FORTIFICATION OF SUGAR COOKIES
WITH
COTTONSEED FLOUR

by

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To my husband, Alfredo, my daughter, Isvette, and
my parents, Miguel and Yolanda.

INTRODUCTION

Cottonseed flour as a protein supplement could play an important role in feeding the malnourished and protein deficient people of underdeveloped areas as well as the growing populations of the industrial areas. Protein malnutrition is a major problem for much of the population of a country such as Venezuela.

Increased interest has developed in the nutritive value of plant proteins that may serve in the diet to extend and partially replace proteins of animal origin such as meat, milk and eggs. Cottonseed flour offers excellent possibilities for supplementing other plant proteins for products with good nutritive value and is suitable for use as human food in a variety of ways.

A very practical question is whether a protein-rich product such as cottonseed flour (CSF), should be made available as such, in the hope that it will be used to supplement the proteins in the basic diet, or whether it should be mixed with some other food to give a more complete food. For nutritional and practical reasons it seems best to use the protein-rich food mixtures of high protein quality and quantity, which can serve as protein supplements to basic diets or as complete foods (Bressani, 1966).

Baked products have been fortified with another vegetable protein flour, soy flour, to improve their nutritional quality. Soy flour, however, is not readily available in Venezuela, but cottonseed flour could be obtained and utilized to improve protein quality of baked products.

Some work using cottonseed flour in baked products, such as bread, cookies and tortillas, has been done (Tsen, 1971, 1975; Bressani, 1965; Bressani et al., 1966; Hulse, 1974; Green, 1976, 1977). Most agree that the product is highly acceptable, indicating that cottonseed flour can improve the nutritive value and be used to make a tasty and toxic-free product when the gossypol has been removed.

The purpose of this study was to improve the protein quality of sugar cookies by substituting cottonseed flour for a portion of the wheat flour. Cookies could provide a convenient means of supplementing protein in diets of children in poverty areas. They could be prepared at a central location and distributed to schools for use in lunch or other feeding programs.

REVIEW OF LITERATURE

Malnutrition in Latin America

Buchanan and Stewart (1977) did an 18 month study of malnutrition in Latin American countries. They found that the most severe and greatest number of cases of malnutrition occur in the shanty towns on the fringes of the larger cities. Rural and isolated areas of most Latin American countries also experience serious malnutrition problems. The most prevalent condition is caloric/protein deficiency. Milner and Abbott

(1969) reported that protein malnutrition is a major problem for much of the population in Venezuela. The average consumption of animal protein is 24 grams/person/day in contrast to an average consumption of 64 grams/person/day in the United States.

Barros (1971) noted that one half of the children of Latin America die before they are 15 years old. According to Bengoa and Donozo (1974) a national survey in Venezuela in 1971 indicated severe protein-caloric-malnutrition (PCM) in 0.9% of over 57,800 children who ranged in age from one to six years. Moderate PCM was found in 14.5% of those children. Factors contributing to the severe malnutrition in Latin America include: poor food habits, low income, inadequate processing, handling, storage and distribution technologies, contaminated water supplies and inadequate and/or ineffective government nutrition policies. As expected, economic factors including the high cost of processing and the resultant relatively high price of processed foods, coupled with the low income of many consumers, were mentioned most frequently as significant causes of malnutrition.

During the last 20 years both food production and population have been increasing in Latin America at about the same rate, now close to 3% per year. As a consequence, the per capita production has not been modified significantly. This problem could become more serious in the near future because the present trend of population growth demands a rapid increase in food production, particularly in the less developed countries, which is precisely the area where food production is in many instances already lagging behind (Behar, 1971).

Ridlchuber and Gardner (1974) and Wilcke (1971) said that an adequate supply of low cost, high quality protein food is needed to break the vicious cycle of poverty, malnutrition and disease. They also agree that there is a real need to fortify cereals as inexpensively as possible during the period of economic development of the various populations. Cereals will remain the primary source of food and protein in the world and, therefore, an important key to the solution of the world food problem (Quentin, 1969).

Already in some parts of the world such as Central and South America, India and Africa, efforts are under way to obtain by conventional processing cereal products suitable for use in food preparation. Considerable progress has been made, and many children and adults are receiving the benefits of increased nutrition through the use of vegetable protein flours, but there is still much room for improvement.

Oilseed Proteins as Human Food

Cottonseed proteins. Mattil (1971) noted that the production of over 28 billion kilograms of oilseed proteins was equivalent to 25 grams of protein per person per day for three billion people. He indicated oilseeds are plentiful and are ordinarily processed industrially, hence they are available for reworking into suitable forms for human consumption.

Cottonseed protein has not been used widely for human food even though the seed kernels contain about 50% protein. One reason was the presence throughout the kernel of minute pigment glands, 50 to 400 micrometers in size, containing gossypol and related pigments. Gossypol is a highly reactive yellow polyphenolic binaphthaldehyde peculiar to the cotton plant (genus gossypum) that has deleterious physiological effects on single-stomached animals such as man. The liquid cyclone process (LCP) has been developed to remove intact pigment glands, packaging the gossypol inside those pigment glands by differential centrifugation in a non-polar solvent such as hexane. The process simultaneously separates the oil (lipids) and concentrates the protein (Anon. 1973) (see Appendix, Table 1A).

Cottonseed proteins have several advantages over soya proteins including a bland taste in contrast to the "beany" taste of soya proteins and greater dispersability in water than soya concentrates.

Cottonseed flour first was used for the purpose of enriching wheat flour by Jones and Divine (1944). Five parts cottonseed flour added to 95 parts of wheat flour produced mixtures containing 16-19% more protein than wheat flour alone and a protein combination that was definitely superior in its growth-promoting value for the same quantity of protein from wheat flour.

Extensive research carried out at INCAP on food containing variable amounts of cottonseed flour has indicated it is safe, nutritious, inexpensive and palatable, when used for human food (Braham et al., 1965b and Bressani et al., 1966, 1967). Using cottonseed protein to supplement low-protein quality diets was studied by Kuppuswany et al. (1949) in India. Their results indicated that 10% cottonseed protein supplement was capable of improving quality of South Indian diets, supplying some of the deficient amino acids as well as additional protein.

Braham et al. (1965b), Bressani et al. (1966), and Scrimshaw et al. (1961) have conducted research on the human consumption of vegetable protein mixtures that contained cottonseed flour as the main source of protein. The flour was found to be high in protein quality.

Bressani and co-workers (1966) stated that cottonseed protein, although still not very well known as a protein supplement for humans could play a very important role in overcoming the deficit in needed quantity and quality of the protein existing in the world today. He pointed out some advantages of using cottonseed protein in food: a) cottonseed flour has a relative large amount of protein in an acceptable quality; b) cotton is grown in practically all areas of the world where there is a deficit of dietary protein and where protein malnutrition prevails; c) since it is grown for its fiber, the oil and residual protein from its seeds are more economical in comparison with other oilseeds; and d) using the technology available today and with proper processing it can yield a product which is adequate for human use. Bressani also has carried out research in the past few years at INCAP in the development of several vegetable protein foods containing from 9 to 38% protein concentrate.

Graham et al. (1969) and Craviote et al. (1962) studied nitrogen balances of malnourished children. They indicated that absorption of nitrogen was equal for the cottonseed protein and milk protein tested. Cottonseed flour was concluded to be a fair protein source. Cottonseed protein has a high protein efficiency ratio (PER) of 2.4 as compared to a PER for casein of 2.5 (Martinez et al., 1970a).

Venkatachalan (1971) tested the nutritive value of cottonseed flour (CSF), CSF+lysine and CSF+skim milk. The amount of lysine added to the diet of the group receiving CSF+lysine was 2.5 g/16 g N. None of the children responded to the CSF diet alone. In the CSF+lysine group, 6 out of 12 children, and in the CSF+skim milk group 9 out of 12 children showed satisfactory clinical responses. By the 30th day, the increase in serum albumin in the CSF+lysine group was $0.59 \pm 0.028\%$, and it was $0.81 \pm 0.142\%$ in the CSF+skim milk group. The best response was obtained when superior quality cottonseed flour with very low gossypol content was used with skim milk. However, the experiment did not include another group receiving the superior cottonseed flour plus lysine.

Castro et al. (1976) fed young rats a protein-free but otherwise nutritionally adequate diet and the same diet supplemented with 10% protein (N x 6.25) from casein, LCP cottonseed flour, soy concentrate, soy isolate, triticale, wheat or rye. The average weight gain of the rats receiving the 10% LCP cottonseed protein diet was greater than that of the rats receiving any of the other experimental diets.

