Cottonseed

A Technological Breakthrough In The World Food Crisis

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Abstract

Frontiers in food research are unlimited, as demonstrated by recent availability and use of good quality protein from cottonseed in the preparation of acceptable and nutritious foods for people. In the past, cotton has been grown for its fiber content; recent technological innovations, such as the liquid cyclone process and breeding programs for glandless cottonseed, now make possible the production of high protein, low gossypol cottonseed flour. An educational team approach could be used by college and university teachers to motivate students in the development of new foods for people.

Daily the news media report problems in supplying food to those in need. Approximately 90 percent of the people in some of the developing nations are poverty stricken, chronically hungry, and malnourished. A challenge exists for agriculturists, cereal chemists, food technologists, and nutritionists to pursue breakthroughs in food research. Recognizing the need for supplementing the food supply with additional sources of nutritious, economical, available, and acceptable food components, many researchers are examining heretofore nonutilized sources of nutrients for people. How many potential food sources has man failed to utilize? Undoubtedly many food discoveries are possible; research frontiers in food are unlimited.

One of the more recent developments in food is that of cottonseed protein. Cotton has been grown for fiber for several thousand years in tropical and subtropical regions of the earth. The cotton plant produces more food for man and feed for livestock than it does of the fiber that bears its name. With each 100 pounds of fiber, the cotton plant yields approximately 170 pounds of cottonseed which results in some 27 to 30 pounds of oil and 78 to 82 pounds of meal, with the balance hulls (4).

History of the Use of Cottonseed

Cotton production is indigenous to many parts of the world. Excavations in Peru and Mexico have uncovered cotton cloth identified as being 4,500 to 7,000 years old. Alexander the Great and his armies in the third century, B.C., invaded India and found that cotton was widely grown; later it was introduced into the countries on the eastern and southern borders of the Mediterranean Sea. From there, usage spread into Europe (4).

In ancient times, the Hindus and the Chinese, using the principle of the mortar and the pestle, developed crude methods for obtaining oil from cottonseed. The oil was used in lamps and the remainder of the pressed seed was fed to cattle. In the United States, use of cottonseed did not develop until after the invention of the cotton saw gin in 1793. During the first half of the nineteenth century a number of patents on processing machinery were obtained. One of the first large-scale commercial cottonseed crushing undertakings was at a mill established in Natchez, Mississippi, in 1834. Many such early mills were unsuccessful because the fuzz or linters which covered the cottonseed kernel were not removed by the gin; thus, the whole seed was crushed and the linters and the hulls absorbed much of the oil. The industry continued to grow, however. In 1860, seven mills in the United States were in operation; 10 years later 26 cottonseed crushing mills existed. This number increased to 45 in 1880, to 119 in 1890, and to a peak of 900 just prior to World War I. Since then the size of the mills has increased and, with improved transportation, the number has steadily declined to 160 mills now in operation (4).

Until the development of the crushing industry, cottonseed had limited cash value. Small quantities of seed were used for fertilizer and livestock feed. As mills began to operate, cottonseed began to acquire a cash value. The four primary products of cottonseed processing mills are oil, meal, hulls, and linters. Cottonseed oil accounts for about 55 percent of the total value of all four products and is used almost entirely as food. At present, cottonseed meal for animal feed, especially for cattle, is the second most valuable product, accounting for 30 to 35 percent of the total product value. Cottonseed hulls are fed as a roughage and serve as a practical addition to the use of pastures. Cottonseed linters are used in the manufacture of absorbent cotton, medical pads, gauze, tissue, and mattress batting, and as cellulose for chemical industries (4).

Cottonseed production shows a moderate increase in recent years (32). The total world production was 24.0 million tons in 1972, 25.2 million in 1973, and 25.3 million in 1974 (9). This world production of cottonseed contained about 3.4 million tons of protein (N $\times$ 6.25). The U.S. production of cottonseed ranged from an average of 5.3 million tons in 1972 to 4.9 million tons in 1973, and to 4.6 million tons in 1974(10).

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Structure of the Cottonseed Kernel

Cottonseed is a dicotyledon composed of two large, flat cotyledons and the so-called axial organs — the radical, hypocotyl, and epicotyl. The cotyledons are folded around the radical and over the top of the hypocotyl in the embryo (3). Various researchers have identified the physical and chemical components of the cottonseed kernel (12, 20, 37, 41, 49).

