Possible Methods for Increasing the Consumption of Cotton and Cotton By-Products

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INTRODUCTION

TWO SIGNIFICANT uses of cotton* make it important as a raw material. It is an important source of cellulose and is used extensively in the textile industry where it comes into competition with linen, wool, and silk. Since most of the cotton is consumed in one or the other of these industries, it seems logical to seek new uses almost entirely in these two fields. As a matter of fact, it appears that the success or failure of a program to increase the consumption of cotton will depend in large measure upon what can be accomplished in these fields.

Linen, wool, and silk are superior to cotton for various specific purposes. But careful study of the scientific literature indicates there are reasons for thinking that cotton under the intensive research efforts provided by a cotton research laboratory, might some day wholly or partly replace the more expensive fibers such as linen, wool, or silk. This belief is based on changes in the physical properties of cotton which have been developed recently by the napping of cotton goods on the inside or outside, providing napped goods with a viscose or resin finish, thereby securing washable and creaseless finishes, fine twisting of cotton threads, increase in the luster of cotton goods by various methods, and similar work. It follows that additional research along these lines apparently is of the greatest importance.

In regard to cotton as a source of cellulose, it is well known that cotton, rayon and paper pulp made from wood all consist largely of cellulose. In considering the possibility of increased consumption of cotton and its by-products from this point of view, the problem has looked discouraging or even hopeless because of the fact that cheap paper pulp at 2c per pound or less, has been substituted in a great many cases for the much more expensive cotton. Rayon, made largely from wood pulp, also has made great inroads on the consumption of cotton, chiefly because of its superior luster.

It is evident that to increase the consumption of cotton or even to maintain the present rate of consumption, it is necessary to determine in what respects, if any, cotton is **different** from other cellulose bearing materials, and then **develop new uses or increase the present uses that depend upon this difference.**

When cotton is considered from the above point of view, it is found that it is different from other cellulose bearing materials in two ways.

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*Acknowledgment is hereby made to Dr. Walter T. Schreiber for ideas obtained from a report by him on this subject.

(1) The cotton fiber is readily processed into cloth that is superior to rayon in all its physical properties except one. The one property in which rayon is superior to cotton is the superior luster or silk-like appearance of the rayon. Cotton cloth is much cheaper than rayon, cotton yarn costing approximately 27c per pound as compared to 50c per pound for rayon. It follows that if the luster of the cotton could be improved in some way so that it is equal or even comparable to rayon, cotton would be much superior to rayon and could be expected rapidly to replace rayon even if the finished goods were sold at the same price as before. Such a development should bring about a very decided increase in the consumption of cotton, since rayon consumption in the United States in 1937 was estimated at 332,336,000 pounds. In addition, the substitution of cotton for rayon would result in a reduction in price of the finished goods that should still further increase the demand for cotton goods. As will be shown later, there are actually good prospects of developing a luster on cotton equal or superior to that of rayon.

The second respect in which cotton is different from paper pulp, its chief competitor as a source of cellulose, is the fact that cotton, unlike paper pulp,* is associated with rather valuable by-products and waste products. These by-products consist of linters, stalks, seeds and hulls. Since these products are **cheap,** unlike the cotton itself, they are promising raw materials for the establishment of a great chemical industry. What has been done already along this line is just a drop in the bucket when compared to what **might** be done. Products that might be made include alcohol, acetone, acetic acid, charcoal, paper, fiber board, soap, linoleum, protein and meat substitutes, paints, wood flour, xylose, decolorizing carbon, furfural and its derivatives, resins or plastics, and similar articles. The increased demand for cotton wastes and by-products would increase the total revenue derived from the growth of cotton, while certain chemicals (resins) made from the by-products might be used to advantage in the processing of the cotton goods.