Hulse (1974) fed young rats bread containing 10 parts cottonseed flour and found significantly higher rates of gain per gram of nitrogen consumed with cottonseed flour bread than with bread without the cottonseed flour. When the breads were fed at the same percentage by weight, the higher protein content in the cottonseed flour bread brought about significantly higher rates of weight gain. The use of cottonseed protein as protein supplements represents, at the moment, the most important role which cottonseed can and will play feeding the malnourished and protein deficient people of underdeveloped areas (Bressani, 1966).

Amino acid composition. The amino acid composition of a protein is the most important factor determining its nutritive quality. The essential amino acid pattern of cottonseed protein in the form of flour is shown in Table 1. It compares favorably with the FAO amino acid requirement pattern for the adult human. Cottonseed proteins are slightly low in lysine and high in leucine, and also contain relatively large proportions of non-essential amino acids.

Bressani (1966) reported that cottonseed flour contains a large proportion of non-essential amino acids, 70%, and 30% essential amino acids. Animal protein contain about 50% of their nitrogen as essential amino acids. The nutritional significance of this has not been studied. Harden and

Table 1. Amino acid composition in g/100 g protein (16 gN) of edible grade cottonseed protein concentrate (Bressani, 1965) with reference to the FAO pattern for high quality proteins (Harden and Yang, 1975).

Amino Acid	Cottonseed	FAO Reference Protein
	(g)	(g)
Lysine	3.30	4.2
Threonine	2.46	2.8
Valine	3.25	4.2
Methionine	1.40	2.2
Isoleucine	2.42	4.2
Tyrosine	2.58	2.8
Phenylalanine	4.17	2.8
Leucine	6.46	4.8
Tryptophan	0.86	
Cystine	1.45	
Aspartic acid	8.01	
Glutamic acid	15.99	
Serine	3.77	
Proline	2.68	
Glycine	2.75	
Alanine	4.13	
Histidine	1.98	
Arginine	7.15	

Yang (1975) reported the amino acid pattern of dough made with wheat flour and with wheat flour plus 18% CSF had higher amounts of essential amino acids than the wheat bread (Table 2).

Acceptability. Vegetable protein mixtures containing cottonseed flour have been tested for acceptability and tolerance by different rural population groups in several Latin American countries. In all of these trials, the mixtures were highly acceptable. The INCAP group reported that vegetable protein mixtures containing cottonseed protein in the form of cottonseed flour have already found a successful market in several countries in Latin America. Venezuela has started testing one of those formulas, number 9, which includes: 38% CSF, 29% maize, 29% sorghum, 3% torula yeast, 1% calcium carbonate, 4,500 I.U. vitamin A; and first reports indicated it should be successful (Bressani et al., 1967).

Research at Texas A & M University indicates several potential uses of cottonseed flour in baked goods and meat applications. These products should have a ready market in school lunch programs (Martinez et al., 1970b).

Baked products. Cottonseed protein in the form of flour is used to supplement cereal grain flour to prepare such bakery products as cookies, crackers, bread, doughnuts and other foods. Amounts between 1 and 6% cottonseed flour reduced dough stickiness, improved machining properties, reduced fat absorption and increased shelf-life of the baked products (Bressani et al., 1966).

Overman (1951) reported that 3 to 10% cottonseed flour

Table 2. Essential amino acid content (g/100 g protein) of dough and baked bread made from wheat flour and from 82% wheat plus 18% cottonseed flour (CSF), (Harden and Yang, 1975).

Amino Acid	Wheat		Wheat+CSF	
	Dough (g)	Baked (g)	Dough (g)	Baked (g)
Lysine	3.0	2.5	4.3	3.8
Threonine	3.4	3.4	3.5	3.6
Valine	4.6	4.0	5.0	5.0
Methionine	1.9	1.7	2.1	2.0
Isoleucine	4.0	3.9	4.0	4.0
Leucine	8.4	8.3	8.7	8.3
Tyrosine	3.1	2.9	3.3	3.3
Phenylalanine	5.8	6.3	7.0	6.7

delayed the development of organoleptic rancidity in raw food mixes and was effective to a lesser extent in baked pastry. This property has been attributed to the tocopherols with antioxidant properties, which are present in cottonseed flour. He said that baked pastry containing 10% cottonseed flour kept more than ten times as long as baked pastry made with wheat flour alone.

Bacigalupo (1969) studied cottonseed flour with gossypol extracted in two ways; a hexane-water-acetone process and the Protal process with a prepress, hexane-defatted, heat treatment. He found the best results were obtained when Protal was added at the level of 10%, and commercial scale tests also showed that acceptability of whole wheat type bread containing 10% Protal was good. It was considered one of the highest quality breads in the city of Lima (Peru).

Dalby (1969) studied the acceptability of bread containing up to 25% cottonseed flour but the dark, heat-treated cottonseed flour gave rise to an unacceptable color. Baladi bread, the traditional bread of Egypt and other near Eastern countries, was supplemented with two samples of cottonseed flour low in gossypol. The first of these cottonseed flours was made from a glandless cottonseed variety; the second was rendered gossypol-free by solvent extraction. Dalby stated that 7% cottonseed flour containing roughly 60% protein, provided protein supplementation equivalent to 12% nonfat milk solids. The 7% added cottonseed flour required 3.5% additional water. Both cottonseed flours produced bread noticeably darker in color than the control, although flour from the glandless variety was significantly lighter than the degossypolized flour.

Fogg and Tinklin (1972) used two grinds and two levels of each grind of glandless cottonseed flour. A basic sugar cookie formula was used as the control. The water binding properties of CSF protein adversely affected tenderness, width, height, spread, weight and specific volume of the cookies. Control cookies were more acceptable than those containing CSF. It appeared that the levels of CSF substituted increased levels of all essential amino acids, therefore, the overall protein quality of cookies containing 6% CSF could add needed dietary protein.

Another product that has been fortified with cottonseed flour is tortillas. Green et al. (1977) found that tortillas can be protein fortified by utilizing the traditional means of preparation and incorporating blends of undefatted glandless cottonseed kernels in sufficient quantities to provide a total of 12, 15 and 18% protein in the blends. This provided a significant increase from 10.5% protein in the corn control to a maximum of 18% protein in the blends on a dry basis and a 42% increase in protein. Amino acid profiles of the cooked tortillas indicated an increase in both the quality and quantity of protein when glandless cottonseed kernels are utilized in blends with corn to make corn tortillas. Furthermore, both the control and cottonseed fortified tortillas were preferred to soy-blend fortified tortillas.

Green and co-workers (1976) used three oilseed flours; deglanded LCP cottonseed flour, glandless cottonseed flour and high nitrogen solubility soy flour to fortify corn tortillas. Analysis of variances of panel scores indicated that panel members had no preference among the corn control tortillas and tortillas fortified with LCP and with glandless CSF. They did, however, show a significant preference for each of these tortillas over soy fortified tortillas. The color of tortillas fortified with glandless and LCP CSF darkened noticeably.

Soy flour in cookies. More work has been done with soy flour to increase protein level of baked products than with cottonseed flour. Fortifying wheat flour with full fat soy flour in making baked products can raise protein content, balance essential amino acid content and increase the caloric value. High protein cookies made from wheat flour fortified with soy flour or protein concentrates and isolates could be successfully marketed. Such high protein cookies, of course, also can be used satisfactorily to supplement dietary protein in child feeding programs at school day care centers and other institutes in poverty areas of the world and, thereby, help alleviate protein malnutrition. Such fortification, however, can adversely affect both rheological properties and baking quality of wheat flour (Tsen and Hoover, 1973).

Emulsifiers to improve high protein baked products. Sodium stearoyl-2-lactylate (SSL) and calcium stearoyl-2-lactylate (CSL) have been used to increase the stability of dough made with high protein flours, particularly the soy flours. SSL and CSL are the reaction products of two naturally occurring food components, stearic acid and lactic acid, neutralized to the sodium or calcium salts. SSL and CSL exhibit the characteristic hydrophobic and hydrophilic structures. SSL and CSL function in food systems as a,emulsifiers, stabilizers, dough conditioners, or processing aids. Fleming and Sosulski (1974) found that in the absence of supplementary gluten, the addition of soy flour to the wheat flour caused proportional decreases in loaf volume and crumb grain. Gluten provides the structural framework which determines the volume of the loaf. This framework is weakened by dilution with soy flour as evidenced by loaf volume depression. Added SSL and CSL were markedly superior to any other dough conditioners to improve the quality of the loaves, and SSL gave superior results when compared with CSL.