Most cottonseeds contain gossypol, a polyphenolic compound located in the pigment glands. Pigments are stored in the so-called "glands" which are dispersed throughout the embryonic cotyledons and hypocotyls of the cottonseed kernel and may be observed as dark specks in a cross section. Boatner and associates (12) have extensively investigated the pigment glands and found that they vary in color and intensity with growth and environmental conditions. Gossypol, a yellow pigment, is an aldehyde and a polyphenolic compound with an acidity comparable to that of acetic acid. Gossypol is an antioxidant, a polymerization inhibitor, and has physiological properties that influence the utilization of cottonseed meal by monogastric animals (3, 18).

Composition of the Seed

1. **Proximate Composition:** Cottonseed contains on the average 44.5 percent hulls and linters and 55.5 percent meats or kernels. The delinted cottonseed contains 36 percent hulls and 64 percent meats. The meats may contain 9.0 to 12.8 percent moisture, 30 percent crude protein, 30 percent oil, 24 percent nitrogen-free extract, 4.8 percent crude fiber, and 4.4 percent ash — depending upon the environment and specific varieties (3). Cottonseed is almost devoid of starch; its energy reserves are confined to oil and protein (49).
2. **Oil:** Cottonseed oil, the major economic component, is composed of approximately 50 percent linoleic, 23 percent oleic, and 23 percent palmitic fatty acids, as well as small amounts of stearic, myristic, palmitoleic, and malvalic acids. Cottonseed oil is liquid at ordinary temperatures and has good flavor and stability to oxidative rancidity, thereby causing it to be one of the world's major edible vegetable oils (3, 31).
3. **Protein:** The proteins of cottonseed can be divided into two groups — water insoluble and water soluble. The bulk of the proteins in cottonseed are considered to be globulins and are soluble in dilute salt solutions. The remaining proteins are classified as glutelins, which require alkali for solubility, and albumins, which are water soluble. Processing or heat treatment of cottonseed reduces the solubility of the proteins in salt solution and increases the amount of alkali needed for solution (3). The reduction in the nutritive value of processed cottonseed is due to lysine destruction and to lysine binding. The amino acid lysine has an amino group on the end of the molecule; when proteins are heated with carbohydrates, this amino group reacts to form a protein-carbohydrate complex. Also, the pigment gossypol reacts with this amino group. Amino groups on the outside of a protein molecule are necessary for the rapid action of the digestive enzymes that separate proteins into amino acids for absorption from the digestive tract. When the amino acids are blocked by reactions, protein digestion is impaired (18, 38).
4. **Other Constituents:** The carbohydrate content of the weight of the dry kernel of the cottonseed is approximately 13 to 15 percent of which 50 percent is in the form of mono-, di-, or trisaccharides. The principal component of the carbohydrate fraction is raffinose, a trisaccharide composed of fructose, glucose, and galactose (3). Martinez and others (40) studied the importance of raffinose and gossypol in the destruction of lysine, the binding of the alpha amino group of lysine, and the impairment of the nutritive quality. The presence of the heat sensitive vitamin thiamin varies as to heat treatments; other B vitamins are affected also by processing temperatures. Cottonseed is a poor source of vitamin A. Vitamin E is found in the oil portion (3).

   The minerals phosphorus, potassium, sodium, magnesium and calcium are found in small amounts in the cottonseed kernel; trace amounts of zinc, iron, copper and manganese are also available (3).

Cottonseed Products in Foods

Cottonseed flour containing 48 to 55 percent protein, 12 percent fat, and 4 percent crude fiber was first sold in the United States in 1876 (3). As early as 1910, scientists at Texas A & M College published a bulletin entitled "Cottonseed Meal as Human Food" which contained the following: "Cottonseed breads and other edibles made from cottonseed meal have been placed upon the market at Brenham, Longview, and especially at Ennis, Texas. Mrs. Dan McCarty of Ennis, Texas, claims to be the first and only purveyor of 'Cottonseed Flour' bread and cakes, and her products are being sold: cottonseed bread, cottonseed rolls, cottonseed ginger snaps, cottonseed doughnuts, and cottonseed Jeff Davis plum pudding." Undesirable characteristics of this cottonseed flour — color, texture and fiber content — caused a cessation of further developments (6).

In the 1930s, the Trader's Oil Mill, Fort Worth, Texas, began to produce limited quantities of a cottonseed flour of uniform color, odor, and taste which imparted desirable characteristics in certain baked food products. The natural gossypol in the cottonseed has been rendered inactive in these products by the application of heat and pressure during the extraction of the oil (3).

In 1959, finding of a gland-free or glandless mutant cottonseed which resulted from crossing the Hopi Moencopi variety of cotton with upland varieties was reported by McMichael (39). The first glandless cottonseed varieties were planted commercially in 1966 and predictions indicate possible use in foods.