In further explanation, cotton fiber contains the purest form of natural cellulose, practically all of it being present as alpha cellulose, the most valuable form of cellulose. The cotton fiber, due to its twist and the spirality of the component crystallites, is in a condition which lends itself ideally to the drafting and spinning processes. Cotton is superior to rayon in many properties, the most important of which are wet and dry strength and general wearing qualities. Rayon is superior to cotton in only one real quality—a smooth surface. This gives rayon a higher luster and better non clinging qualities. The non clinging property is more important than may immediately appear on the surface, because it is a quality that women consider essential

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*Lignin is a by-product of the paper industry, but so far few important uses have been found for it.

in slips and other undergarments. Thus it appears that any means of smoothing out the surface of the cotton fiber would open up unlimited fields in which cotton could replace rayon and silk. Likewise any means of increasing the felting and insulating ability of cotton should make it a serious competitor of wool. This study hopes to show that there are good prospects of being able to do much along both these lines. In order to approach this problem logically, something of the nature of the cotton fiber itself must be understood. The cotton fiber is a single cell which grows out of the epidermal cells of the cottonseed. These cells first grow out to their ultimate length as a very thin cell wall of cellulose enclosing a liquid interior. Thus at this stage the cotton fiber is a long thin sack filled with liquid. When the fiber has reached its full length, the liquid gradually deposits layers of cellulose on the interior of the thin sack. During this time there is a gradual drying up of the fiber so that finally there is mature cotton fiber with a hollow lumen on the inside. The evaporation of the water and deposition of the cellulose lead to a collapse of the sack to give the twisted ribbon shape of the mature cotton fiber. The concentric layers of cellulose composing the cotton fiber are in turn composed of long chains of cellobiose units which spiral around the fiber in much the same manner as the individual fibers in a cotton yarn go to make up the thread. These cellulose crystallites are embedded in a cementing material which is believed essentially similar to cellulose itself. W. K. Farr[1,2] speaks of this cementing material as pectin or pectic acid and estimates that it is about 2% of the total. It is preferable to consider it simply as cellulose composed of crystallites of shorter length and less regular arrangement than the main part of the fiber. Using this picture as a basis it is seen that the possibilities of modifying and improving various properties of the cotton fiber are enormous. By softening this cementing material to allow the crystallites to slip over one another, it may be possible to reorientate them to give both great length of staple and greater strength to the individual cotton fiber. W. K. Farr[3] has succeeded in dissolving this cementing material without apparently affecting the crystallites.

Cellulose containing no active group but the hydroxyl would naturally be a more inert material than wool or silk or other protein-like compounds which contain both the amino and carboxyl groups. Likewise the valence bonds in cellulose are carbon carbon and carbon oxygen bonds only, whereas in proteins there is the additional nitrogen carbon bond which can be shown by thermodynamic considerations to be less stable than the others. It may be said that these are purely theoretical considerations but they seem to indicate that cellulosic fibers can be made which will be superior to protein fibers in strength and resistance to deterioration. Certainly in any comprehensive research program these factors should be considered. Thus in considering the nature of the cotton fiber and its low cost in comparison with other fibers, the prospect of industrially profitable results from research investigations on cotton are very promising.

As to cottonseed, it is a valuable raw material which is available at a relatively low cost because it is a by-product of the ginning of cotton. The possibilities in its use are numerous because of its complex nature, and they are best considered as individual problems depending on the part of the cottonseed used. From cotton linters cellulose is obtained, oil and protein are secured from the cottonseed meats, and xylose, furfural, and similar carbohydrate degradation products from the hulls.

A third raw material which must be considered is the whole cotton plant. The Cameron Dockery project[4,5,6,7] which has been carried on at the University of North Carolina for nearly ten years has concerned itself mainly with the possibilities of this material. It has been shown that the yield of cellulose per acre per year is about 750 pounds. It has also been shown that baled whole cotton can be stored indefinitely without appreciable deterioration. The whole cotton plant has been ground up, the oil solvent-extracted from this material, and the extracted material pulped by a special process to give a cellulose pulp suitable for rayon. It is also possible to separate the lint cotton from the extracted material. All this work so far has been done on a laboratory scale so that exact data on the economic possibilities of the project are not available. One of the present writers worked with Dr. Cameron for several years. He feels that although nobody is going to "make millions" out of the whole cotton project, it has great possibilities as part of a general cotton research program.