Tsen and Hoover (1971) found that SSL and CSL, added to a sponge formula at 0.25% to 0.50% levels, can spare or replace shortening normally required in white (plain) bread containing 12% soy flour. SSL was more effective than CSL in sparing shortening in producing high protein bread; 0.50% SSL replaced all shortening and gave a loaf superior in volume and loaf score to one with 3% shortening.

Knightly (1973) reported that SSL possessed both dough conditioning and emulsifying properties. In breaking studies, the author found that SSL improved dough strength, and the weakening effect of sugar, eggs, high protein flour (soy flour) and NFDM was countered in yeast-raised sweet goods.

Tenney et al. (1972) reported that SSL produced more homogenous cake batters with smaller and more uniformly distributed air bubbles than batters prepared without emulsifier. They also said that these studies have shown SSL functions by aiding the formation of a homogeneous stable system with very finely divided fat droplets.

Marnett and Tenney (as reported by Knightly, 1973) found that the calcium salt of stearoyl lactylate was relatively soluble in aqueous mediums and possessed less emulsification power than would be desirable for cake batters. Calcium stearoyl-2-lactylate is also essentially insoluble in fat and thus its dispersibility is not improved by solution in the shortening. It was chosen for use in bread and other low-fat, yeast-raised goods because of its superior dough conditioning properties as compared with other stearoyl lactylate salts. Breads with an acceptable loaf volume could be made from wheat flour fortified with up to 20% whole or dehulled soy product by adding 0.5% SSL.

Tsen et al. (1975a) also reported high protein cookies baked from flour fortified with 12% soy and 0.5% SSL. Chocolate chip, coconut, oatmeal and sugar cookies, in preliminary organoleptic evaluations for both flavor and texture, were rated acceptable for flavor. Their appearance and color were similar to unfortified cookies. Tsen et al. (1975b), in another study, evaluated SSL for effectiveness in improving the quality of sugar cookies made from soft and hard red winter wheat (SRW and HRW) flour with two different baking methods. The surfactant improved cookie spread and top grain scores more when creamed into a shortening and sugar mixture than when used in a powder form. Consumer acceptability of cookies was evaluated by elementary school pupils. Results indicated that children would have no preference between cookies made from SRW or HRW flour treated with 0.5% SSL. Sodium stearoyl-2-lactylate effectively improves the quality of regular and high protein cookies made from the SRW flour.

Hutchinson et al. (1977) reported the use of SSL to improve the shelf-life of cookies. After three months, texture scores were high with 0.375% SSL. On storage, the cookies hardened with all levels of surfactant, but the percentage change was less at the SSL levels above 0.375% than at levels below 0.375%.

Del Vecchio (1975) found that with 0.4 g SSL per 540 g dry mix, SSL increased cake volume by 25 cc from 1300 to 1325 cc, but with 1.0 g SSL, the volume decreased by 15 cc compared to the control. The number of tunnels was decreased with both levels.

Xanthan gum, a high molecular weight natural polysaccharide, is produced in a pure culture fermentation of Xanthomonas campestri growing in glucose, a suitable nitrogen source and hydrogen phosphate. It contains five sugar units; two glucose, two mannose and one glucouronic acid. The gum gives starch doughs the strength and elasticity to rise, and it is promising for use in baked products for persons allergic to gluten (Anon., 1975). It forms foam cells and expands with air and carbon dioxide generated by yeast or leavening agents such as baking powder or soda. Xanthan gum improves the cohesion of starch granules and produces a bread-like structure comparable in appearance, mouth feel, loaf volume, and staling to most commercial breads. Xanthan gum maintains specific loaf volumes of both wheat and corn starch breads and is suitable when soy concentrates or isolates are added (Christianson et al., 1974). Workers at North Regional Research Center also have indicated that xanthan gum is promising for making high protein products; they replaced as much as one-fourth of the starch with an equal weight of 73% protein soy concentrate or a soy isolate with 95% protein. Even with total protein up to 22%, additional dough strengtheners or improvers were not necessary. With addition of xanthan gum, dough absorption increases as does the time required for dough development, primarily because more water and time are necessary for hydration of xanthan gum. Dough stability increases when xanthan gum is added to unbleached soft wheat flour. This unique aspect indicates the effectiveness of xanthan gum as a gluten substitute, especially during mixing (Christianson, 1976).

Ranhotra et al. (1975) said that soy flour and soy protein concentrates could not be used at high levels without severely decreasing bread quality. They found that the use of shortening, yeast, gum and soy flour or concentrate in amounts exceeding 1.9% xanthan gum, 10% shortening, 7.5% yeast, and 0, 20, 30, and 40% soy did not improve bread quality further and strict adherence to water requirements of batters is imperative to the production of good quality bread.

MATERIALS AND METHODS

Cookies were prepared according to the formula given in the Appendix (Table 2A). The basic sugar cookie formula was the same as the one used by Fogg (1971). To increase the protein level, 12, 24, 36, and 48 percent LCP cottonseed flour was substituted for that portion of the wheat flour of the basic formula. To improve eating quality, two surfactants, SSL and XG, were added to the formula at the 1% level. Each of the various levels of cottonseed flour with one of the surfactants constituted a replication (rep). Reps were prepared in random order.

Ingredients and Preparation

Ingredients, except eggs, were procured in quantities sufficient for the entire study at the start of the experimental work. Fresh eggs were obtained weekly as needed. Liquid cyclone processed cottonseed flour was obtained from the Southern Regional Research Laboratory (SRRL) of the United States Department of Agriculture.

Analysis of the LCP cottonseed flour as determined by

SRRL is given in the Appendix (Table 3A). The cottonseed flour and hydrogenated shortening were stored at 3°C until used. Other ingredients were stored at 22°C ± 1°C. One day before each of the baking periods the cottonseed flour, wheat flour, cream of tartar, sugar, soda, salt and either xanthan gum (XG) or sodium steroyl-2-lactylate were weighed. Shortening and eggs were weighed on the day of baking. All ingredients were at room temperature for mixing.

In the preliminary work 1.0% surfactant (XG or SSL), based on the total weight of the flour, was found to give good results with the levels of cottonseed flour we were using. Lemon extract was added to alter flavor of the high protein cookies. The mixing method used in this study is given in Table 4A. Cookie dough was divided into two equal portions before rolling. One portion was rolled 4 mm thick by using metal guides and cut into 50 mm diameter circles. These cookies were used for all subjective and objective evaluations except shortness.

The second portion of dough, used for shortness evaluations, was rolled 2 mm thick and cut into strips using a special cutter (Appendix, Fig. 1a) 80 mm x 18 mm designed and made for use with the shortometer (Appendix, Fig. 1b). Cookies 2 mm thick were baked 10 min, and the 4 mm thick cookies were baked 15 min in an electric rotary-hearth oven maintained at 191°C (375°F) (see Appendix, Fig. 2). After cooling at room temperature on wire racks for one hour, cookies used for shortness were evaluated. All other cookies were placed in plastic bags, sealed and held at room temperature 18 hours until other evaluations were done.

Evaluation

Eating quality was evaluated 18 hours after baking by a panel of six selected students and faculty members in the Department of Foods and Nutrition and trained to evaluate shape, surface characteristics, color, aroma, texture, tenderness, and flavor of cookies. The score card was designed using a seven point rating scale with seven considered very desirable (Appendix, Fig. 3). To evaluate shelf life of the cookies, two cookies of each variable were stored in air tight plastic bags, 21 x 16 cm. Cookies again were assessed subjectively by the investigator after one and two months of storage.

Moisture. Percentage moisture was determined by the C.W. Brabender semi-automatic rapid moisture tester (model SAS). The instrument was preheated for 60 minutes to 120°C. The cookies were pulverized in a Waring blender (model FC1-15) and kept covered with wax paper until weighed. Duplicate 5 g samples of each variable of cookies were spread evenly on the bottom of the teflon coated pans and again covered with waxed paper until ready to place in the preheated instrument. Readings were taken after the samples dried 50 min.