Attempts have been made over the years to devise methods to produce cottonseed meal or flour suitable for human consumption from the regular glanded seed (3, 17, 22, 32, 44). A vegetable protein product containing cottonseed flour, called Incaparina, was formulated at the Institute of Nutrition of Central America and Panama (INCAP) (13, 14, 46). Long-term rat feeding studies (15) and metabolic studies in convalescent malnourished infants and children were used to evaluate a number of cottonseed flours as the only source of dietary protein. All results indicated that a properly processed cottonseed flour, low in gossypol or the glandless variety, could be used as the main or only source of dietary protein (24, 25).

As early as 1961, cottonseed flour was used successfully as a nutritious filler for sausage and frankfurter-type meat products under sponsorship of the Food and Agriculture Organization of Rome, Italy. The nutritive value of the cottonseed flour-containing sausage was about equal to that containing nonfat dry milk (7). In Peru, a salted product containing 56 percent of cottonseed flour and a sweet product containing 50 percent of cottonseed flour were developed. Research conducted in the United States using glandless cottonseed flour indicated that this flour possessed properties needed for bakery doughs such as water-holding capacities, antioxidant qualities, and benefits in cookie shape retention (48). Matthews et al. (43) found that substituting 25 percent of cottonseed flour for wheat flour in making doughs and breads resulted in poor loaf volume and that formulation changes or mixing of doughs, or both, were necessary. Rooney and others (45) found that oilseed flours (glandless cottonseed, sesame, peanut, and sunflower) differed markedly in functional characteristics for mixing and baking into yeast leavened breads. However, a significant increase in protein quality of the cottonseed-fortified bread was obtained.

Abdou and Kassim (1) studied the acceptability of breads containing 25 percent cottonseed flour; the breads were acceptable for taste and smell but were objectionable in color. Tsen and others (47) used dough conditioners to improve the texture when substituting soy flour for wheat flour in the baking of high-protein breads. Undoubtedly other additives such as those used by Hart and others (28) in baking bread from sorghum and barley flours are available for use in improving the texture of breads made with cottonseed flour. Fogg and Tinklin (21) substituted varying levels and grinds of glandless cottonseed flour for equivalent weights of wheat flour in plain sugar cookies to increase the nutritional value.

In 1968, scientists at the Texas A & M University Oilseed Products Research Center found that a pleasant, nutlike product could be produced from undefatted glandless cottonseed kernels. The glandless kernels are edible as nuts after toasting, roasting, or frying and can be used in candies, cookies, and other bakery items (34).

Development and Usage of the Liquid Cyclone Process

In 1968, pioneering work led to the liquid cyclone process (LCP) at the U.S. Department of Agriculture Southern Research Laboratory, New Orleans, Louisiana, which resulted in the production of a flour containing about 70 percent protein, 0.6 percent lipids, and acceptably low levels of gossypol. This flour was bland in flavor, light cream in color, and acceptable in taste. This LCP process was a further development of the differential settling process. A cyclone separates particles and liquids on the basis of their size and specific gravity and the specific gravity of the liquid in which they are suspended. The filtrate is then desolventized, ground to flour, sterilized, and packaged (19, 22, 23).

This liquid cyclone process is being utilized in a commercial-scale new plant adjacent to the Plains Cooperative Oil Mill in Lubbock, Texas. This plant, in 1975, will begin to produce 25 tons daily of a 65 to 70 percent protein cottonseed flour. The Grain Processing Corporation, Muscatine, Iowa, will merchandise this defatted, bland, near-white cottonseed flour under the trademark Pro-Fam C-650 (8).

Chemical analyses and biological studies using white rats fed diets of both cottonseed flours and breads baked from both LCP and glandless cottonseed flours, conducted by Harden and Yang, showed that the proteins were of good biological value (26). Castro (16) concluded that addition of 5 percent LCP cottonseed flour to diets containing triticale, soy concentrate, soy isolate, and wheat flour caused improved weight gain of rats and high protein efficiency ratios.

Consumer acceptability studies using a substitution of 18.8 percent cottonseed flour for wheat flour in baking yeast breads have shown good consumer acceptance. The cottonseed bread is heavier, more compact, and rougher in texture, with a color comparable to that of whole wheat bread. The color may not be a problem, however, as consumers tend to associate the darker color with more nutritious foods (26).

By substituting cottonseed flour for two-thirds of the wheat flour in a nonsweet cracker similar in texture to snack crackers already on the market, the crude protein content of the crackers was increased from 9.1 to 40.0 percent. Chemical analyses and biological studies using white rats fed these crackers showed that the protein from cottonseed flour could make a significant nutritive contribution to the diet of human beings. Consumer acceptability studies by 805 individuals tasting these high protein cracker crisps indicated a favorable response on a hedonic rating scale (27).

