Practical Considerations in Commercial Utilization of Oilseeds

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ABSTRACT

In the past 40 years oilseeds have gained a dominant position in the U.S. agriculture. Soybeans have made more rapid progress in the feed and food industries than other oilseeds because of the low cost in their production, easy adaptability to solvent processing, and importance to the feed and food industries. The foreign markets have been a great asset to the soybean industry. However, each of the other oilseeds is finding its special place in the industry through modification of the seed by plant breeding, the development of new techniques in oil mill processing and other technical modifications. Even geographical location of a crop can be a deciding factor in the economics of successful operation. Production and processing of oilseeds in other countries often presents economic and food acceptance problems that are entirely different than those in the U.S. Both the favorable and unfavorable factors involved in production, composition, processing and conversion of the protein concentrates into acceptable foods are discussed. The recent oilseed research and development which holds promise for increasing utilization of oilseed in foods is reviewed. This includes progress in the breeding of high protein soybeans, new centrifugal techniques for reducing the gossypol in cottonseed meal, progress in the development and production of glandless cottonseed, processing new varieties of sunflower seed, the potential for new and improved oil solvents, the advantages of extrusion processing of oilseed meals, and other techniques which might be expected to improve the color, flavor, texture and other properties of oilseed proteins for foods.

INTRODUCTION

This paper deals with the properties of the major oilseeds which are presently being processed into oil and meal, feeds and foods, and in the technical and economic factors which are important to their utilization. The oilseeds included are soybeans, peanuts, cottonseed, safflower, sunflower and sesame.

In assessing the future of the oilseeds industry it is necessary to take into account the ever changing values of the oil and protein. Since the beginning of modern oilseed processing in the U.S. the oil has been in greater demand and has had a higher price than the meal or protein. Presently a substantial surplus of oil exists and the excess over domestic requirements must be exported. The world's need for protein appears to be increasing more rapidly than the need for oil, which raises an important question on how to keep the supply of protein and oil in balance with demand. With the present trends the price of oil will go still lower and the price of meal will have to increase to cover the cost of growing and processing the seed.

In comparing the potential of the various oilseeds, factors as the relative quality oil and proteins, oil and protein yields per acre, color, flavor, protein solubility, functional and nutritional properties of the various protein concentrates and isolates must be evaluated. This introduces many problems other than evaluating the protein only for animal feeds as has been the custom during the early years of industry.

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SOYBEANS

Soybeans have made a great advance in the past 40 years and hold a dominant position in the oilseeds industry. The price of soybean oil and meal has markedly influenced the price of other oilseed products. There is a tendency among investigators and producers of other oilseeds to feel they are in competition with soybeans and perhaps they are but in a broader sense they are all in competition with each other.

Soybeans have an advantage over other oil seeds because of (a) their low cost of production, (less than 10 min of man labor per bushel), (b) their easy adaptability to solvent extraction, and (c) their important contribution to the animal feed industry. While the soybean protein ranks above all the other oilseed proteins nutritionally, the oil has had a relatively low rating as an edible oil. However because of its low cost, soybean oil is utilized in the largest tonnage, thus indicating the great importance of the basic cost of production in the success of a product.

The U.S. 1968 production of one and a tenth billion bushels of soybeans accounted for about 75% of the world's production. Soybeans have now reached a plateau so far as utilization in the U.S. is concerned and 25-30% of the crop of whole beans and an equal percentage of the oil must be exported; otherwise a market glut of both beans and soybean oil in our country would exist.

In competition for future markets it appears that protein will be in relatively greater demand than oil and thus the soybean has an advantage over most other oilseeds since it contains two parts of protein to one part of oil, whereas the other commercial oilseeds contain two to three parts of oil to one part of protein. It should be noted also that the approximate 8% of hull or seed coat on the soybean is substantially less than for most other oilseeds which vary in the range of 30% to 45%.