Color. Color differences were determined by using the Gardner automatic color difference meter, model # AC-2A. Standardization was done before each sample was read using a light brown ceramic tile with the following reading: Rd (reflectance), 37.6; a (redness), +6.2; b (yellowness), +14.9. Readings were taken by placing the cookie in a clear glass petri dish so the center bottom surface of the cookie was measured. Four readings were made, rotating the sample 90° after each of the first three readings.

Amino acid analysis. Amino acid analysis for samples of baked cookies that contained 0, 12, 24, 36, 48% cottonseed flour plus 1% XG and 24% cottonseed flour plus 1% SSL were determined using a Beckman 120C amino acid analyzer by personnel in the Department of Grain Science and Industry. Samples were hydrolyzed for 31 hr with p-toluenesulfonic acid for determination of amino acids (Bates, 1977).

Spread ratio. Spread ratios were determined according to the method of Tsen et al. (1975b) after the cookies had cooled one hour. Six cookies were randomly chosen from each variable and laid end to end for width measurement (W) and stacked for thickness measurements (T). The relationship W/T is the calculated spread ratio.

Tenderness. Tenderness of the cookies was determined using the Bailey shortometer (Appendix, Fig. 1b). Six randomly chosen samples of each replication of each variable were measured by placing the cookie across the supporting bars and recording the weight in grams required to break the sample with the movable third bar.

Analysis of Data

Data for each measurement were analyzed using the following analysis of variance (ANOV). Four replications were done for each combination of kinds of surfactant and amounts of cottonseed flour.

Source of Variation	D/F
Kind of surfactant (K)	1
Error (a)	6
--	
Amount cottonseed flour (A)	4
K x A	4
Error (b)	24

For shelf-life studies, the following split plot ANOV designs was used.

Source of Variation	D/F
Kind of surfactant (K)	1
Error (a)	6
--	
Amount cottonseed flour (A)	4
Length of storage (M)	2
MA	8
KM	2
KMA	8
Error (b)	84

When treatments on interactions were significant, least significant differences (LSD) $p \leq 0.05$ were calculated.

RESULTS AND DISCUSSION

Fresh Cookies

The mean squares and probabilities for objective and subjective evaluations in which no significant interactions were found between kind of surfactant and amount of cottonseed flour appear in Tables 3 and 4. Mean squares and probabilities for objective and subjective evaluations with significant interactions between kind of surfactant and amount of cottonseed flour appear in Table 5.

Analysis of variances of some objective evaluations (Table 3) indicate no significant differences for percentage moisture of any of the cookies, but the amount of cottonseed flour in the cookies does result in significant differences in color; reflectance (Rd), redness (a) and yellowness (b).

Subjective evaluations (Table 4) where no interaction between the kind of surfactant and level of cottonseed flour was indicated also resulted in significant differences for amount CSF in all properties evaluated; tenderness, texture, shape, color, and overall acceptability.

In Table 5, the mean squares for subjective and objective evaluations with significant interactions indicate kind of surfactant did not result in significant differences; but the amount of cottonseed flour was significant for spread ratio, tenderness, and aroma.

Amount of cottonseed flour. In Table 6, the mean scores for eight replications of several measurements with the five

Table 3. Mean squares and probabilities for objective evaluations with no significant interactions between kind of surfactant (K) and amount of cottonseed flour (A).

Source of Variation	D/F	Moisture, % MS	Moisture, % (Prob.)	Color Rd MS	Color Rd (Prob.)	Color a MS	Color a (Prob.)	Color b MS	Color b (Prob.)
Kind of surfactant (K)	1	0.182	(0.608)	23.271	(0.559)	19.768	(0.165)	0.795	(0.681)
Error (a)	6	0.624		60.261		7.921		4.254	
Amount (A)	4	0.139	(0.451)	39.715	(0.006)*	37.303	(0.000)*	7.120	(0.000)*
K x A	4	0.008	(0.994)	5.269	(0.644)	3.211	(0.397)	0.776	(0.254)
Error (b)	24	0.146		8.322		3.028		0.542	

Table 4. Mean squares and probabilities for subjective evaluations with no significant interactions between kind of surfactant (K) and amount of cottonseed flour (A).

Source of Variation	D/F	Analysis of Variance							
		Surface		Color		Texture		Tenderness	
		MS	(Prob.)	MS	(Prob.)	MS	(Prob.)	MS	(Prob.)
Kind of surfactant (K)	1	0.018	(0.847)	0.317	(0.345)	0.199	(0.490)	0.170	(0.376)
Error (a)	6	0.448		0.360		0.368		0.197	
Amount (A)	4	1.451	(0.004)*	1.712	(0.001)*	5.286	(0.000)*	1.982	(0.000)*
K x A	4	0.184	(0.638)	0.412	(0.135)	0.173	(0.280)	0.089	(0.525)
Error (b)	24	0.284		0.212		0.128		0.108	

Table 4. (Continued)

Source of Variation	D/F	Analysis of Variance					
		Flavor		Shape		Overall	
		MS	(Prob.)	MS	(Prob.)	MS	(Prob.)
Kind of surfactant (K)	1	1.689	(0.028)	0.053	(0.560)	0.989	(0.082)
Error (a)	6	0.206		0.243		0.227	
Amount (A)	4	5.636	(0.000)*	0.567	(0.002)*	3.438	(0.000)*
K x A	4	0.099	(0.603)	0.175	(0.149)	0.153	(0.301)
Error (b)	24	0.143		0.094		0.119	

Table 5. Mean squares and probabilities for objective and subjective evaluations with significant interactions between kind of surfactant (K) and amount of cottonseed flour (A).

Source of Variation	D/F	Analysis of Variance					
		Spread Ratio		Tenderness		Aroma	
		MS	(Prob.)	MS	(Prob.)	MS	(Prob.)
Kind of surfactant (K)	1	0.497	(0.485)	0.588	(0.453)	0.370	(0.475)
Error (a)	6	0.898		0.917		0.639	
Amount (A)	4	5.853	(0.000)*	7.287	(0.000)*	3.534	(0.000)*
K x A	4	1.028	(0.085)	0.712	(0.008)*	0.515	(0.028)*
Error (b)	24	0.440		0.161		0.157	

Table 6. Comparison of means for several measurements with eight replications using five levels cottonseed flour (CSF).

Measurement	Amount CSF					
	0%	12%	24%	36%	48%	$LSD_{0.05}$
Color:						
Reflectance (Rd)	36.87^{a}	28.48^{b}	22.98^{c}	20.08^{c}	20.75^{c}	2.98
Redness (a+)	2.60^{a}	4.38^{a}	7.12^{b}	7.52^{b}	7.10^{b}	1.79
Yellowness (b+)	$23.12^{a,b}$	23.84^{b}	22.95^{b}	21.78^{c}	22.04^{c}	0.76
Subjective Evaluations[d]:						
Color	4.67^{a}	5.80^{b}	$5.37^{b,c}$	4.77^{a}	$5.10^{a,c}$	0.47
Shape	6.05^{a}	5.83^{a}	5.87^{a}	5.48^{b}	5.44^{b}	0.32
Surface characteristics	5.81^{a}	$5.33^{a,b}$	$4.98^{b,c}$	$4.98^{b,c}$	4.71^{c}	0.55
Texture	3.98^{a}	5.71^{b}	5.77^{b}	5.83^{b}	5.85^{b}	0.37
Tenderness	4.54^{a}	5.77^{b}	5.50^{b}	5.12^{c}	$4.81^{a,c}$	0.34

[a,b,c] Means in same row with same letter are not significantly different ($p<0.05$).

[d] Seven point scale with 1, very undesirable to 7, very desirable, was used.

amounts CSF used in this study are compared. Objective evaluations of color indicate increased levels of CSF caused cookies to become darker (as Rd decreased); redder, as the a value increased and yellower as the b value decreased. However, mean values for reflectance and redness of cookies with 24, 36, and 48% CSF are not significantly different. Similarly, the differences in yellowness of cookies with 36 and 48% levels are not significant.

Color observations recorded by the sensory panel indicate the control sample was least desired by the panel in terms of overall color. Apparently, the panel liked cookies that were darker, more yellow and less red as found when 12 and 24% CSF were added. Three other subjective evaluations assessed by the panel were shape, surface characteristics and texture. The panel gave higher scores for the shape and surface characteristics of the control samples. Cookies with the lower levels of added CSF were all scored significantly higher than the cookies with 36 and 48% CSF for shape and with 48% CSF for surface characteristics. Results indicate that the cookies with 12 and 24% CSF were the most tender; increasing the proportion of CSF decreased tenderness of the cookies.

