Quality of Sugar Cookies Fortified with Liquid Cyclone Processed Cottonseed Flour with Stabilizing Agents[1]

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ABSTRACT

Eating quality of sugar cookies fortified with 0, 12, 24, 36, and 48% liquid cyclone processed cottonseed flour (CSF) and containing 1% sodium-stearoyl-2 lactylate or 1% xanthan gum was evaluated. Eating quality scores were highest for cookies with 12 and 24% CSF, but cookies with 36 and 48% were acceptable. Sodium-stearoyl-2 lactylate generally gave higher, but not significantly higher, cookie scores than did xanthan gum. CSF, when used at all levels except the 48% level, improved tenderness and overall acceptability scores after one and two months' storage. Protein levels were increased from 6 to 15.6% with the addition of CSF, but protein quality was not improved, as shown by chemical scores and protein efficiency ratio values of the cookies in combination with casein.

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Cottonseed flour (CSF) has been added to bread, cookies, and tortillas (Bressani 1965, Bressani et al 1966, Fogg and Tinklin 1972, Green et al 1976, Hulse 1974, McPherson and Ou 1976, Tsen and Hoover 1971, Tsen et al 1973). The products have not been entirely successful when enough CSF was used to markedly increase protein content. Acceptable products are thought to be possible, however, particularly when less than 25% CSF is used. CSF is therefore a potential protein supplement for malnourished and protein-deficient people, including many in the Latin American countries where CSF is more obtainable than is soy or other high-protein flours.

Cookies could conveniently supplement protein in diets of children who live in poverty areas. The cookies could be prepared at a central location and distributed to schools for lunch or other feeding programs. The purpose of this study was to improve the eating quality of sugar cookies fortified with high levels of CSF.

MATERIALS AND METHODS

Preparation of Cookies

The cookies were prepared using the basic formula and mixing procedure of Fogg and Tinklin (1972). CSF was substituted for 12, 24, 36, and 48% of an all-purpose commercial wheat flour. The wheat flour contained 10.2% protein (N × 5.7) and 0.43% ash (both 14% mb). The liquid cyclone-processed CSF, from which the gossypol was removed during protein concentration, contained 66% protein (N × 6.25, db) and 7.4% ash. Two quite different types of stabilizing agents, sodium stearoyl-2 lactylate (SSL) and xanthan gum (XG), each having improved the quality of other baked products, were added at the level of 1% of the combined flour weight to improve the cookie quality. Lemon extract was added to alter the flavor.

Cookie dough was divided into two equal portions before rolling. One portion, rolled 4 mm thick, was cut into circles 50 mm in diameter. These cookies were used for all subjective and objective evaluations except shortness. The 4-mm thick circles were baked 15 min in an electric rotary hearth oven maintained at 191°C

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(375° F) and after cooling were placed in plastic bags, sealed, and stored at room temperature 18 hr before being used in sensory and objective evaluations. Cookies used for color, moisture, spread ratio, and eating quality evaluations were too large for the capacity of the shortometer; therefore, comparative measurements of tenderness were made by using a second portion of dough rolled 2 mm thick and cut into 80 × 18-mm strips. Shortness evaluations were made after the cookies had baked 10 min (191°C) and cooled at 22 ± 2°C for 1 hr.

Baking Tests

Spread ratio (W/T, where W is average diameter and T is average thickness of six cookies) was calculated according to the method of Tsen et al (1973). Tenderness (baking strength) was determined on duplicate samples, corrected for spread, by a 1,000-g capacity shortometer. Color differences (reflectance, redness, yellowness) were evaluated with the Gardner automatic color difference meter, model AS-2A, series 200, according to the procedures given by Fogg and Tinklin (1972).

Subjective Evaluations

Eating quality was evaluated 18 hr after baking by an experienced panel of six persons. To evaluate shape, surface characteristics, color, aroma, texture, tenderness, flavor, and overall eating quality, a seven-point rating scale was used, with 7 considered very desirable, 4 acceptable, 3 slightly undesirable, and 1 very undesirable. Cookies were stored in sealed, airtight plastic bags at room temperature (22 ± 2°C) for up to two months for shelf-life evaluations.

Chemical Analyses

For determination of moisture, duplicate 5-g samples of each cookie were placed in a Brabender rapid moisture tester (model SAS) and dried 50 min at 121°C. Protein content was determined by the micro-Kjeldahl procedure (AOAC 1975). The amino acid composition of each sample was determined using a Beckman model 120 C amino acid analyzer.