High Protein Soybeans

Soybean plant breeders are developing new varieties of high protein soybeans, regarding the ratio of protein to oil. It is too soon to predict the results of this new direction of plant breeding research but there are indications that soybeans containing more than 50% protein will be developed. With such a substantial increase in protein there will be some loss of oil. Maintaining the present yields is the difficult part of the breeding problem.

The use of soybean protein in food products has not developed with the speed that many people had anticipated. To gain a larger share of the food market, the soybean protein products need further improvement in flavor, color and protein solubility. Of these several factors flavor ranks as the most important.

PEANUTS

Peanuts, also called ground nuts, are grown in many countries throughout the world. World production of peanuts is about 18.3 million tons. The countries with highest production are India, Mainland China, Nigeria, Senegal and the U.S., in that order, with India producing an excess of six million short tons and the U.S. an excess of one million tons.

In comparing peanuts with soybeans there is a sharp contrast in the methods for their use in the U.S. and other countries. In the U.S. all the peanuts which pass the food grade standards, which amount to about 65% of the crop, are processed as whole peanuts for use in food products. About 65% of the food grade peanuts are used in peanut butter and the remainder are used as salted peanuts and in confections. The most recent development in peanut utilization is that of the low calorie peanuts developed at the Southern Regional Laboratory. The reduction in calories is effected by removing about 80% of the oil from the whole peanut by a pressure operation at a certain moisture level and then reforming the peanut to approximately its original shape. However this is still a limited area of utilization. The per capita consumption of peanuts in the U.S. is now in excess of 7.5 lb.

There are no major unsolved technical problems in the use of peanuts in the U.S. with respect to flavor, color or texture. Our government controls acreage, production and pricing, thus preventing the accumulation of a surplus. Peanuts that do not meet strict standards for food requirements are processed for edible oil by pressure methods, and the meal, if free of aflatoxin, goes to animal feeds or to fertilizer.

Peanut utilization in other countries has a different pattern. Outside the U.S. most of the peanuts are processed for oil or exported to other countries for oil processing. A very minor part of foreign grown peanuts or peanut protein finds its way into human food uses. It has been reported that two thirds of the world's peanut supply is processed for oil.

As an example of foreign utilization, India, the largest peanut producing country, processes her peanuts for oil and uses the defatted meal for animal feed or fertilizer. It is difficult to understand why peanuts, which are such a popular food in the U.S. are so unpopular as a food in India and many other developing countries. By way of speculation the difference appears to be partly because of the low social status of peanuts in India and partly because India has not yet solved the processing technology necessary for making the meal and protein acceptable for food uses.

Because of the relatively high price of oil in India the most economical use of peanuts would appear to be to remove the oil by a prepress solvent process and then to convert the defatted meal into protein concentrates and isolates for use in foods. A special project which has been supported by UNICEF and presently in development is the use of peanut protein isolate to extend buffalo milk, also called toning of the milk. Perhaps a workable alternative procedure would be to use peanut milk as an extender for the buffalo milk. The high fat content of buffalo milk (about 9%) makes its combination with peanut protein a very attractive project for India and probably for other countries also.

At present there is no significant commercial solvent processing of peanuts. However the Southern Regional Laboratory and others have made extensive studies of the process and their data indicate that it is a feasible operation. The most difficult step in the process is the preparation of full fat flakes. The high oil content of peanuts in relation to their protein increases the problem of making flakes strong enough for solvent processing. If the preparation of flakes should prove to be too difficult to control in commercial operation then the earlier suggestion of using a prepress solvent process should be feasible.

Because of the relatively good nutritive value of peanuts and their good characteristics for food utilization it appears that peanuts would have a great advantage over most of the other oilseed as a source of protein for developing countries.

On the negative side of peanut production and utilization are their substantial fertilizer requirements for satisfactory yield, which increases cost of production, and the strict requirement of aflatoxin elimination. Since these problems have been so well solved in the U.S. the urgent need for more food protein should stimulate the solution of these problems in other countries.