Means for the different amounts of CSF with each SSL and XG are compared for spread ratio, shortness and for the subjective evaluations of aroma, flavor and overall acceptability in Table 7. Interactions between kind of surfactant (K) and amount of cottonseed flour (A) were not significant (Table 4) for flavor and overall acceptability but were significant for spread ratio, shortness and aroma (Table 5).

Table 7. Comparison for several measurements of means with four replications for kinds of surfactants (sodium steroyl-2-lactylate, SSL, and xanthan gum, XG) and amounts of cottonseed flour (CSF).

Measurement	Amount CSF						
	0%	12%	24%	36%	48%	$LSD_{0.05}$ A means	$LSD_{0.05}$ K means
Spread Ratio:							
SSL	$^{x}6.50^{a}$	$^{x}7.44^{a,b}$	$^{x}7.55^{b}$	$^{x}9.08^{c}$	$^{x}8.25^{b}$	0.97	0.56
XG	$^{x}6.80^{a}$	$^{x}7.82^{b}$	$^{y}8.81^{c}$	$^{x}8.92^{c}$	$^{y}7.60^{a,b}$		
Shortness:							
SSL	$^{x}2.00^{a}$	$^{x}1.96^{a}$	$^{x}2.27^{a}$	$^{x}3.26^{b}$	$^{x}4.89^{c}$	0.58	0.23
XG	$^{y}2.26^{a}$	$^{x}2.11^{a}$	$^{x}2.14^{a}$	$^{y}3.00^{b}$	$^{y}3.65^{c}$		
Aroma:							
SSL	$^{x}6.62^{a}$	$^{x}6.04^{b}$	$^{x}5.62^{b}$	$^{x}5.25^{c}$	$^{x}4.83^{c}$	0.58	0.72
XG	$^{x}6.37^{a}$	$^{x}5.88^{a,b}$	$^{x}5.33^{b,c}$	$^{y}4.42^{d}$	$^{x}5.42^{b,c}$		
Flavor:							
SSL	$^{x}6.46^{a}$	$^{x}6.33^{a}$	$^{x}5.87^{b}$	$^{x}5.00^{c}$	$^{x}4.79^{c}$	0.39	0.35
XG	$^{x}6.33^{a}$	$^{x}6.08^{a}$	$^{y}5.25^{b}$	$^{y}4.37^{c}$	$^{y}4.36^{c}$		

Table 7. (Continued)

Measurement	Amount CSF						
	0%	12%	24%	36%	48%	$LSD_{0.05}$ A means	$LSD_{0.05}$ K means
Overall Acceptance:							
SSL	$^{x}5.44^{a}$	$^{x}6.25^{b}$	$^{x}5.85^{c}$	$^{x}5.08^{a}$	$^{x}4.50^{d}$	0.36	0.39
XG	$^{y}5.04^{a}$	$^{x}6.04^{b}$	$^{x}5.46^{c}$	$^{y}4.42^{d}$	$^{x}4.58^{d}$		

[a,b,c,d] Means in same line with different superscript on right side indicate significant ($p \leq 0.05$) differences for amount of cottonseed flour.

[x,y] Means in same column with different superscripts on left side indicate significant ($p \leq 0.05$) differences between surfactants.

Comparisons of spread ratio means with SSL indicate that cookies with 0 and 12% CSF are not significantly different; with 36 and 48% CSF, the spread ratio was highest when 24 and 36% CSF were used and the spread ratio was lower when the CSF content was either decreased or increased. Cookies with 0, 12, and 24% CSF were significantly more tender, as indicated by the lower shortness values, than those with 36% CSF. Cookies with 48% CSF were the toughest. Comparing the shortness values with the data from sensory evaluation given in Table 6, we see that the panel chose the 12 and 24% levels as more tender which agrees with the shortness values. Increasing the proportion of CSF caused tougher cookies as indicated by both objective and sensory evaluations.

The sensory evaluation panel found aroma less pleasing as the amount of CSF was increased. Differences were significant between 0 and 12% and between 24 and 36% CSF. The flavor of the control and the cookies with 12% CSF were rated highest followed by the cookies with 24% CSF and then by cookies with 36 and 48% CSF. Flavor scores generally decreased with increasing amounts CSF although the differences between 0 and 12% CSF and between 36 and 48% were not significant when either surfactant was used. In terms of overall acceptability, the panelists rated the cookies with 12% and 24% CSF over the control cookies, the addition of up to 48% CSF to a basic cookie recipe seems acceptable (scores greater than 4) on the basis of results for overall acceptability obtained with this trained sensory panel.

Kind of surfactant. Comparison of mean values for the several measurements for kind of surfactant (Table 7) indicate SSL generally gave higher scores than XG. The two emulsifiers did not give significantly different results for spread ratio (Table 7) except with 24 and 48% CSF when the differences were significant between SSL and XG.

When the two emulsifiers were compared for shortness, at three of the five levels of CSF used, there was a significant difference between the two emulsifiers. With the lower levels CSF, SSL gives cookies which are more tender although the difference is significant only in the control cookies. With higher CSF levels in cookies, XG gives more tender cookies, and these differences are significant when 36 and 48% CSF was used.

For aroma, no significant difference between the two surfactants were found except with 36% CSF, in which case scores for the cookie aroma with SSL were significantly higher than when XG was used.

Scores for flavor for cookies with XG were significantly lower with 24, 36, and 48% CSF than flavor scores of cookies with SSL. In all cases scores for cookies with SSL were higher than scores for cookies with XG; however, with 0 and 12% CSF those differences were not significant ($p \leq 0.05$).

Means for overall acceptability were significantly different between XG and SSL only when 0 and 36% CSF was used, when SSL resulted in higher scores than XG. At all other levels of CSF used, the differences between kinds of surfactant were not significant. Overall acceptability for the two surfactants was almost the same, with SSL rated slightly but generally not significantly higher than XG.

The results of this investigation show that we can make cookies which are acceptable using up to 48% CSF substituted for wheat flour plus a surfactant such as sodium steroyl-2-lactylate or xanthan gum. Scores of four or more on the seven point scale which was used were considered acceptable and a score of seven was very desirable. Means of cookies even with 48% CSF were never scored less than four when assessed by the sensory panel.

Fogg and Tinklin (1972) reported that control cookies were more acceptable than those containing CSF. However, our results indicate that, in general, cookies with 12, 24, 36, and 48% CSF substituted for wheat flour were scored favorably when a surfactant such as SSL was used. Cookies with 12 and 24% were scored even higher than the control on the basis of overall acceptability.

Our results are similar to those of Tsen et al. (1974a) who used soy flour in several kinds of cookies. However, the highest level used by Tsen and co-workers was 24% soy flour, and we have used up to 48% cottonseed flour and found the cookies rated acceptable. He used SSL and sodium stearoyl fumarate (SSF), and we used SSL and XG. All gave similar results.

Dalby (1969) found that the bread with 25% CSF gave rise to an unacceptable color. Our results indicated the color of the cookies, though darker, were still scored favorably. Scores for color were highest with 12 and 24% CSF, and the control sample was scored lowest by the sensory panel in terms of its overall color.

Shelf-Life

Aroma, flavor, tenderness and overall acceptability of the cookies was evaluated by the investigator. Means scores of eight reps are given in Table 8. Evaluations were made initially and after one and two months storage. Kind of surfactant did not influence significantly the quality of the cookies, but the amount of CSF (A) and the length of storage time (M) do influence the aroma, tenderness, flavor and overall quality of the cookies. Significant ($p \leq 0.05$) interactions were found between amount of CSF and length of storage time (MA) for tenderness and flavor. No other interactions, KA, KM, or KMA, were noted.

Mean scores for sensory evaluation of aroma, tenderness and flavor of cookies at three storage times at room temperature using five levels CSF are shown in Table 9. Means are used for combined data of SSL and XG since kind of surfactant did not cause significant differences in shelf-life studies. The higher the percentage CSF and the longer the time of storage the lower were the scores for aroma of the cookies. Cookies with 36% cottonseed flour were scored significantly lower than all other cookies initially. After one and two months storage mean scores for cookies with 48% CSF were

Table 8. Mean squares and probabilities for sensory evaluation of shelf-life.

