COTTONSEED PROTEIN PROCESSING AND UTILIZATION—
AN EXAMPLE OF NUTRITIONAL FOOD TECHNOLOGY

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Abstract

The most serious feature of worldwide malnutrition is the lack of adequate protein in quantity or quality at a reasonable price in developing countries. The development of regional vegetable protein mixtures, such as Incaparina, is a promising and successful approach. Cottonseed is a logical inexpensive source of valuable protein, limited mainly by its free gossypol content and lysine destruction during oil processing. Compromise processes and new oil extraction techniques can minimize present utilization difficulties. Cultivation of glandless cotton can eliminate gossypol. Both approaches yield high quality flours suitable for protein supplementation.

Such utilization research calls for an interdisciplinary approach from the agricultural to the social sciences, including Nutrition Food Technology which is applicable to many protein resources besides cottonseed. Opportunities for progress are great. However, technology is not the limiting factor in alleviating malnutrition: the initiation of socio-political changes are urgently needed.

Introduction

The severity of worldwide malnutrition has been amply stressed in recent popular and professional articles and is often a news item from some developing country. It has been well documented that the availability of protein in adequate quantity and quality is the most serious nutritional deficiency facing mankind (1, 2).

Traditional protein sources, such as animal products, are in short supply and far too expensive and wasteful of land resources to be practical on a worldwide basis. Other promising protein resources are either still highly experimental, overly expensive, or in serious conflict with existing food distribution and consumption patterns. Nevertheless, population pressures in developing countries continue to tax food resources and immediate corrective measures have long been needed.

A Promising Approach

One of the most successful efforts to supply needed protein, which is providing a partial solution in several Latin American countries and represents a useful guide for other parts of the world, is a commercial vegetable protein mixture called Incaparina (3). This protective food, consisting of cottonseed flour, corn flour, torula yeast, calcium carbonate and vitamin A, was designed to take maximum advantage of regional protein resources. The cottonseed or soy flour base and cereal ingredient may be partially replaced by legume protein (4). Depending upon crop availability and price, a number of low cost nutritive foods can be produced which are tailored to the customs and dietary needs of the populace. Moreover, this can be accomplished by food manufacturers locally, without entailing costly import programs or involving self defeating politically tainted give-away programs.

The success of Incaparina has hinged on the regional availability of edible cottonseed flour and upon the extensive research conducted by the Institute of Nutrition of Central America and Panama (INCAP) in Guatemala City in cooperation with other organizations, particularly the Southern Utilization Research Laboratory of the U.S.D.A. This work is an outstanding example of Nutritional Food Technology in an international context.

Cottonseed Protein

Utilization of cottonseed protein for human or non ruminant feeding had been seriously hampered in the past due to gossypol, a toxic pigment in the seed which affects monogastric animals (5). Consequently, cotton seed meal was (and unfortunately still is in many processing plants) considered suitable only for ruminant feed, or worse yet, as fertilizer. In addition, the oil extraction operation was designed to economically remove the maximum amount of cottonseed oil with little thought to residual meal.

Florida Agricultural Experiment Stations Journal Series No. 2805.
quality. In the process, the seed is subjected to heat and extraction conditions which adversely affect the originally high quality seed protein, primarily by reducing lysine availability and secondarily by imparting a burnt flavor and dark brown color to the meal.

Since the \( \varepsilon \)-amino group of lysine is quite reactive, it combines easily with other reactive meal components, including gossypol. Such reactions reduce free gossypol by forming less harmful bound gossypol compounds. However, the bound lysine is not assimilated upon digestion, thus this essential amino acid is partially lost with an attendant reduction in protein quality. Severe processing also affects the availability of other essential amino acids, but lysine is the most labile.

INCAP Food Technologists in cooperation with the U.S.D.A. and a local cottonseed processor successfully modified an existing prepress solvent extraction operation. By careful selection of seed; maintenance of low temperatures during cooking, expelling, and desolventization; and reducing expeller load, it was possible to produce a low gossypol flour containing 50% good quality protein (6). The flour which meets FAO Standards is light yellow and has a bland unobjectionable cereal-like taste. The storage stability is good and the flour or Incaparina is easily stored, shipped, and distributed in flexible paper or plastic containers.