SAFFLOWER

Safflower, a thistle like plant, is an ancient crop; it was grown in the Nile valley and in other parts of Africa, as well as Asia and parts of Europe. In its historical past it was grown primarily for a red dye, which was obtained from its flowers, and used as a red coloring for rice, rolls and confections. Development studies and small scale production carried out in California, prior to 1950 led to its commercial production in the U.S.

In the U.S. safflower is grown west of the Rocky Mountains where production, which is still expanding, accounts for about one half of the world supply of 640,000 tons. Approximately one half of the U.S. production is exported to Japan. Next to the U.S. in safflower production are India and Mexico. In California safflower is usually planted in the fall and harvested in May or June. Yields in nonirrigated areas range from 350-1500 lb/A whereas on irrigated land the yields will range from 1800-3000 lb/A. Experimental yields of 2½ tons per acre have been reported.

Composition of Safflower

Although the original varieties of safflower seed grown in the U.S. contained 49-52% hull, the newer commercial varieties have only 35-45% and 55-65% kernel. The whole seed contains about 35-50% oil and 13-17% protein. A completely dehulled kernel contains about 60% oil and a completely decorticated and oil free meal contains 60-70% protein. Safflower has wide genetic variability and the plant breeders are developing brown-striped and white varieties which have thin hulls containing only half as much hull as the present commercial varieties. These new types of seed contain proportionately higher amounts of oil and protein.

The fatty acid composition of commercial varieties is 78% linoleic, 11% oleic, 3% steric and 6% palmitic acids. However new varieties which are called oleic acid types contain as much as 75% oleic acid. The iodine number of safflower oil ranges from 140-150.

The first limiting amino acid for safflower protein is lysine; its methionine and isoleucine are in a borderline concentration. A glucose-safflower protein ration supplemented with 0.35% lysine gave a growth response on chicks equivalent to a corn-soy ration. When fed as a single source of protein the safflower is not equal to that of the soybean; however if properly supplemented with other proteins it is valuable as a feed ingredient.

USES OF SAFFLOWER

When safflower oil was first introduced into the U.S. markets it was anticipated that it would be used as a drying oil and for the production of alkyd resins. However the chloresterol problem was presented to the U.S. public shortly after the appearance of safflower oil and it immediately found a premium in the food market. It has been reported that the oleic acid type oil can be used as a cooking oil.

Consideration has been given to the use of the protein for food. However its use in this area has been delayed because the meal has a bitter taste which is difficult to remove. Functional uses might be developed where only low concentrations are needed.

If protein concentrates and isolates are to be developed it would be necessary to remove the seed coat, which is not done in normal processing.

The agronomists, and particularly the plant breeders, have been largely responsible for developing a thistle into a valuable oilseed crop by improving its composition and yield. Their work promises further improvement in reducing the amount of hull and also in developing varieties with specialized fatty acid composition.

The premium which is paid for certain oils containing unsaturated fatty acids and its somewhat limited competition with other oilseeds in the Western area are factors which suggest that the safflower will maintain or perhaps improve its position in relation to the other oilseeds grown in the U.S.

SUNFLOWER

The world production of sunflower seed in recent years has increased to more than 3.4 million tons and this new interest in sunflower has spread to the U.S. especially in the cotton producing areas where cotton acreage allotments have been greatly reduced because of the cotton surplus. Up to this time much of the surplus cotton acreage has been used for soybeans, and the present soybean acreage in Louisiana, Mississippi and Alabama is more than that used for cotton. The new interest in sunflower is indicated by the domestic processing of 20 million pounds of oil in 1967.

Recent interest in sunflower in the U.S. appears to have been stimulated partly by their success in Russia and the availability of the new and improved Russian varieties. During the past 20 years scientists of the Soviet Union have developed high yielding, high oil varieties of sunflower that can be harvested by a combine, and Russia has become the world's largest producer of sunflower seeds. Sunflower production has increased also in other Eastern European countries and in South America, principally in Argentina. Since 1961 the world supply of sunflower seed oil has increased more than 60% and has surpassed that of peanut, cottonseed and coconut oils; now is second to soybean oil.