Biological Methods

Biological value of the supplemented cookies was evaluated by animal growth experiments using 24-day-old male weanling rats of the Sprague-Dawley strain. Eight animals were randomly assigned to each diet. Test animals were given food and water ad libitum for 28 days. The experimental diets are given in Table I. Protein content of CSF-supplemented cookies used in the diets was 6.04, 8.52, 10.75, 13.11, and 15.60% for cookies with 0, 12, 24, 36, and 48% CSF, respectively. Because of the low level of protein in the control diet (0% CSF), all diets contained 5% protein from casein blended with the 5% protein from the cookies or reference casein. Cookies were ground in a roller mill, passed through a No. 20 mesh

TABLE I
Diet Composition for Assay of Protein Efficiency Ratio

	Quantity, %					
Ingredient[a]	A	B	C	D	E	F[b]
Reference casein	5.0	...	...	...	...	...
Casein	5.0	5.0	5.0	5.0	5.0	5.0
Cookies[c]	...	82.78	58.68	46.51	38.14	32.05
Cottonseed oil	18.23	...	5.31	7.99	9.83	11.17
Salt mix (USD XIX)	5.0	5.0	5.0	5.0	5.0	5.0
Vitamin mix (AOAC)	1.0	1.0	1.0	1.0	1.0	1.0
Cellulose	1.0	1.0	1.0	1.0	1.0	1.0
Wheat starch	64.77	5.22	24.01	33.50	40.03	44.78

[a] Moisture was found to be similar for all cookies; therefore, adjustment for it was not necessary.
[b] Prepared with cookies with 0, 12, 24, 36, and 48% cottonseed flour substitutions for diets B, C, D, E, and F, respectively. Diet A was the control.
[c] Amount to provide 5% protein.

TABLE II
Objective Measurements of Various Combinations of Cottonseed Flour (CSF) and Two Stabilizing Agents, Sodium Stearoyl-2 Lactylate (SSL) and Xanthan Gum (XG), in Sugar Cookies

	Amount of CSF, %					
Measurement	0	12	24	36	48	LSD[a]
Color[b]						
Reflectance	36.9 x[c]	28.5 y	23.0 z	20.1 z	20.8 z	3.0
Redness	2.6 x	4.4 x	7.1 y	7.5 y	7.1 y	1.8
Shortness						
SSL[d]	2.0 x[e]	2.0 x	2.3 x	3.3 y[e]	4.9 z[e]	0.6
XG[d]	2.3 x[e]	2.1 x	2.1 x	3.0 y[e]	3.7 z[e]	
Spread Ratio						
SSL[d]	6.5 x	7.4 x,y	7.6 y[e]	9.1 z	8.3 y[e]	1.0
XG[d]	6.8 x	7.8 y	8.8 z[e]	8.9 z	7.6 x,y[e]	

[a] Least significant difference = 0.05.
[b] Means of eight replications with both SSL and XG when differences between kind of stabilizing agent were not significant.
[c] Means in the same line followed by different letters showed significant ($P \leq 0.05$) differences for amount of CSF.
[d] Means of four replications.
[e] Means significantly different between stabilizing agents.

TABLE III
Subjective Measurements[a] of Various Combinations of Cottonseed Flour (CSF) and Sodium Stearoyl-2 Lactylate (SSL) and Xanthan Gum (XG) in Sugar Cookies

	Amount of CSF, %					
Measurement	0	12	24	36	48	LSD[b]
Color[c]	4.7 x[d]	5.8 y	5.4 y,z	4.8 x	5.1 x,z	0.5
Texture[c]	4.0 x	5.7 y	5.8 y	5.8 y	5.9 y	0.4
Tenderness[c]	4.5 x	5.8 y	5.5 y	5.1 z	4.8 x,z	0.3
Aroma						
SSL[e]	6.6 x	6.0 y	5.6 y	5.3 z[f]	4.8 z	0.6
XG[e]	6.4 x	5.9 x,y	5.3 y,z	4.4 w[f]	5.4 y,z	
Flavor						
SSL[e]	6.5 x	6.3 x	5.9 y[f]	5.0 z[f]	4.8 z[f]	0.4
XG[e]	6.3 x	6.1 x	5.3 y[f]	4.4 z[f]	4.4 z[f]	
Overall acceptance						
SSL[e]	5.4 x[f]	6.3 y	5.9 z	5.1 x[f]	4.5 w	0.4
XG[e]	5.0 x[f]	6.0 y	5.5 z	4.4 w[f]	4.6 w	

[a] Seven-point rating scale: 7 = very desirable; 1 = very undesirable.
[b] Least significant difference = 0.05.
[c] Means of eight replications with both SSL and XG when differences between kind of stabilizing agent were not significant.
[d] Means in same line followed by different letters showed significant ($P \leq 0.05$) differences for amount of CSF.
[e] Means of four replications.
[f] Means significantly different between kinds of stabilizing agents.