Alford reported having fed children with diets containing 30 percent of their daily protein needs from cottonseed flour for six months with no adverse physiological effects (2). Evidently, development of acceptable nutritional and functional cottonseed food products is possible (29, 50).

The General Mills Company tested market acceptance in Pakistan of meat and soybean protein kabobs, which might instead be made with meat and cottonseed protein, as cotton is grown in Pakistan and soybeans are not. The Dutch are working on a combination of cottonseed flours with cassava flour and the French are experimenting with cottonseed protein in Chad, Africa, where cotton is produced in abundance. Problems of taste, texture, and custom hamper the acceptance of such new protein foods (5).

Other possible food products obtainable from cottonseed include the by-product liquid extract from the wet-extraction procedure which produces glandless cottonseed flour. Recently this extract was shown to contain a whippable substance with commercial potential as an egg white extender or substitute (35). In a later study, wet-extracted concentrate spray dried at two pH levels was evaluated for use in protein-fortified bread and as a component in meat loaf to reduce juice and fat cook-out during baking. Such products could reduce meat requirements in low cost diets (36). Further concentration of the proteins to produce isolates have been reported (11, 30, 42).

Educational Team Approach

The experimentation and production of cottonseed protein marketable products requires the team approach in an educational system. The university research team may consist of the following:

1. Agronomists — to produce the most marketable species with the highest yield per acre at the lowest product cost,
2. An agricultural engineer — to constantly devise more efficient methods for processing the cottonseed kernels to produce the most acceptable protein,
3. A nutritionist — to constantly develop acceptable commonly consumed foods, to test consumer and biological acceptability, and to determine protein ratios and concentration of other nutrients required in an adequate diet,
4. An agricultural marketing specialist — to explore outlets for food companies, to produce foods that are highly acceptable to low income populations in the United States, as well as for emergency feeding in different locales of the world.

Such a team of specialists must motivate a group of enthusiastic imaginative students whose job one day may lie in this area of feeding the mass of population both in the United States and in other nations. These students should be introduced to this integrated research team early in their undergraduate curriculums by touring food research centers, by developing and tasting experimental products, and by being trained to regard food as a necessity for survival.

Students should be trained to realize that people in poverty and in disaster have the same tastes and psychology of eating as other people, namely, they prefer the well-known foods of their respective cultures. They want food that everyone else eats, and they prefer that which is ready-to-eat and requires no extensive preparation. Students today need to recognize the things that make up the minimum necessities of life for all population groups. For example, elaborate and contemporary equipment such as electronic ovens, freezers, and mixers, as desirable as it may be in a highly affluent industrial society, may be completely useless in an energy-short emergency when the demand for food is increased several times that of a stable situation.

A new focus for education is educating for change. What more effective method can be used for training university youth for constructive change than participating in the design of food products that are undreamed of in today's market? What better way to learn the difference between an additive that reduces cost, increases supply, and improves nutritive quality, and an adulterant that is used to dilute "good" food with none of these beneficial effects?

The nutrition education component would be accomplished by students' awareness of "fabricated" or "engineered" foods for extension of the food supply, enhancement of nutrients in diets, and economy of resources. The student, in expanding his own acceptance of food, increases not only his own nutritional status but is better able to communicate concern for the nutritional needs of others.

Summary

There is little doubt that cottonseed proteins will be useful in many food items and that they have a particularly great potential in areas of the world with the greatest problems of undernourishment and starvation. Palatable, nutritious, and acceptable food products can be nade by incorporating varying levels of cottonseed protein into many food items, in ways that may be new and different or as yet unheard of today. No clear-cut information is available on the possibility of allergies to cottonseed protein as compared to other protein sources.

With the growing trend toward fabricated convenience foods, a part of man's protein needs can be met through the use of cottonseed flour. Many laboratories in the United States and in other areas of the world are studying various aspects of cottonseed protein but more facts are needed about the processing of these proteins and much more study is needed on their basic chemistry and that of their associated pigment and flavor components. Perhaps these problems can be surmounted through the multidisciplinary problem-solving approach of concerned university researchers and their students.

In the next 25 years, before the year 2000, the world will produce between one-half and three-fourths of a billion tons of cottonseed. Cottonseed flour has great potential value in the food processing industry. With the growing world population, correspondingly expanded need for proteins cannot be met economically by animal proteins. The day may come when cotton will be grown, not solely for its fiber and edible oil yield, but also because its protein is needed for human nutrition.

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