The export of sunflower seed oil into Europe by the Soviet Union has displaced part of the U.S. exports of soybean oil to that area. The recent increase of oil supplies, which is attributed mostly to increased production of sunflower and soybean, has caused a general reduction in oil prices. The price of sunflower oil at Rotterdam has decreased from an average of 12.2 cents per pound in 1961 to an average of 8.5 cents in 1968.

Sunflower oil is highly unsaturated and sometimes is called a drying or semidrying oil. It contains only traces of linolenic acid. It is regarded as a high quality oil and is reported to be much accepted in Europe as a salad and cooking oil, it is used also for making margarine and shortening.

Composition of Sunflower Seed

The new varieties of sunflower seed developed in the Soviet Union have a lower percentage of hull and a higher oil content than the varieties previously tested in the U.S. Technically the sunflower is a one-seeded fruit or achene. The seed has a translucent tissue-paper like covering which is the seed coat. In separating the achene into component parts, a portion of the seed coat appears in both the hull and kernel fractions.

Sunflower Seed Protein

An assay of the meal protein for essential amino acids showed adequacy for humans and pigs, except for lysine. For starting chicks the protein is short in lysine, leucine and threonine and probably in sulfur amino acids. The animal feeding tests which have been reported show that the meal can be used in feeds for nonruminants only at a rather low level. From the presently available data it appears that the nutritional value of the protein when used as a single source of protein in the diet is lower than that of most oilseed proteins. When used in food products it should be supplemented with other proteins, unless its primary use is functional.

Because of the greater value of oil to protein in sunflower seed and processing problems which arise from removal of the hulls the protein has not been seriously investigated for use in foods, feeds or industrial products. The dehulled and defatted meal is light in color, sweet in taste and high in protein, qualities not usually found in oilseed meals. Its sweet taste and light color suggest easy adaptability in food products.

Further processing of the dehulled and defatted meal into a protein isolate does not appear feasible. Extraction of the protein from the meal requires the use of an alkaline solution which causes the development of an undesirable green color in the protein, presumably because of the presence of chlorogenic or qunic acids or both. The sunflower seed protein, prepared by alkali extraction and acid precipitation and then washed with 70% ethanol had a nitrogen content of 18.69%, which is equivalent to a nitrogen to protein conversion factor of 5.34. However it does appear possible to prepare a protein concentrate by washing the dehulled and defatted meal with an acid solution or by washing with alcohol.

It does not appear likely that either a sunflower protein isolate or concentrate will be developed for food uses soon. In the present method of processing for oil most or all of the hulls are left in the system. The hulls assist in the perculation of the solvent through the meal and their separation later in the process would probably not be feasible. If the hulls were separated from the kernels prior to solvent extraction it is doubtful that solvent equipment now in use would operate satisfactorily and it would be necessary to develop a new solvent process.

The future of sunflower seed in the U.S. is still to be determined and it appears that its success will depend on yields per acre and the success of the farmer in protecting his crop from destructive pests including birds. Some agronomists have expressed their opinion that the present yields of sunflower are not high enough for a successful crop in the cotton area. Yields have been in the range of 1700-2100 lb/acre. The oil content varies widely; in the Red River Valley of the North the oil content is expected to reach 55%.

The Texas A&M Experiment Station as well as others are interested in developing new sunflower hybrid varieties which are expected to have greatly increased yields over the Russian varieties; some plant breeders have predicted yields as high as two tons per acre. If this high yield should be approximated, sunflower would be a very successful crop and would provide a very high quality of edible oil at a very low price. If the seed contains 50% oil it would produce as much as 2000 lb of oil per acre. If sunflower should become a substantial crop in the U.S. then the price of vegetable protein for food and feed would have to increase to pay the cost of oilseed processing. Speculation on the future of sunflower seeds in the U.S. is the most exciting factor in the oilseeds industry at the present time.