Source of Variation	DF	Analysis of Variance							
		Aroma		Tenderness		Flavor		Overall Acceptability	
		MS	Prob.	MS	Prob.	MS	Prob.	MS	Prob.
Kind of surfactant (K)	1	0.208	(0.581)	0.080	(0.630)	0.027	(0.90)	0.169	(0.650)
Error (a)	6	0.599		0.311		1.54		0.760	
Amount (A)	4	6.409	(0.000)*	7.53	(0.000)*	15.44	(0.000)*	11.049	(0.000)*
Storage (M)	2	6.033	(0.000)*	27.677	(0.000)*	20.662	(0.000)*	21.377	(0.000)*
MA	8	0.309	(0.410)	1.874	(0.000)*	0.806	(0.010)*	1.440	(0.000)*
KA	4	0.516	(0.150)	0.646	(0.123)	0.535	(0.136)	0.236	(0.445)
KM	2	0.058	(0.82)	0.200	(0.561)	0.048	(0.852)	0.131	(0.590)
KMA	8	0.147	(0.86)	0.219	(0.75)	0.196	(0.72)	0.058	(0.980)
Error	84	0.296		0.345		0.297		0.251	

Table 9. Mean scores for 8 reps for sensory evaluation of aroma, tenderness, and flavor at three storage times (0, 1, 2 mo) using five levels cottonseed flour (CSF).

Measurement	Mo	Amount CSF					
		0%	12%	24%	36%	48%	$LSD_{0.05}$
Aroma	0	5.88^{a}	5.88^{a}	5.75^{a}	4.75^{b}	5.00^{a}	0.76
	1	5.69^{a}	5.69^{a}	5.31^{a}	5.00^{a}	4.56^{b}	
	2	5.19^{a}	5.19^{a}	4.88^{a}	4.50^{a}	3.75^{b}	
Tenderness	0	6.13^{a}	6.25^{a}	$5.50^{a,b}$	4.50^{c}	$5.13^{b,c}$	0.82
	1	4.19^{a}	5.38^{b}	$4.94^{a,b}$	$4.69^{a,b,c}$	3.89^{c}	
	2	3.63^{a}	4.56^{b}	$4.31^{a,b}$	$4.00^{a,b}$	2.69^{c}	
Flavor	0	6.25^{a}	6.13^{a}	$5.63^{a,b}$	4.75^{c}	$4.88^{b,c}$	0.77
	1	5.81^{a}	5.69^{a}	$5.44^{a,b}$	4.88^{b}	3.88^{c}	
	2	4.75^{a}	4.88^{a}	4.75^{a}	3.79^{b}	2.50^{c}	

[a,b,c] Means in same row with same letter are not significantly different ($p \leq 0.05$).

were significantly lower than cookies with all other levels CSF.

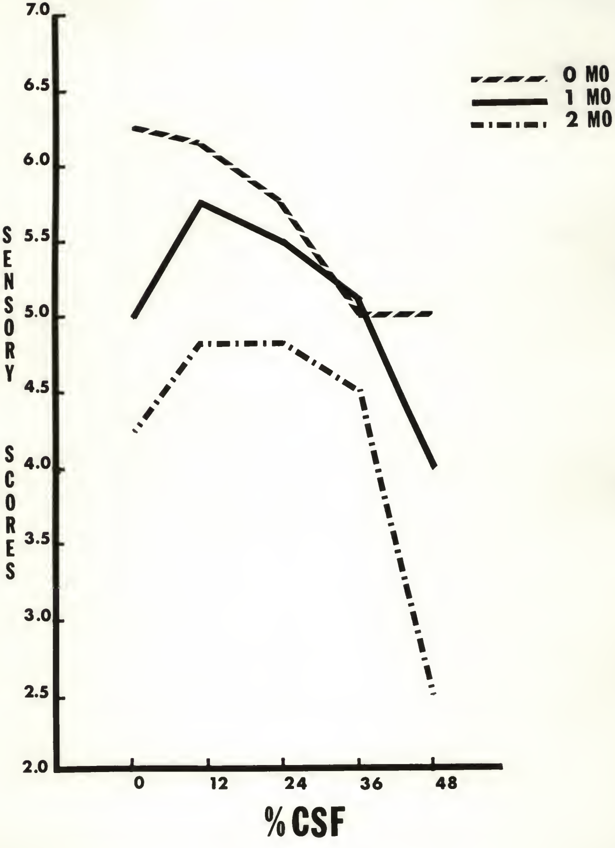
Mean scores for tenderness after one and two months storage were significantly lower for cookies with 48% CSF than other cookies. Apparently the addition of some CSF improves tenderness scores for cookies stored up to two months as scores were highest for 12, 24, and 36% CSF cookies after one month storage. After two months storage, tenderness scores were low for all cookies, but again 12, 24, and 36% CSF cookies had the highest score.

The flavor of cookies with 36 and 48% CSF was significantly lower at all storage times than for cookies with 0 and 12% CSF. After one month storage, cookies with 48% CSF and after two months storage, cookies with 36 and 48% CSF no longer received acceptable scores.

Overall acceptability of the cookies initially and after one and two months storage with five levels cottonseed flour is shown in Fig. 1. Length of storage time and the amount of CSF influence the shelf-life of the cookies. At the higher levels of CSF and with longer storage times, scores in general were lower. With 12 and 24% CSF, cookies generally had higher scores than control cookies or cookies with 36 and 48% CSF. Those differences were significant after one month storage, and after two months storage cookies with 48% CSF were scored significantly lower than all other cookies and were considered unacceptable (Appendix, Table 5A).

If optimum levels of surfactant were determined and used,

Figure 1. Sensory scores (7, very desirable to 1, very undesirable) for overall acceptability of cookies with five levels cottonseed flour (CSF) and three storage times.



7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
SENSORY SCORES
0 MO
1 MO
2 MO
0
12
24
36
48
% CSF

cookies with higher levels of CSF might be made with longer shelf-life. Overman (1951) reported that baked pastry containing 10% CSF kept more than ten times as long as baked pastry made with wheat flour alone. We had lower scores with one and two months storage, in general, as the proportion of CSF was increased in the cookies, but the levels of CSF used were all greater than 10%.

Hutchinson et al. (1977) reported a shelf-life study on cookies with different levels of surfactants. One surfactant they used was also SSL. He found after three months of storage texture scores were higher. He reported that the best amount of SSL to improve shelf-life was 0.375% and perhaps, this is one of the reasons why our results do not agree with Hutchinson's work as we used 1% SSL.

Amino Acid Analysis

The essential amino acids found in each of the different levels of cottonseed flour cookies is shown in Table 10. The amino acid content in the cookies with different levels of cottonseed flour, in general, was improved with the addition of cottonseed flour. Isoleucine, leucine and valine decreased with the addition of CSF. Histidine, now believed to be an essential amino acid for infants by some workers (Guthrie, 1975), did increase with the addition of CSF as did lysine, threonine and phenylalanine.

Levels of the non-essential amino acids increased in these cookies which agrees with the reports by Bressani (1965)

Table 10. Amino acid content of cookies made with different levels of cottonseed flour (CSF) plus xanthan gum (XG) or sodium steroyl-2-lactylate (SSL) g per 100 g/protein.

Amino Acid	0%	12% 1%XG	24% 1%XG	24% 1%SSL	36% 1%XG	48% 1%XG
Lysine	2.41	2.63	3.07	3.58	3.03	3.77
Threnonine	3.31	3.46	3.92	3.70	3.63	3.43
Valine	4.00	3.62	3.97	3.62	3.73	3.89
Methionine	2.09	1.52	2.25	1.67	1.68	1.96
Isoleucine	2.93	2.68	2.83	2.81	2.77	2.69
Leucine	7.26	6.68	6.75	6.67	6.54	6.47
Tyrosine	3.32	3.30	3.35	3.11	3.53	3.27
Phenylalanine	4.93	5.04	5.56	5.15	6.06	5.32
Histidine	1.67	2.00	2.32	2.26	2.14	2.62

[a]Corrected to 100% recovery, Kjeldahl protein basis.

for CSF. Additional work to determine the protein efficiency ratio (PER) for these cookies with added CSF would be desirable. Since cookies with up to 48 per cent added CSF were rated favorably by the trained panel, evaluation of acceptability by children in countries such as Venezuela would be useful.

Tsen et al. (1975b) stated that high protein cookies can be used satisfactorily to supplement dietary protein in child-feeding programs at school, day care centers and other institutions in poverty areas of the world and thereby alleviate protein malnutrition. He found the 24% soy cookies were acceptable by school children in Kansas but he did not evaluate them in other areas of the world where protein deficiencies are more widespread.