Bearing in mind what has been said already, three classes of problems suggest themselves. These are:

(1) Changes in the physical properties of cotton whereby the cotton may become a more serious competitor of linen, wool and silk.

(2) Development of a luster or finish on cotton comparable or superior to rayon whereby cotton may replace rayon.

(3) Intensive utilization of linters, stalks, seeds, and hulls in the chemical industry.

Specific problems along these various lines are suggested below. Many of these problems are not original but are included here for the sake of completeness. In most cases a bare statement of the problem is made without any detailed discussion. Many of the problems suggested overlap each other. In other cases several different ways of accomplishing the same object are suggested.

PROJECTS BASED ON THE COTTON FIBER

In connection with problems on the cotton fiber, there are two main objectives—first, to increase the luster so as to make cotton a competitor of silk, linen or rayon; second, to increase its felting and insulating properties to make it a competitor of wool.

(1) A chemical modification of the outer surface layers of cellulose.

Cellulose has one primary and two secondary alcohol groups for each six carbons. Hudson[8] has shown that in the case of starch the primary alcohol group can be oxidized to a carboxyl group without breaking up the chain. Thus we have a means of forming a whole series of esters or salts. If this was done superficially the tensile strength and other properties of cotton due to its internal structure would not be modified. We would only change the surface. If the primary alcohol group can be oxidized to an acid, it is probable that by careful oxidation we could stop at the aldehyde stage. This would give a number of other condensation possibilities. The secondary alcohol groups would give on oxidation a ketone group. Due to the greater difficulty in oxidation in this case and the relative inertness of the ketones, it does not appear that this line of investigation would be especially fruitful. Of course the esterification and etherification of the alcohol groups in cellulose is so well known that it need not be mentioned at this point.

(2) Improvement in the methods of mercerization to increase the luster and strength of cotton. Study the effects of time, temperature, use of wetting out agents and other mercerizing agents such as sulfuric acid.

(3) Use of Schwertzer's reagent or a similar compound to smooth the surface and increase the luster of cotton. The formation of Schwertzer's reagent and its special action on cotton is based on the utilization of the coordinate covalency of copper for ammonia. The equilibrium concentration of the complex covalency ion is kept rather low due to the volatile nature of the ammonia. If for ammonia a less volatile amine might be substituted it is entirely possible that much improved results would be obtained.

(4) The conversion of the outer layer of the cotton fiber to a cellulose ester or ether to increase the luster of cotton.

(5) The use of thiocyanates or other solvents for cotton to increase its luster.

(6) The softening of the cementing material (pectin of Farr) which holds the crystallites of the cotton fiber together, by some solvent action and the use of tension or draft on the

fiber in this condition to give increased luster, increased strength and increased elasticity by a reorientation of the crystallites so that they have a greater twist, a changed angle with the fiber axis and a more or less stretched condition.

(7) Treatment of the cotton fiber with a solvent or plasticizer which would render the whole fiber plastic and the application of tension to the fiber in this condition resulting in an increased staple length as well as increased luster. This might well be done on a machine similar to a comber.

(8) The treatment of the cotton as it comes off the card with a cementing material in a volatile solvent whereby the cotton fibers might be stuck together to give a greatly increased staple length.

(9) Plasticize the surface of the cotton fiber during spinning to give a stronger, more compact yarn.