Extensive research with this new flour (in close cooperation with nutritionists who conducted dietary surveys and feeding studies, anthropologists who studied food habits, economists who developed the merchandising system, and a progressive local food manufacturer with packaging and distribution know-how) resulted in commercially successful Incaparina. The product closely resembles “atole”, a traditional Guatemalan corn-based beverage and at 4 U. S. cents/3 servings is manyfold cheaper than milk and about as nutritious. Since the means of preparation, taste, and rheological properties are similar to atole, Incaparina has gained acceptance with those who need it most.

**Newer Processes and Products**

Despite this promising start, cottonseed protein is still underutilized in both human and animal feeding. The process modifications described are still a compromise since small amounts of free gossypol remain in the flour and available lysine is reduced about 20%. More severe processing conditions can further reduce free gossypol at the expense of available lysine. Milder conditions spare lysine but gossypol increases.

INCAP Food Technologists have determined that gently treated expeller processed meal which retains about 6% oil, relatively large quantities of free gossypol, and most of the initial available lysine can be utilized for non ruminant feeding (7). The meal is cooked with small amounts of calcium and iron salts which react with free gossypol and alleviate meal toxicity. Such a process is quite promising in many areas of the world where solvent extraction of cottonseed is not practiced and animal feed cost restricts the growth of animal industries. It may be possible to even produce a human grade flour from such plants by very careful control of the process variables. The main difficulty here is that conditions which reduce free gossypol while sparing lysine tend to leave quantities of oil in the meal which processors deem economically unacceptable. Prepress solvent extraction eliminates this problem but introduces additional capitalization costs.

There are several experimental oil extraction processes which can spare lysine and reduce gossypol. Solvent extraction with hexane, although it adequately removes oil not pressed out by the expeller, fails to solubilize free gossypol. Acetone is an excellent solvent for gossypol as well as for cottonseed oil and can reduce gossypol while allowing less severe processing conditions which conserve lysine and impart a lighter color to the resulting flour (8). The Southern Regional Utilization Laboratory has developed a mixed solvent extraction process. This hexane-acetone-water azetrope has the advantage of rupturing the gossypol containing pigment glands of cottonseed, thus facilitating a more thorough removal of gossypol along with the oil. The flour quality is also improved and simpler oil extraction equipment can be used (9).

Although in theory these two techniques can upgrade cottonseed protein above the quality of the presently commercial INCAP process, there are the following limitations to their immediate industrial application. 1—Cottonseed extracted by acetone or acetone containing solvents often possesses a characteristic off-flavor due to acetone condensation products which cannot be removed even by thorough desolventization. Use of pure acetone and controlled extraction conditions in
well designed equipment can prevent this off-flavor development. 2—Acetone is considerably more expensive than hexane, requiring more economical solvent recovery methods. The azeotrope method, although it uses only 53% acetone must be carefully maintained at the optimum composition for proper extraction. Such modifications require additional capital investment, increased operation cost, and dictate quality control measures currently not needed in the oil processing industry. 3—Cottonseed flour, despite its potentially high protein quality and low cost (5 to 6 U. S. cents/lb; feed meal 2.5 to 3.5 cents/lb), has no widespread demand. Except for its use in Incaparina (since 1959) and as a functional additive in some bakery products, there are no large scale food uses and hence no great impetus to upgrade the quality. The light tan color of even the best flour precludes its use in foods where darkening is objectionable.

A recent advance which promises to upgrade cottonseed flour still further is due to the success of plant breeders in Texas in developing glandless cotton. The new varieties contain no gossypol, thus the lysine damaging processes required to reduce free gossypol are not needed. It is too soon to assess the commercial potential of glandless cotton. If the fiber quality and yield compare favorably with glanded varieties, and there are no serious cultivation problems, glandless cottonseed may be available for flour production. Given a favorable cotton market, such flour could achieve some of soybean's importance as a food ingredient.

In fact, workers at the Southern Utilization Laboratory have recently produced experimentally several interesting new products: a white cottonseed flour which has great promise as a protein supplement where light color is essential (10); roasted glandless seed with a pleasant nut flavor; and cottonseed butter, somewhat similar to peanut butter.