COTTONSEED

Cottonseed, which until recently has been second to soybeans in world production, with 22 million tons in 1968, has not been able to compete on an equal basis with soybeans in feed and food products because of its gossypol problem. Gossypol, although not present in the hull, occurs in the cottonseed kernel in a concentration range of 0.8% to 2.0%. The gossypol is harmless to ruminants but toxic to mongrastic animals, and cannot be fed to swine or poultry unless the gossypol is removed or its concentration greatly reduced. An acceptable concentration is about 0.04% for free gossypol.

The present method of high temperature processing of cottonseed causes part of the gossypol to react with the lysine of the protein and converts it from free to bound gossypol. Binding the gossypol to the protein eliminates its toxic effects but the loss of available lysine reduces the nutritional value of the protein. Gossypol when present in the meal and protein concentrates seriously darkens their color, which is an endesirable reaction when the products is intended for food uses.

Research has been going on for many years to find processing methods which will remove gossypol from cottonseed. Recently two methods have been proposed which will be briefly described.

AHW Process

This approach is a solvent extraction method which uses an azeotrope of acetone-hexane-water (42.5:55.0:2.5%) at a solvent to a flake ratio of 2.4 to 1 which extracts the gossypol along with the oil.

A vibrating screen extraction process has been described which uses a maximum temperature of 135 C and the extracted meal has a total gossypol content in the range of 0.08% to 0.17%, and an available lysine of 4.2 g/16 g of meal nitrogen. Feeding tests show that it can be used in cereal-based rations for feeding swine and poultry. However the use of impure acetone in the solvent results in reactions which develop unpleasant flavors and odors. These odors are attributed to the formation of diacetyl alcohol and mesityl oxide and prevent its use in foods. Further research and development is necessary to remove these undesirable flavors and reactions before this process can be used to develop products for the food industry.

The Liquid Cyclone Process

About 20 years ago it was discovered that when cottonseed is suspended in an organic solvent, such as hexane or a mixture of hexane and chlorinated hydrocarbon at a very low moisture level in the system, and is disintegrated in a colloid mill, the pigment glands are dispersed without breaking open. The pigment glands can then be separated from most of the protein by flotation or sedimentation, depending on the gravity of the suspending liquid. When suspended in a mixture of chlorinated and nonchlorinated hydrocarbons, which is adjusted to a specific gravity of 1.378, the glands float to the top. If the disintegration is carried out in hexane only, the hulls, coarse meal and pigment glands settle to the bottom. This mechanical process of removing unbroken pigment glands from cottonseed has been modified by increasing the force of gravity, by passing the disintegrated material through a liquid cyclone.

In this process two fractions are separated, one which is high in pigment glands or gossypol as well as carbohydrate components of the seed and the other low in pigment glands and high in protein. When the full fat meal is used in the liquid cyclone process it functions also as a solvent extraction process as well as for separating the pigment glands.

The high protein product is quite bland in flavor and has a light cream color. It contains 70% protein which is 98% soluble and contains less than 1% lipids. It contains about 0.04% to 0.07% free gossypol and 0.30% total gossypol and a lysine content of 3.85 g of lysine per 15 g of nitrogen. The product is suitable for use in swine and poultry feeds as well as for human food. Although at present the process is not in commercial operation there is no apparent reason to believe that it cannot be made successful.

Glandless Cottonseed

The most recent development in the cottonseed industry is that of glandless varieties of cottonseed which has many aspects of a dream product. In view of the potential of this new product for both feed and food, one feels that progress in planting commercial acreage is slow. The delay has been occasioned by the necessity for establishing that the fiber of the glandless cotton variety is the equivalent, in all its fiber characteristics. to that from the glanded varieties. This equivalence seems now to have been established and the glandless cotton planted for 1969 is estimated to be in excess of 4,000 acres.

Glandless cottonseed can be processed in the existing solvent extraction plants. In processing for use in food products it will be necessary to give strict attention to sanitary conditions, which has not been required up to this time in feed production. The dehulled and defatted glandless meal contains about 60% protein, is nearly white in color and bland in flavor. It has been reported that using available commercial equipment, it is feasible to produce a 70% protein concentrate from the glandless meal by air classification.