Although the details of the process are, of course, an industrial secret, we believe that this idea is the basis of the new heat resistant tire cord fabric recently put on the market by the Bibb Manufacturing Company of Macon, Georgia. Cotton in its natural unbleached and unscoured state has a thin coating of cotton wax. This cotton wax melts at about the same temperature as beeswax. By treatment of this wax with a solvent, it could be softened sufficiently so that it would act as a binding agent to give a stronger more compact yarn. The Bibb Manufacturing Company claim that their H. R. cord is superior in tensile strength, both wet and dry, and resistance to the injurious effect of heat due to internal friction or other causes, to both rayon and ordinary cotton cord. Mr. Rozar, Director of Sales Development of this company, said in a letter to one of the authors recently, "Tests we have made indicate that using Bibb H. R. cord it is the rubber in the tire, not the cord, that wears out and, that if a sufficiently durable rubber could be obtained, a set of tires would last the life of the ordinary car." This is quoted as an example of the results that we feel may be obtained by research along some of the lines suggested in this paper.

(10) The treatment of cotton by the Lanatin[9] or some similar process to give a fiber resembling wool. This is a patented process which probably involves the treatment with sodium hydroxide without tension. Lanatin or Lanatinized fibers should not be confused with the Italian casein product, Lanital. The lanatin cloths on the market at present are made from jute, hemp, etc., and resemble wool in feel and appearance.

(11) Treatment of cotton with a plasticizer or resin to give increased stiffness to the fibers thus permitting its use in pile fabrics, plushes, etc., to replace wool or mohair.

(12) Treatment of napped cotton goods with a resin or other finishing compound to give material that will have the softness and warmth of wool.

(13) Development of designs and finishes on cotton to make it resemble wool as far as felting and surface appearance are concerned, so that cotton could replace wool in men's suiting and ladies' dress goods without increased warmth or insulating properties.

(14) Research on the spinning of very fine counts of cotton to give yarn of increased strength and fineness.

(15) Research on the kierboiling and bleaching of cotton with special emphasis on the use of sulfonated fatty alcohols and other detergents with the main object of increasing the absorbency of cotton to replace linen in towels, etc.

(16) The use of special phosphates in the kierboiling of cotton whereby increased absorbency is obtained even in the presence of hard water.

(17) Cotton cloth of net-like structure coated with a cellulose ester to replace cellophane or similar products.

(18) Continuation and extension of the study of the use of cotton in highway construction. Investigation of the possibility of the use of raw or lint cotton to add strength and body to concrete without the necessity or expense of first making it into cloth.

(19) Production of artificial leather by coating cotton cloth with a synthetic resin.

(20) Use of synthetic resins or lacquers, together with a finely woven cotton cloth, to give oil cloth without a smooth oily finish.

(21) Washable finishes on chintzes, shirtings, ginghams, etc., by use of synthetic resins or cellulose ester preparations.

(22) Improvement of the wearing qualities of cotton cloth by use of permanent finishes.

(23) Cellophane reinforced with cotton cloth of net-like construction to prevent tearing and cracking.

(24) The use of para sulfonal chloride or similar compounds to change the dyeing and finishing properties of cotton cloth, thus giving patterns and designs by a printing process which is cheaper than weaving. The resulting product is sometimes called "immunized" cotton.[10,11,12]

(25) The use of some solvent or aqueous solution in the spinning of cotton yarn to increase the twist, fineness and strength of the resulting yarn.

(26) The use of loose cotton as a resin filler to decrease brittleness and increase strength.

(27) The incorporation of small amounts of dyed loose cotton in cellophane to give novelty effect. This would also increase tearing strength.

(28) Use of loose cotton as a binder in rubber articles—tires, shoes soles, etc.

(29) Finishing cotton with a slight napping to give softness, increase weight and give a dull soft tone.

(30) Finishing cotton with a cellulose ester solution or resin containing a delustering pigment to give a dull soft luster and still have a non clinging garment suitable for slips and women's underwear in general.

(31) Use of fine count highly mercerized cotton yarn for ladies' sheer hose.