NUTRITIONAL FOOD TECHNOLOGY

In this brief description of cottonseed processing and utilization it can be seen what Nutritional Food Technology is and how it functions in the key role of upgrading under-utilized or formerly nonexistent food resources; putting them in a safe, inexpensive, acceptable form; and getting them most efficiently to the malnourished segments of the population. This is a necessary and rewarding activity which must be greatly accelerated in the future.

In today's protein-poor areas, it is senseless to produce a valuable protein in cottonseed, downgrade it to ruminant feed by damaging oil extraction processes, ship it to developed countries at a low price, and then import expensive food and feed in an inefficient attempt to overcome protein deficits. Yet this is precisely the situation in some regions experiencing endemic protein malnutrition. Much can still be done to upgrade and utilize cottonseed protein where cotton is a commercial crop. In some regions soybean, peanut, or minor oilseed crops have promise, supplemented by useful cereals and legumes. Fish protein concentrate, leaf protein, and even single cell protein produced by microorganisms from petroleum or industrial and agricultural by-products will someday be utilized for human feeding.

The protein utilization problems are many—color, flavor, toxicity, cost, nutritional variability, quality control, acceptance and merchandising, to name a few. Close cooperation is needed between many disciplines from the agricultural sciences (to make the raw materials available) to social sciences (to determine how to incorporate new or supplemented foods into traditional diets without disruptive effects upon established cultural patterns). Otherwise, improvements of technology may be quite limited and changes induced even dangerous.

In conclusion it should be stressed that Nutritional Food Technology holds great promise for increasing the quantity and quality of world food supplies while reducing waste and inefficiency. However, the most brilliant application of technology alone cannot overcome suicidal population increases or undo the effect of widespread agricultural malpractices in developing countries. Technology provides a useful tool, but it is not a crutch or substitute for intelligent planning in the political-social sphere. It does little good to study and apply the complex laws of nature to render technical solutions while the simple laws of common sense are being ignored or even violated.

LITERATURE CITED

RECOVERY OF VOLATILE FLAVORS FROM CELERY

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ABSTRACT

Investigations were conducted on practical methods for recovering the essential oil from fresh celery in good yield. First, celery puree was flash vaporized in tubular heat exchangers into a distillation column where the vapors were concentrated and the essential oil removed to yield up to 17 ppm. Second, batches of celery puree were steam distilled and the vapors were passed directly to a distillation column for concentration and removal of the essential oil. This gave a yield of about 17 ppm of oil and eliminated fouling of heat exchanger tubes. A third procedure, which was a modified batch distillation method, was found to be the most successful. Batches of celery puree were heated rapidly and uniformly to remove the essential oil from the puree within a minimum time. The vapors were condensed at about 210° F into the top of a packed distillation column where a second distillation was conducted at slower rates. By conducting the second distillation the volume of aqueous phase condensed into the oil trap was materially reduced and a more efficient recovery of the essential oil was obtained. Up to about 28 ppm yield was obtained, which amounted to 89% of the essential oil indicated by analysis.

Dehydrated celery has little flavor and it is desirable that volatile flavor components be recovered and restored to the dried product. In previous investigations by Gold and Wilson (2) the essential oil was recovered from celery juice by essence recovery techniques in yields of 0.5-1.0 part per million. In 1965, Wilson (4) reported a method for separating celery essential oil by steam distillation of batch quantities of field-run celery. The yield of oil obtained by counter-current liquid-liquid extraction of the steam distillate was 3-7 ppm. This represents a five-fold increase in yield over that obtained by essence recovery techniques used by Gold and Wilson. However, there were substantial losses of essential oil through sorption on container walls and further losses were sustained in transfers during extraction.

Since preliminary analysis of celery leaves and stalks had indicated the presence of substantially more essential oil than had been recovered before, the current study was undertaken to provide a means of increasing yield to a practical point. This was done by grinding celery to a puree so that the oil need not migrate from the center of a large piece during distillation and by using a fractionating column to improve the operation. The yield of oil was increased to 28 ppm which was a four-fold increase over that obtained in previous studies.

EXPERIMENTAL

Pascal celery waste discarded during harvest at Belle Glade and Oveido, Florida, was used