The nutritive value of the glandless cottonseed protein should be higher than that of the meal processed from the glanded varieties and should approach that of the soybean protein; there should not be a problem in its use in feeds for poultry and swine. The meal should sell at a price above that received for the glanded meals. As yet there has been very little testing of the glandless flour and concentrates in food products but there should be a vast improvement on the cottonseed protein concentrates presently on the market which are derived from the glanded varieties. Since the glandless products have better color and flavor than corresponding soybean products and the cost of production should be comparable to other oilseed protein concentrates there should not be a serious problem in finding substantial foreign as well as domestic markets for these products.

SESAME

The world production of sesame seed is about 1.5 million tons. The principal producing countries are Mainland China, Taiwan, India, Latin America, Africa and Mexico. The U.S. has imported annually in the range of 13-24 million pounds in recent years, most of it being used in the baking and confectionary industries and some crushed for oil.

In Latin America, the oil, which is easily refined, is considered to be the "Queen" of vegetable oils, the most outstanding characteristic of which is stability. This remarkable quality is derived from a powerful antioxidant, found in the unsaponifiable fraction and called sesamolin, which on hydrolysis yields sesamol, a methylene ether of oxyhydroquinone.

Composition

The sesame seed contains oil in the range of 48-55% and proten 20-26%. The oil has an iodine number of 112 and is made up of about 44% linoleic acid, 42% oleic and 13% saturated acids. In processing the sesame seed for food it is necessary to eliminate the hulls as they contain oxalates. The dehulled and defatted meal contains protein in the range of 45-61%.

The limiting amino acid in sesame protein is lysine. It has been demonstrated that when sesame protein was used at a 20% level, as the only source of protein in a chick ration a good growth was obtained by supplementing it with 0.5% lysine. However the sesame protein has an excess of methionine. It is well known that sesame and soybean proteins supplement each other nutritionally. Thus the sesame protein would fit very well into food and feed programs. So far as is known the sesame meal is free of antigrowth factors. Preliminary tests have indicated sesame yields of 800-1200 lb of seed per acre in some southern areas of the U.S. This yield would appear to be adequate for a commercial crop.

The excellent properties of sesame oil and good quality of the protein indicate that sesame would be a good oilseed for replacing the decreasing cottonseed acreage. However because of its character of uneven ripening sesame seed has a serious problem of shattering from its pod before or during harvesting or both. In countries with low labor costs sesame is harvested by hand.

A plant breeding program was initiated at the South Carolina Experiment Station, Texas A & M and Nebraska in the 1940's. As yet, nonshattering strains with sufficient yield and suitable harvesting characteristics have not been developed. Until this program is successful the U.S. must import its requirements of sesame seed and seek some other oilseed to replace the decreasing cottonseed acreage.

DISCUSSION

Because of excessive production of soybeans in the U.S. over our domestic market requirements there must be an increase in our export markets of soybeans, oil and meal to maintain a reasonable price for these products. Although the price of protein remains good the price of oil is very low, indicating an imbalance in the productions of these two products.

Since the U.S. uses peanuts mostly as whole peanuts, their production here has little or no effect on domestic markets of oil and protein. The updating of peanut processing in foreign countries could make a valuable contribution to their protein requirements.

Safflower oil has good domestic and foreign markets and minimum competition from other oilseeds in its present area of production and should maintain or possibly increase its economic position in relation to other oilseeds.

Sunflower seed requires further testing in the U.S. before its success as a replacement crop for vacated cotton acreage can be determined. If new hybrid varieties should meet yield expectations of two tons of seed per acre sunflower would be a successful oilseed crop in the U.S. A successful sunflower seed crop will further depress the domestic price of oil.

The new liquid cyclone process for extracting oil and removing gossypol from cottonseed is a promising commercial operation. The liquid cyclone equipment looks promising also for the solvent extraction of other oilseeds for the food industry. The development of glandless varieties of cottonseed, with its nearly white and tasteless meal is an exciting new development for the cottonseed industry.

New nonshattering varieties of sesame must be developed before this crop can be produced successfully in the U.S.

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