Morck et al. (1976) did do a survey in South American countries, and found that South American consumers expressed interest in protein fortified cookies and crackers and would purchase them provided they tasted good.

SUMMARY

Effect of substitution of wheat flour sugar cookies by liquid cyclone processed cottonseed flour (CSF) with two different kinds of surfactants, sodium stearoyl-2-lactylate (SSL) and xanthan gum (XG), on eating quality, shortness, color, spread ratio and the amino acid content was investigated.

Increased levels of CSF caused darker cookies. Color observations recorded by the sensory evaluation panel indicated the control sample was least desirable in terms of overall color. The panel gave higher scores for the shape and surface characteristics of the control samples and those with the lower levels of added CSF than the cookies with higher CSF levels.

The overall acceptability for the two surfactants was almost the same with SSL rated slightly but generally not significantly higher as compared with xanthan gum. The panelists scored cookies with up to 24% CSF higher than the control cookies. Although the 36% and 48% CSF cookies were rated lower than the cookies with 12 and 24% CSF, they still were considered acceptable. Aroma was scored lower as the amount of CSF increased. Evaluations of tenderness indicated increasing the proportion of CSF caused tougher cookies by both objective and subjective evaluations. The amino acid content of CSF cookies generally was improved with the addition of cottonseed flour.

Shelf-life was studied and, in general, sensory scores for aroma, tenderness, and flavor were lower the higher the percentage CSF and the longer the time of storage. Overall acceptability was good for cookies with up to 36% for two months storage, although scores also were lower at the upper levels CSF used and with longer storage times.

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APPENDIX

Table 1A. The liquid cyclone process used to prepare cottonseed flour (Martinez, 1970).

1. Prime quality seed is used
2. Linters and hulls are separated from the seed using normal procedures
3. Cottonseed kernels (meat) are dried and rolled to form flakes which are extracted with hexane to remove the oil
4. Extracted flakes are ground as a slurry with commercial hexane
5. The ground, dilute slurry is pumped under pressure, through liquid cyclone in several stages
6. The cyclone separates the liquid in two fractions
7. Purified high protein content product of greatly reduced gossypol content obtained
8. A lower protein content with 90% of initial gossypol content is obtained
9. Fraction (7) is desolvetized, ground, sterilized and packaged for edible purposes
10. Degossypolized flour obtained contains more than 65% protein with about 57% recovery of original protein in the seed

Table 2 A. Formula for sugar cookies with five levels cottonseed flour.

Ingredients	Levels of Cottonseed Flour				
	0%[a]	12%	24%	36%	48%
	(g)	(g)	(g)	(g)	(g)
Wheat flour, all purpose	151.0	132.8	114.8	96.7	78.5
Cottonseed flour	-	18.1	36.2	54.3	72.5
Hydrogenated shortening	94	94	94	94	94
Eggs	48	48	48	48	48
Sugar	150	150	150	150	150
Cream of tartar	3.1	3.1	3.1	3.1	3.1
Soda	1.9	1.9	1.9	1.9	1.9
Salt	0.8	0.8	0.8	0.8	0.8
Flavoring[b]	-	1	1	1	1
SSL or XG[c]	-	1.5	1.5	1.5	1.5

[a]Basic formula.

[b]Lemon extract.

[c]Amount determined in preliminary work.

Table 3.A. Analysis of cottonseed flour

Moisture	2.70%
Lipids	0.44%
Free gossypol	0.02%
Total gossypol	0.14%
Nitrogen	10.27%
N. Solubility	99.60%
Protein	62.19%
Protein (M.F.B.)	65.97%
Fiber	2.20%
Ash	7.40%
Hexane p.p.m.	10.00
Lysine g/16gN.	3.95%

Southern Regional Research Laboratory, USA. Department of Agriculture.

Table 4A. Mixing method for sugar cookies

Mixing step	Speed setting[a]	Time
		(min)
Cream shortening, sugar, salt, egg[b] and flavoring. Scrape.	2	2
Cream. Scrape.	6	1
Add flour, soda, cream of tartar and surfactant[c]. Scrape.	1	1/2
Mix. Scrape.	2	1
Roll[d] and cut. Bake at 375°F for 15 min.[e]		
Cool on wire racks at room temperature for 1 hr.		

[a]Kitchen-Aid Model K5-A.

[b]Beaten separately 1 min at speed 1.

[c]Previously sifted 4 times.

[d]One portion rolled 2 mm thick and one portion rolled 4 mm thick.

[e]Cookies used for shortness evaluations were baked 10 min.

Figure 2. Equipment used for measuring tenderness.

A. Cutter for making cookie strips.

B. Bailey shortometer.

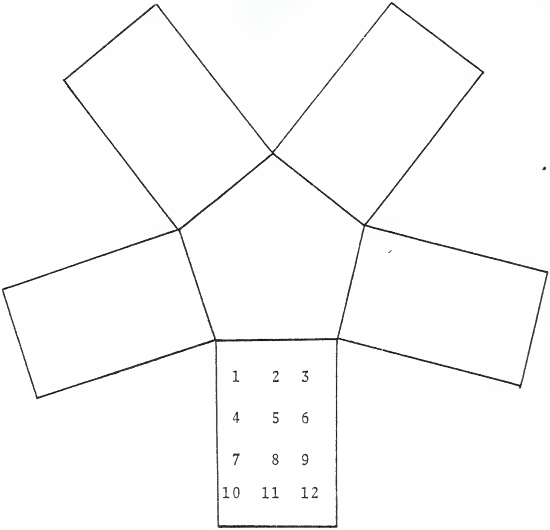

Fig. 3. Placement of cookies used while baking in rotary hearth oven.

Figure 3. Form used for scoring cookies with cottonseed flour.

Score Card for Sugar Cookies

Name________________________ Date__________________

Factor	Samples				
External Characteristics[a]					
Shape, Well rounded					
Surface, Well-broken top containing numerous small island.					
Color, even light brown, not dark or pale					
Internal (Crumb) Characteristics					
Aroma, pleasant, light, no "off" notes					
Texture (Grain), uniform cell structure					
Tenderness, tender, but not excessively crumbly					
Flavor, pleasing, no pronounced off-taste					
Over-all eating quality, all qualities that make the product desirable (acceptable)					

SCORING KEY:

7 Very desirable

6 Desirable

5 Moderately desirable

4 Acceptable

3 Slightly undesirable

2 Undesirable

1 Very undesirable

Table 5A. Mean scores for overall acceptability with five levels cottonseed flour at zero, one and two months room temperature storage.

Surfactant	Mo	Amount CSF					
		0%	12%	24%	36%	48%	$LSD_{0.05}$
	0	6.25^{a}	6.12^{a}	$5.75^{a,b}$	5.00^{b}	5.00^{b}	0.70
	1	5.00^{a}	5.75^{b}	5.50^{b}	$5.06^{a,b}$	4.00^{c}	
	2	4.25^{a}	4.81^{a}	4.81^{a}	4.50^{a}	2.50^{b}	

[a,b,c,d]Means in same line with different superscript on right side indicate significant ($p \leq 0.05$) differences for overall acceptability.

Table 6A. Mean scores for objective measurements.