PROJECTS BASED ON COTTONSEED PRODUCTS

(32) Application of modern engineering principles to cotton ginning machinery with the hope of increasing the yield and quality and decreasing the cost.

(33) The use of cottonseed protein or cottonseed meal in the making of plastics and the use of cotton linters as a filler in plastics.

(34) Use of cotton linters as a source of alpha cellulose. Cotton linters are at present the best and purest source of alpha cellulose but they have lost ground in competition with wood pulp which has been much improved to meet the demand of the rayon industry for a high grade alpha cellulose pulp. The conversion of cotton linters into alpha cellulose is a cheaper and simpler process than that used for wood, resulting in less degradation and loss. The decreased use of cotton linters in the manufacture of rayon has been to some extent due to the fact that the supply of cotton linters has not been uniform and dependable. By proper control and sales methods much of this business could be recovered. It should be emphasized at this point that there is much evidence in the literature to indicate that cotton cellulose including both cotton linters and lint cotton is superior to wood pulp for rayon manufacture. During 1938 Gerhard Dierkes[13] published a series of articles in the Deutsche Textilwietschaft in which he showed that rayon made from cotton linters was superior in transverse stability and hence in wearability to that made from wood pulp. There is much other evidence leading to the same conclusion.

(35) Use of cotton linters in place of loose cotton in several previously suggested uses such as felts, suitcases, mats, for reinforcing rubber, etc.

(36) Increased cottonseed oil production by use of solvent extraction methods. By present methods several per cent of the oil is left in the cake.

(37) Sulfonation of cottonseed oil to replace sulfonated castor, olive or other soluble oils.

(38) Conversion of cottonseed oil into amides, alcohols and other derivatives useful as detergents, wetting agents, etc.

(39) Recovery of xylose from cottonseed hulls.

(40) Development of new uses for xylose and its compounds. It is an excellent non fattening sweetening agent and a reducing agent for use with both vat and sulfur dyes.

(41) Production of furfural from xylose and the development of new uses for furfural and its derivatives. This is an aldehyde and thus has many of the possibilities of other aldehydes.

(42) Further development of decolorizing carbon[14] made from residual (after xylose removal) cottonseed hulls.

(43) Plastics may also be made from xylose and furfural.

(44) Use of furfural as a dye intermediate.

(45) The production of food products from cottonseed meal similar to peanut products now on the market.

(46) A study of the action of enzymes or ferments on cottonseed meal.

(47) A study of the action of enzymes on cellulose as a possible means of controlled degradation of cellulose. It is well known that termites are capable of using cellulose as a food, hence their digestive system must contain an enzyme which will degrade cellulose.

PROJECTS BASED ON THE WHOLE COTTON PLANT

(48) Investigation of the possibilities suggested by one of the authors in an article in the American Dyestuff Reporter.[15] This article suggests that the whole cotton plant be harvested like hay or grain, baled and stored. Then at any suitable time the whole plant is ground, the oil extracted by a solvent, the oil free material separated into a lint cotton material and a woody material. This lint cotton material may have a limited use as a fiber and would certainly be useful as a source of cellu-

lose pulp similar to that obtained from cotton linters. The woody material would be suitable for a low grade cellulose pulp for brown paper, etc.

(49) Making of cellulose pulp from the oil-free whole cotton plant. This would give a cheap pulp that might find many uses.

(50) Further investigations of the nitric acid method[16] of pulping the whole cotton plant or other similar vegetable material. One of the authors has shown that this method gives a high grade alpha cellulose pulp from the whole cotton plant. The equipment and chemicals required make this process considerably cheaper than the methods used for wood.

(51) A study of the suitability of the whole cotton plant for destructive distillation and the recovery of wood alcohol, acetic acid, charcoal, etc. It has been demonstrated that corn cobs are superior to wood for this purpose and the same may be true of cotton stalks or the whole plant.

(52) A study of the conversion of cotton stalks or the whole plant into paper.