TABLE IV
Sensory Scores[a] After Storage of Cookies Supplemented with Cottonseed Flour (CSF)

Measurement	Months	Amount of CSF, % 0	12	24	36	48	LSD[b]
Overall acceptance	0	6.3 x[c]	6.1 x	5.8 x,y	5.0 y	5.0 y	0.7
	1	5.0 x	5.8 y	5.5 y	5.1 x,y	4.0 z	
	2	4.3 x	4.8 x	4.8 x	4.5 x	2.5 y	
Aroma	0	5.9 x	5.9 x	5.8 x	4.8 y	5.0 x	0.8
	1	5.7 x	5.7 x	5.3 x	5.0 x	4.6 y	
	2	5.2 x	5.2 x	4.9 x	4.5 x	3.8 y	
Tenderness	0	6.1 x	6.3 x	5.5 x,y	4.5 z	5.1 y,z	0.8
	1	4.2 x	5.4 y	4.9 x,y	4.7 x,y,z	3.9 z	
	2	3.6 x	4.6 y	4.3 x,y	4.0 x,y	2.7 z	
Flavor	0	6.3 x	6.1 x	5.6 x,y	4.8 z	4.9 y,z	0.8
	1	5.8 x	5.7 x	5.4 x,y	4.9 y	3.9 z	
	2	4.8 x	4.9 x	4.8 x	3.8 y	2.5 z	

[a] Eight replications, using both sodium stearoyl-2 lactylate and xanthan gum.
[b] Least significant difference = 0.05.
[c] Means in same row with same letter are not significantly different ($P \leq 0.05$).

TABLE V
Weight Gain and Protein Efficiency Ratios (PER) of Rats Fed Cookies Supplemented with Cottonseed Flour (CSF)

Factor	Amount of CSF (%) in Cookies 0	12	24	36	48
Feed intake (protein g)[a]	43.6 y[b]	40.1 y	40.8 y	39.3 y	39.3 y
Growth (g)[a]	110.4 y	80.6 z	82.3 z	78.9 z	80.7 z
PER[c]	2.52 y	2.04 z	2.03 z	2.01 z	2.06 z

[a] Average for eight rats for 28 days.
[b] Means in same row with same letter are not significantly ($P \leq 0.05$) different.
[c] Weight gain/protein intake (based on 28-day values). Calculated on the basis of 5% protein from casein, 5% protein from CSF cookies.

TABLE VI
Amino Acid Profiles of Combinations of Casein and Cookies Supplemented with Cottonseed Flour (CSF)

Amino Acid Score[a]	Amount of CSF (%) in Cookies 0	12	24	36	48
Amino acid[b]					
Isoleucine	74	72	74	73	73
Leucine	78	75	75	74	74
Lysine	60[c]	61[c]	63[c]	63	67
Phenylalanine + tyrosine	102	102	105	105	103
Threonine	60[c]	61[c]	64	62[c]	60[c]
Valine	72	69	71	70	71

[a] FAO/WHO provisional scoring pattern.
[b] Scores based on analysis of amino acids in diets containing 5% protein from cookies and 5% from casein; no values available for tryptophan + cystine.
[c] Chemical score.

screen, and mixed with the remaining dietary components. The six diets were assigned to cages by a randomized complete block (cage level) design.

Statistical Analyses

Data were analyzed by two-way analysis of variance (ANOV) using four replications for each combination of kind of surfactant and amount of CSF. A separate split plot design and ANOV was used to analyze data from shelf-life studies for 0, 1, and 2 months of storage. When treatments or interactions were significant, least significant differences ($P \leq 0.05$) were calculated.

Differences in protein quality were analyzed using one-way ANOV and Duncan's multiple range test ($P \leq 0.05$).

