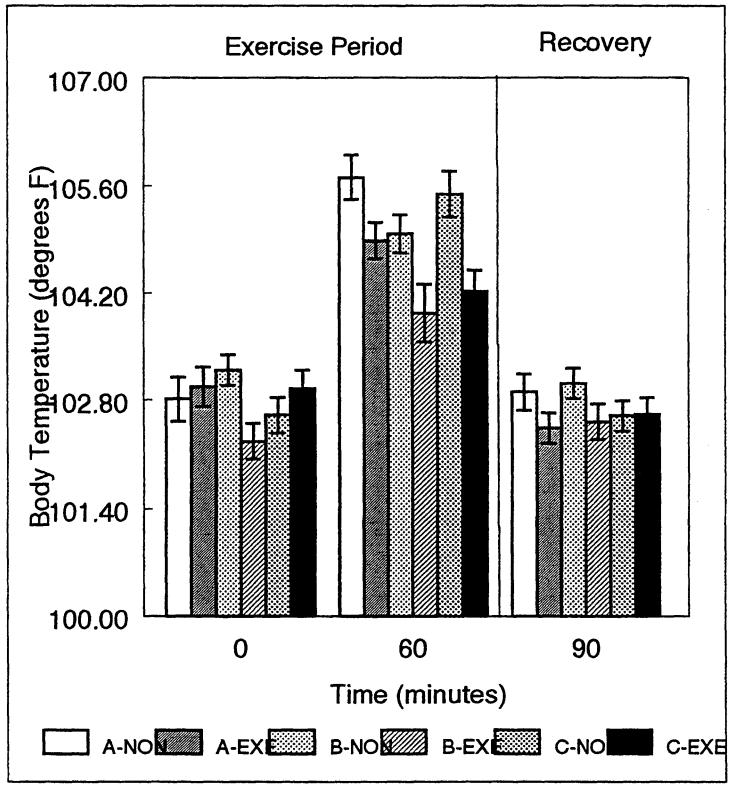

FIGURE 1. Effect of dietary fat level, source, and physical conditioning on body temperatures of canine athletes during treadmill exercise [1,2]

[1] LSMeans±SEM for 3 dogs per diet-treatment combination ($P < .10$)
[2] Diets: Diet A, control containing 12% fat as beef tallow; Diet B, containing 16% fat (8% beef tallow and 8% corn oil); Diet C, containing 16% fat (8% beef tallow and 8% coconut oil)
[3] Treatment: NON, non-conditioned; EXE, physically conditioned
Legend: A-NON, diet A non-conditioned; A-EXE, diet A conditioned; B-NON, diet B non-conditioned; B-EXE, diet B conditioned; C-NON, diet C non-conditioned; and C-EXE, diet C conditioned

Discussion

An athlete is defined as one who is

trained to compete in sports or exercises involving physical strength, speed, or endurance (Bakke, 1993). Certainly, dogs enrolled in a variety of field competitions would meet the present definition of an athlete. Canine athletes are involved in a wide variety of activities and compete under extreme environmental conditions. The sport of field trials is one of the fastest growing outdoor activities in the United States, particularly in the southeast region. However, since the beginning of field competitions, trainers have searched for methods to improve canine performance. Holloway and co-workers (1961) reported 85% of hunting dog owners surveyed indicated some type of olfactory problem. Although the source of these conditions was not determined, olfactory function has always been of primary concern for trainers of canine athletes. Myers and co-workers (1988a, 1988b, 1991b) have documented several conditions which affect the olfactory function of canines. These conditions included canine distemper and parainfluenza viral infections. However, these conditions are not believed to be the cause of impaired olfactory function in this study due to the fact that precautionary physical examinations, an aggressive vaccination program, and baseline olfactory measurements were utilized prior to the initiation of the project.