(53) Mixing cellulose pulp from cotton stalks or the whole plant with cement, silica, gel, etc., to give fireproof shingles, wall board, beaver board, etc.

(54) Cellulose pulp plus plaster of paris or similar material to give building blocks and insulating material for use in the building industry.

(55) Use of the whole cotton plant or cotton stalks to make a product similar to plastic wood.

(56) Use of the whole cotton plant to make fillers for resins, etc.

(57) Use of whole cotton plant as a source of oxalic acid or other organic chemicals.

(58) Use of whole cotton plant as a source of absorbent carbon.

In conclusion the authors maintain that King Cotton must get rid of his inferiority complex. They do not agree with those who contend that the economic position of cotton is necessarily hopeless, but on the contrary take the position that much could be done to stabilize and maintain cotton prices by a comprehensive and intensive research program along the general lines indicated. Emphasis should however be put on projects leading to the use of cotton in high grade and expensive material rather than cheaper class of goods as has been done in the past. One of the most encouraging features of this problem is that cotton is one of the cheapest of all fibers. This gives the research worker the opportunity to use relatively expensive processing and finishing procedures on the cotton and still compete on a price basis with the other fibers. All signs point to an increased interest on the part of both public and private interests in this country in research on projects aiming to increase the industrial consumption of agricultural products. If the suggestions made in this paper serve as an additional incentive to attempt such work on cotton or its products, the authors will feel that their efforts have been well worth while.

Bibliography

1. Farr, W. K. "A New Viewpoint in the Study of Cellulosic Fibers" Textile Research 7:65-9 (1936)

2. Farr, W. K. "The Formation and Structure of Cellulose Membranes" Paper Trade J. **101** No. 15, 87-90 (1935)

3. Farr, W. K., and Eckerson, S. H., "Separation of Cellulose Particles in Membranes of Cotton Fibers by Treatment with Hydrochloric Acid" Contrib. Boya Thompon Inst. 6:309-13 (1934)

4. Cameron, F. K. "Cellulose from Cotton" Manufacturers Record 106, No. 7, 33, 64 (1937)

5. Cameron, F. K. "The Growing and Processing of Whole Cotton" Manufaturers Record 107, No. 8, 27, 52 (1938)

6. Macormac, A. R. "Utilization of the Whole Cotton Plant" Scientific M **43** 285 (1936)

7. Milne, D. "Whole Cotton—an Annual Source of Cellulose" Rayon and Textile M. **19** 540-2 (1938)

8. Hudson, C. S. "New Oxidations in the Carbohydrate Group" Address, Chapel Hill meeting Amer. Chem. Soc. (1937)

9. Mack, P. B., and Phillips, C. R. "Lanatin—A New Wool Substitute" The Broadcast **6** 27-29 (1938)

10. Hall, A. J. "Immunized Cotton" Dyer Calico Printer 56 184-5 (1926)

11. Mullin, C. E., and McGee, R. L. "Immunized Cotton" Textile Colorist **53** 85-7, 127 (1931)

12. Hopkins, E. R. "Immunized Cotton" Amer. Dyestuff Reporter **23** 147-9 (1934)

13. Durkes, G. "The Maintenance of the Molecular Structure of Cellulose in the Manufacture of Staple Fiber Rayon" Dent. Textilewirt **5** No. 17, 11-14; No. 18, 5-14; No. 19, 22-5 (1938)

14. Basore, C. A. "A High Grade Decolorizing Carbon from Extracted Cotton Seed Hulls," Bull. 2, Eng. Exper. Station, Ala. Polytech. Inst., Auburn, Ala. (1931)

15. Macormac, A. R. "The Whole Cotton Project" Amer. Dyestuff Reporter **26,** 389,-96

16. Macormac, A. R., and Cameron, F. K. "Pulp from the Whole Cotton Plant," "Comparison of Soda and Nitric Acid Pulps" J. I. E. C. **29,** 96-7 (1937)