Amount	CSF	Day	Measurements					
			Moisture, %[a]	Spread ratio[b]	Shortness[c]	Rd[c]	a[c]	b[c]
Control:								
	SSL[d]	1	1.0	6.96	1.91	36.92	0.92	23.76
		2	2.9	6.79	2.21	34.19	2.80	23.5
		3	2.0	6.63	1.92	33.76	2.63	22.92
		4	1.1	5.61	1.96	44.12	2.03	24.78
	XG[d]	1	2.6	6.63	2.90	30.99	3.60	23.84
		2	1.1	7.83	2.29	29.62	6.29	23.06
		3	1.5	6.64	1.87	38.74	1.50	22.74
		4	1.7	6.08	2.00	46.62	1.00	25.17
12%								
	SSL[d]	1	1.0	6.98	2.29	30.16	1.90	23.94
		2	2.2	7.27	1.87	28.98	2.60	23.39
		3	1.9	7.87	2.29	27.35	2.68	23.58
		4	1.0	7.63	1.37	33.98	4.07	24.88
	XG[d]	1	1.4	7.59	2.00	22.90	7.80	23.00
		2	1.1	7.76	2.37	24.15	7.10	23.26
		3	1.2	8.39	2.12	28.37	5.26	23.79
		4	1.8	7.52	1.96	31.98	3.65	24.90

Table 6A. (Continued)

Amount CSF	Day	Measurements					
		Moisture, %[a]	Spread ratio[b]	Shortness[c]	Rd[c]	a[c]	b[c]
24%:							
SSL[d]	1	1.4	7.56	3.04	19.18	9.84	21.76
	2	1.8	6.83	2.04	24.16	5.70	23.33
	3	2.0	7.91	2.00	26.08	3.40	23.10
	4	1.2	7.89	2.00	27.27	6.48	24.98
XG[d]	1	1.2	7.62	2.30	15.98	9.34	20.9
	2	1.6	9.21	2.25	21.25	9.29	22.57
	3	1.4	9.19	2.0	24.36	5.87	22.94
	4	1.5	9.23	2.0	25.6	7.03	24.0
36%:							
SSL[d]	1	1.0	8.21	4.66	18.91	9.48	21.68
	2	1.8	1.99	3.54	20.97	7.70	22.40
	3	1.7	8.95	2.54	22.17	5.95	21.88
	4	1.4	9.15	2.29	22.52	9.50	23.25
XG[d]	1	1.2	8.86	3.9	21.48	7.44	21.5
	2	1.2	9.08	3.04	11.56	9.28	18.45
	3	1.0	9.85	2.71	19.45	9.19	21.49
	4	1.88	7.89	2.33	23.6	7.62	23.58

Table 6A. (Continued)

Amount	CSF	Day	Measurements					
			Moisture, %[a]	Spread ratio[b]	Shortness[c]	Rd[c]	a[c]	b[c]
48%:								
	SSL[d]	1	1.9	7.57	5.64	16.24	9.99	20.42
		2	1.7	9.99	5.25	21.90	6.00	22.00
		3	1.7	7.86	4.21	19.48	6.35	21.52
		4	1.1	7.59	4.46	23.60	6.80	23.06
	XG[d]	1	0.9	6.48	4.4	19.08	7.60	21.88
		2	1.6	8.44	3.75	20.91	6.80	22.15
		3	1.3	7.76	3.12	20.19	7.8	22.05
		4	2.0	7.65	8.33	24.60	5.48	23.22

[a]$\bar{x}$ for three values; [b]$\bar{x}$ for five cookies; [c]$\bar{x}$ for six measurements; [d]surfactant used.

Table 7A. Mean scores for subjective measurements[a].

Amount	CSF	Day	Measurements							
			Shape	Surface	Color	Aroma	Texture	Tend.	Flavor	Overall
Control:										
	SSL[b]	1	6.00	5.67	4.50	6.00	4.33	4.33	5.83	5.25
		2	6.17	6.33	5.00	6.50	4.50	4.67	6.00	5.00
		3	6.83	6.33	5.17	7.00	3.50	5.33	7.00	6.33
		4	6.27	5.17	4.50	7.00	2.83	4.00	7.00	5.17
	XG[b]	1	5.00	5.50	4.83	6.00	4.33	4.83	6.00	5.33
		2	5.50	6.83	3.83	6.00	4.00	4.00	6.17	4.17
		3	6.33	5.67	4.67	6.83	3.50	4.67	6.67	5.17
		4	6.33	5.00	4.83	6.67	4.83	4.50	6.50	5.50
12%:										
	SSL[b]	1	6.00	5.17	5.83	5.67	5.00	5.50	6.33	6.00
		2	5.83	5.66	6.33	6.67	5.83	5.67	6.50	6.83
		3	5.83	5.67	6.33	5.67	5.83	6.00	6.00	6.33
		4	5.67	5.83	6.00	6.17	5.17	5.83	6.50	6.33
	XG[b]	1	5.50	4.50	4.60	5.50	6.00	5.83	5.83	6.33
		2	6.33	5.67	5.83	5.83	6.16	6.00	6.33	6.0
		3	5.67	5.17	5.67	6.17	5.83	6.0	6.33	6.17
		4	5.83	5.0	5.83	6.00	5.83	5.33	5.83	5.67

Table 7A. (Continued)

Amount	CSF	Day	Measurements							
			Shape	Surface	Color	Aroma	Texture	Tend.	Flavor	Overall
24%:										
	SSL[b]	1	6.00	5.50	5.00	4.67	5.50	6.00	5.66	5.58
		2	5.67	5.17	5.83	5.67	6.00	6.33	5.83	6.00
		3	5.83	4.83	5.67	6.33	5.67	5.50	6.17	5.83
		4	6.00	4.33	4.83	5.83	5.67	5.17	5.83	6.00
	XG[b]	1	5.66	4.66	5.50	5.0	6.33	5.5	5.17	5.67
		2	5.83	4.33	5.0	5.0	5.5	5.5	5.0	5.17
		3	5.83	5.33	5.83	5.83	5.5	5.33	5.33	5.5
		4	6.17	5.67	5.33	5.50	6.0	4.67	5.50	5.50
36%:										
	SSL[b]	1	5.50	4.67	5.33	5.00	5.66	5.17	5.00	5.00
		2	5.83	5.33	4.50	4.83	6.33	5.33	4.67	4.83
		3	5.50	5.17	5.33	5.50	6.00	5.00	5.00	5.17
		4	5.33	4.67	5.00	5.67	5.67	5.17	5.33	5.33
	XG[b]	1	5.17	4.5	3.83	4.5	6.17	4.83	3.83	4.17
		2	5.33	4.66	3.67	3.5	5.5	5.5	3.67	3.83
		3	5.0	5.83	5.0	4.33	5.83	5.0	4.67	4.5
		4	6.17	5.0	5.50	5.33	5.50	5.0	5.33	5.17

Table 7A. (Continued)

Amount	CSF	Day	Measurements							
			Shape	Surface	Color	Aroma	Texture	Tend.	Flavor	Overall
48%:										
	SSL[b]	1	5.17	5.00	5.00	4.50	5.50	4.67	5.00	4.33
		2	5.67	4.67	5.17	5.17	6.33	4.83	4.50	4.66
		3	5.17	4.33	5.00	4.33	6.00	5.17	4.50	4.33
		4	5.17	4.17	4.33	5.33	5.83	4.67	5.17	4.67
	XG[b]	1	5.5	4.0	5.61	5.0	6.0	5.17	4.6	5.0
		2	5.5	5.0	5.5	5.5	6.0	4.83	4.5	4.5
		3	5.33	4.5	4.67	5.17	5.83	4.67	4.17	4.5
		4	6.0	6.0	5.50	6.0	5.33	4.50	4.17	4.33

[a] $\overline{x}$ for scores of six panelists; [b] surfactant used.

FORTIFICATION OF SUGAR COOKIES
WITH
COTTONSEED FLOUR

by

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AN ABSTRACT OF A THESIS

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The importance of all the possible approaches for improving the efficiency of food utilization, especially those which have the greatest potential for future use, must be recognized. This is the basis for fortifying food with proteins.

Wheat flour sugar cookies were substituted with varying amounts of liquid cyclone processed cottonseed flour (CSF) with two different kinds of surfactants, sodium stearoyl-2-lactylate (SSL) and xanthan gum (XG). Eating quality, shortness, color, spread ratio and the amino acid content of sugar cookies were assessed. Amount of CSF was significant ($p \leq 0.05$) for spread ratio, tenderness and aroma. In general, the differences between kinds of surfactant were not significant.

Increased levels of CSF caused darker cookies. Color observations recorded by the sensory evaluation panel indicated the control sample was least liked by the panel in terms of overall color. The panel gave higher scores for the shape and surface characteristics of the control samples and those with the lower levels of added CSF than the cookies with the higher levels CSF.

Overall acceptability for the two surfactants was almost the same with SSL rated slightly but generally not significantly higher as compared to xanthan gum. The panelists scored cookies with up to 24% CSF over the control cookies. Although the 36% and 48% CSF cookies were rated lower than the cookies with 12 and 24% CSF, they still were rated as acceptable. Aroma was scored lower as the amount of CSF increased. Evaluations of tenderness indicated increasing the proportion of CSF caused tougher cookies by both objective and subjective evaluations.

The amino acid content of CSF cookies generally was improved with the addition of cottonseed flour. Shelf-life was studied and, in general, sensory scores for aroma, tenderness, flavor and overall acceptability of the cookies with both surfactants were lower as the amount of CSF and time of storage was increased.