While some anecdotal evidence exists, these data are the first to indicate a beneficial effect of physical conditioning on the olfactory acuity of canine athletes when subjected to moderate exercise. Behavioral olfactometry measurements revealed canine athletes enrolled in a physical conditioning program were able to maintain a greater olfactory acuity compared with dogs who were not physically conditioned. Non-conditioned dogs displayed a 64.15% decrease in olfactory acuity following treadmill exercise, while EXE dogs showed no significant changes. These data may be explained by increased respiratory function of the dogs during exercise. Dogs that are not physically fit breath more through the mouth during periods of intense exercise as opposed to breathing through the nose when exposed to intense physical exertion. Because of increased heat load during exercise, dogs forces more air through the lungs and out of the mouth. It is highly probable that decreasing the amount of air flow through the nasal passage reduces the amount of odorants passing over the olfactory membranes. This mechanism would substantially reduce the athlete's ability to detect odors. Likewise, increased dehydration of the nasal mucosal layer would contribute to the altered function of the olfactory system. It is highly probable that dehydration of the nasal mucosal membrane would result in decrease enzyme activity and decreased membrane fluidity. These conditions could alter neuro-signal transduction and odorant receptor function in the olfactory mucosal layer, thereby potentially impairing olfactory function in canine athletes. Conversely, a canine athlete in top physical condition would be able to reduce the amount of air breathed through the mouth. Although the complete mechanism for decreased odor detection in non-conditioned canine athletes was not fully defined in this experiment, a combination of decreased air flow across the nasal membranes and decreased hydration status of the mucosal layer may significantly decrease odor detection capabilities in these canine athletes.

Athletic performance can be affected by a host of physiological alterations. Significant changes were detected in several physiological parameters in canine athletes during this study. One of the more important factors during prolonged, submaximal exercise is thermoregulation. An athlete's ability to regulate and dissipate body heat during exercise

is an important consideration, not only for the safety of the athlete, but a major factor in acceptable performance (Fortney, and Vroman, 1985; Naylor, et al., 1993; Kerr, et al., 1983). The ability of canine athletes to thermoregulate in a variety of environmental situations has been reported (Young, et al. 1959; Baker, et al., 1983; Kozlowski, et al., 1980; Baker, et al., 1984). However, these data are the first to illustrate the effects of dietary fat source in combination with physical conditioning on body temperature in canine athletes. Physical conditioning has been reported to be a beneficial factor in improving an athlete's ability to dissipate metabolic heat during exercise (Fortney and Vroman, 1985). In the present study, a differential response to physical conditioning was detected. Physically conditioned dogs fed the low fat diet had increased ($P < .10$) mean rectal temperatures following treadmill exercise compared with EXE dogs fed increased levels of dietary fat. Likewise, non-conditioned dogs fed the predominately saturated diet had higher ($P < .10$) mean body temperatures following exercise compared with conditioned dogs fed the same diet. Although a common belief among field dog trainers indicates increased dietary fat may predispose the canine athlete to heat exhaustion, these data illustrate the contrary. While the complete mechanism(s) for lowered body temperature due to increased dietary fat was not explored in this study, these data suggest a significant benefit to thermoregulation in canine athletes during prolonged, submaximal exercise.

Implications

The present study was designed to evaluate the effects of dietary fat source and physical conditioning on physiological parameters of canine athletes. In summary, physical conditioning of canine athletes prevented a reduction in olfactory acuity following one hour of treadmill exercise. Although further studies are required, these data indicate a beneficial effect of regular physical conditioning for canine athletes who are engaged in activities which require quality odor-detecting capabilities. Physically conditioned dogs fed predominately unsaturated fat had lower resting body temperature compared with non-conditioned dogs fed the same diet. Like wise, physically conditioned dogs fed increased dietary fat had lower body temperatures following treadmill exercise compared with non-conditioned dogs fed the same diet. Therefore, feeding increased dietary fat to canine athletes could provide beneficial effects which could result in enhanced field performance. These factors should be considered when developing a training program for canine athletes.