RESULTS

Effect of Level of CSF

As indicated in Table II, increased CSF resulted in significant ($P \leq 0.05$) decreases in reflectance values and increases in redness and shortness values, particularly at high levels of CSF. Spread ratio was higher with 24 and 36% CSF and lower when the CSF content was either increased or decreased (Table II). No significant differences in moisture were found.

Overall eating quality as assessed by the sensory panel (Table III) was highest for cookies with 12 and 24% CSF, but cookies with 36 and 48% CSF were still rated acceptable (4.0 or above). Aroma was found to be less pleasing as the amount of CSF increased. However, increased levels of CSF resulted in significantly ($P \leq 0.05$) higher color, texture, and tenderness sensory scores. Dalby (1969) found that the color of bread with 25% CSF was unacceptable, and Wan et al (1979) indicated that, of the various cottonseed products, liquid cyclone-processed cottonseed flour presented the most color-associated problems when used for food products. Our results indicated that cookie color, although dark—as indicated by significantly ($P \leq 0.05$) lower reflectance values for cookies with 24, 36, and 48% CSF, was scored favorably by the sensory panel. Those scores were highest with 12 and 24% CSF; 0% CSF cookies were scored lowest, although not significantly lower than were cookies with 36 and 48% CSF.

Effect of Type of Stabilizing Agent

Means comparing the two types of stabilizing agent and the amount of CSF are given for spread ratio and shortness in Table II and for aroma, flavor, and overall acceptance in Table III. When these two types of stabilizers were compared for their effect on shortness, SSL gave the more tender cookies with 0, 12, and 24% CSF, although the difference was significant only with 0% CSF. With 36 and 48% CSF, XG gave significantly shorter cookies.

Generally, SSL gave higher scores for eating quality than did XG, but usually the differences were not significant (Table III). Flavor, however, was rated significantly higher for cookies with SSL than for cookies with XG when 24, 36, and 48% CSF were used.

Shelf Life

Results for aroma, flavor, tenderness, and overall acceptability of the cookies evaluated after one and two months' storage at room temperature are given in Table IV. Differences between kinds of stabilizer were not significant; therefore, results were pooled to give eight replications for each level of CSF. Generally, higher percentages of CSF and longer times of storage gave lower scores for aroma, tenderness, flavor, and overall acceptability. The addition of some CSF improved overall acceptability scores after one and two months' storage. Overall acceptance scores were

significantly ($P \leq 0.05$) higher for cookies with 12 and 24% CSF than for cookies with 0 or 48% CSF after one month of storage. After two months' storage, the 12, 24, and 36% CSF cookies were scored higher than were the 0 and 48% CSF cookies, but the differences were not significant ($P \leq 0.05$). However, after two months' storage, cookies with 48% CSF were the only ones considered unacceptable, with scores less than four.

Tenderness scores were higher for cookies with 12, 24, and 36% CSF than for cookies with 0 and 48% CSF after both one and two months' storage. In some cases, those differences were significant ($P \leq 0.05$).

Protein

Growth, as measured by protein efficiency ratio, did not improve as the amount of CSF was increased in cookies (Table V). Hayes et al (1978) noted that CSF alone has a higher chemical score than soy does, but obtaining high scores with CSF blends is difficult because CSF is broadly deficient in several essential amino acids. They suggest improving quality by blending with animal protein. We calculated amino acid scores for the cookie and casein combination (Table VI), using the Food and Agriculture Organization/World Health Organization provisional amino acid scoring pattern for children (FAO 1973). Lysine and threonine were limiting for cookies with 0 and 12% CSF, lysine for 24% CSF cookies, and threonine for cookies with 36 and 48% CSF. However, the amount of protein increased from 6.0% in the control cookies to 15.6% in the 48% CSF cookies.

DISCUSSION

Fogg and Tinklin (1972) reported that cookies with no CSF were more acceptable than were those containing CSF. The results of this investigation indicated that acceptable cookies could be made with up to 48% CSF substituted for wheat flour, using a stabilizing agent such as SSL or XG. Scores of four or more on the seven-point scale we used were considered acceptable, and a score of seven was very desirable. Means of fresh cookies with 48% CSF were never less than four in the eating quality evaluations.

Tsen et al (1973), using up to 24% soy flour with SSL and sodium stearoyl fumarate, prepared cookies that were acceptable to school children in Kansas, but these were not evaluated by children in areas of the world where protein deficiencies are more widespread. We would like to have some of those children evaluate higher protein cookies such as ours.

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