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WHAT'S DOWN THE DOG FOOD AISLE?

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Introduction

Many professional handlers, with a kennel full of top-rated pointers or retrievers, know the local dog food sales representatives by their first names. However, most dog owners buy their canine companion's food at the local feed store or at a local discount store. Selecting a quality diet can be a bewildering experience, especially if you want a long and healthy life for your dog. How can you be sure you are meeting the dog's dietary needs and getting your money's worth with your current dog food? Much of the information required to answer this question can be found on the bag. However, understanding the information presented can be difficult.

Most bags of dog food have a brightly colored picture on the front and slogans that promise long life and peak performance. The information you, as an informed dog owner, need is generally on the back or side of the bag, often in relatively fine print. Let's start with the feeding chart. Most packages of dog food will have a table showing recommended rates of feeding the product, usually depending on the size of the dog. Size is important because it determines, along with the exercise the dog receives, the energy requirement of the dog. Requirements for other nutrients, such as protein, are generally tied into the need for energy. As body size and activity increase, so does the energy required to maintain the dog's body weight. The tables provide a guide for average rates of feeding. Occasionally, you will find a dog that requires more or less than the recommended amounts. Not all animals are average, but in general, begin feeding the recommended amounts shown on the bag. The feeding recommendations are based on the energy available in that particular product and some adjustment can be made later as you gain experience with that brand of dog food for your dog. Older dogs, that exercise less, can become over-weight, which is why so-called "lite" or older dog formulas are available. Younger dogs that exercise more, will require more food. A greyhound in training can require 20% more food than one kept in a kennel. Sled dogs in a cold environment can require 2 to 4 times more energy than the same dog kept in a warm kennel and receiving limited exercise. The guaranteed analysis of the product displays the guaranteed minimum concentrations of key nutrients in the diet. All states have laws determining the analysis of animal diets. These laws specify which nutrients must be reported on the label. Crude protein, crude fat, crude fiber, and percent moisture are always reported, with the content of some minerals, such as calcium, often listed as well. Let's examine the components of the guaranteed analysis in turn.

Nutrients

Crude protein. Crude protein is the nitrogen content of the diet, multiplied by a factor of 6.25, which is the average nitrogen content of protein. Crude protein expresses a "protein equivalent", but some small part of the nitrogen in the feed will not be in protein. This

is called non-protein nitrogen. Ruminants, such as cows and sheep, can utilize non-protein nitrogen via the action of the microorganisms in their large multi-chambered stomachs. Animals with simple stomachs, such as dogs, can not use this non-protein nitrogen to the same extent. What will be reported in the analysis is a guaranteed minimum crude protein content, showing the lowest amount of crude protein allowed in the product. Higher quality dog foods will contain lower amounts of non-protein nitrogen and higher concentrations of usable proteins sources. The National Research Council, which specifies nutrient requirements for animals, specifies a minimum of 10.5 % of the diet dry matter as true protein. The amount in any specific dog food required for health will vary depending on its ingredients. Most exceed 10.5 % crude protein by a good margin. Requirements for performance dogs are not well characterized, however limited research indicates a minimum of 25% crude protein from meat based sources.

Crude fiber. Crude fiber is an estimate of the insoluble carbohydrate portion of the diet. Crude fiber is generally comprised of plant material containing cellulose, a carbohydrate, and is measured by boiling the feedstuffs in a weak acid and a weak base. What is left is crude fiber and is comprised of various forms of cellulose and associated compounds. Cellulose is not digestible by simple-stomached animals in a manner that provides any nutritional value. Higher crude fiber can be an indication of less expensive ingredients in the product. Some fiber is needed, however, for the production of firm stools and efficient movement of material through the digestive tract. Higher fiber is usually found in dog foods which are formulated for older dogs or dogs suffering from obesity. Fiber is utilized to dilute the nutrients in the product and reduce the amount of energy available per pound of food. Dietary requirements for crude fiber is generally 4 % on a dry matter basis. Dietary fiber plays an important role in maintaining body weight, health, and normal stool production.

Water. Moisture is the amount of water contained in the diet. Dry dog foods will usually contain 10 % to 12 % water. Moist dog foods will contain 25 % to 30 % water, and canned foods approximately 75 % water. Remember, the dog needs the nutrients contained in the dry matter, therefore price comparisons should take moisture content into account. However, palatability and the need for refrigeration also come into consideration. Dog foods with a higher water content are often more palatable, and can be appealing to dogs with dental problems and to owners that prefer the "rich, meaty appearance".

Crude fat. Crude fat is measured by dissolving the fats out of the feedstuffs with a solvent such as ether. Anything that dissolves in ether is included in the crude fat, including waxes from plant materials that have little nutritional value to your dog. Dry dog foods for adult dogs will contain from 5 % to 12 % crude fat, with 5% listed by NRC as the minimum fat, not crude fat, requirement. True fat content will be closer to crude fat content in foods with a higher proportion of animal products in the formulation. Fat increases palatability. Certain unsaturated fats are required for healthy hair coat and a variety of body functions. Fats can also become rancid, and reduce palatability if the product is stored improperly or for an extended period of time.

AAFCO Statement

Listed on the bag is the statement of nutritional value. This statement will say something to the effect of "Following AAFCO procedures, it has been determined that the

product in this bag provides a normal healthy life for dogs consuming it on a regular basis". AAFCO is the (Association of American Feed Control Officers) group that regulates the labels on animal feeds. Dog food companies regularly feed their products to dogs on a long-term basis, following AAFCO procedures, to insure that dogs can live healthy, clinically normal lives.

Additional information

Additional information located on the pet food bag includes the following:

The name, address, and phone number of the manufacture of the diet.

The name of the product.

The stage of life it is appropriate for (puppy, adult, geriatric).

An ingredient list starting with the ingredient with the greatest content by weight.

The manner in which the diet was formulated, either AAFCO protocols or NRC formulas.

Discount versus Name Brands

The guaranteed analysis on the bag is a chemical analysis, not a biological analysis. Unfortunately, chemical analysis measures the chemical composition of the food, not how the components of the food meet the biochemical needs of the dog. An example is crude protein, which is based on the nitrogen content of the food, not the amino acid content of the diet that make up the true protein. Discount brands tend to use lower quality ingredients, that while they meet the chemical analysis, may not meet the true nutrient requirements of the dog. Animal by-product based dog foods are higher quality than discount brands containing a high proportion of vegetable products. Digestibility as well as nutrient content of premium brands is generally higher. That said, the discount brands that carry the AAFCO statement are dog foods on which a dog can live and thrive.

Ingredients

The ingredients used in dog foods fall into several broad catagorize: protein sources, such as meat by-products or legumes such as soybeans; energy sources, such as fats, oils, or grains;
fiber sources, such as alfalfa meal or beet pulp; and some purified nutrients, such as vitamins and minerals. Many of these are by-products, which are made from secondary parts after the primary product is made. Often, a by-product is cooked or hydrolyzed to break it down some before processing into the dog food. An example is chicken by-product, which is what is left over after the parts used for human consumption are removed. Animal by-products are generally high quality foodstuffs for dogs, and are quite fit for consumption, especially after being cooked, ground, and dried, which is often the case.

Summary

Most high quality dog foods on the market exceed the minimum nutrient requirements as specified by the National Research Council. The primary differences between brands include the quality of ingredients used to supply those nutrients, the level of the nutrients in the diet, and the moisture content of the diet and thus its form (such as either a canned food or a dry kibble). A dog owner who is familiar with the ingredients and understands how to read the nutrient content specified can make informed choices about the diet he or she feeds her dog. Further articles in this series will focus on ingredient quality and examine more closely nutrient requirements at various stages of life.