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Sensory and Nutritional Quality of Fortified Corn Muffins[1]

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ABSTRACT

Corn muffins were fortified with peanut, soybean and Liquid Cyclone Processed (LCP) cottonseed flours to achieve average protein concentrations of 5.55, 7.12 and 8.44 g/muffin and dietary fiber at concentrations of 1.20, 2.40 and 3.60 g/muffin. Average muffin weights ranged from 36.1 to 43.1 g. Quality of the control and fortified muffins was determined by sensory methods and animal feeding tests.

Sensory acceptability ratings for the peanut and soybean flour fortified muffins were higher than the rating of the LCP cottonseed flour. No difference was found between the sensory acceptability ratings of the muffins supplemented with peanut and soybean flours. Similar acceptability ratings were obtained for muffins fortified with the different levels of protein concentrations. Muffins supplemented with peanut flour at the level of 8.22 g protein/muffin and 1.20 or 2.40 g fiber/muffin were as acceptable to the sensory panel as the nonfortified corn muffins. Protein supplementation of corn muffins allowed weanling mice to sustain a maximal growth rate on a smaller dietary intake when compared to the nonfortified muffins.

Keywords: peanut flour, oilseed flour, protein supplementation, dietary fiber fortification, nutritional quality, sensory quality, fortified corn muffins.

Demand for edible proteins for human consumption in 1990 is expected to increase by 59% over the 1970 supply (Senez, 1976). Since animal proteins are costly to produce and are insufficient to meet this demand, plant protein sources such as oilseeds and grains are needed to help achieve protein sufficiency.

Oilseed proteins are used to fortify bakery foods such as cookies (Moreck *et al.*, 1976; Tsen, 1976), bread (Mecham *et al.*, 1976; Patel *et al.*, 1977), breakfast cereals (Franta, 1976; Gravani, 1976) and cake doughnuts (Lawhon *et al.*, 1975). The nutritional and physiological impact of cereal products in human nutrition were amply reviewed by Lorenz and Lee (1977).

Tsen (1976) stated that protein fortified cookies are convenient and economical items which can be used effectively to increase the dietary protein of children and adults. This could be applied also to protein fortified bread, breakfast cereal, snack foods and other baked goods. Protein fortification of conventional foods acceptable to the consumer may partially fulfill the demand for edible proteins. Most of the literature concerning protein fortification deals with one or two aspects of food quality; i.e., sensory, chemical, storage stability or nutritional quality.

A recent interest has developed in the fiber content of human foods. Much of this interest resulted from the observation that dietary fibers may prevent the occurence of several gastrointestinal diseases (Burkitt, 1977). As a result of this interest, total pound sales of ready-to-eat bran cereals increased 20% during 1975 (Gravani, 1976). Most of the published literature on protein fortification of foods did not consider the influence of high concentration of dietary fibers in addition to high concentration of protein or the sensory or nutritional qualities of the fortified foods.

The objectives of this study were to: 1) evaluate sensory quality of corn muffins as influenced by oilseed source and amount, 2) evaluate the sensory quality of protein fortified corn muffins with and without the addition of dietary fiber, and 3) evaluate the nutritional quality of corn muffins fortified with relatively high levels of peanut flour and dietary fiber.

Materials and Methods

Corn meal and other corn muffin ingredients were obtained from local commercial sources at Gainesville, Florida. Peanut flour was obtained from Gold Kist, Lithonia, Georgia; Staley 1-200 soybean flour was obtained from A.E. Staley Manufacturing Co., Decatur, Illinois; and deglanded Liquid Cyclone Processed (LCP) cottonseed flour was obtained from Texas Tech University, Lubbock, Texas. Protein contents of these flours were 49.8%, 43.8% and 46.4% respectively. These values were calculated from actual nitrogen contents of the flours (AOAC, 1970) as determined in the present study and shown in Table 2 using protein conversion factors of 5.46 for peanut, 5.71 for soybean and 5.30 for cottonseed (Orr and Watt, 1957).

Formulae used to prepare control and fortified corn muffins are shown in Table 1. Weights of oilseed flours varied because of the varying protein contents and desired concentrations of protein in the finished product. Three levels of protein fortification representing 1.77 ± 0.05 x (I), 2.27 ± 0.01 x (II) and 2.70 ± 0.10 x (III) the total protein content of conventional corn muffins, in addition to the control treatment, were used. Total proteins included proteins from milk, whole eggs, corn meal and the oilseed flours. Addition of similar amounts of water to the LCP cottonseed and the soybean mixtures resulted in batters with thinner and thicker consistencies, respectively, in comparison to peanut mixture. In addition, baked cottonseed fortified muffins exhibited a tough crust and soft interior; baked soybean fortified muffins had a dry interior. Since the texture of baked muffins influences the sensory acceptability ratings, it was decided to control muffin texture by balancing the consistency of the various batters prior to baking; this was achieved by varying the amount of water added to batter mixtures. Optimum amounts of water were determined in preliminary trials. Less corn meal was used in the fortified mixtures to allow for the added oilseed flours. All other ingredients used in producing corn muffins were the same regardless of type of oilseed flour used. Mixing of ingredients and baking were carried out according to conventional methods. Each muffin mixture was divided into 4 muffins.

Dietary fiber "Alphacel" was obtained from ICN Life Science Group, Cleveland, Ohio and was added to the two highest peanut

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fortified muffin mixtures at concentrations of 1.20, 2.40 and 3.60 g/muffin.

Moisture, nitrogen, lipid and ash contents of the baked muffins were determined according to recommended AOAC methods (1970). Results were expressed on wet weight basis. A proportional factor was used to convert nitrogen contents to protein values. This factor was calculated on the basis of both the relative contribution of protein sources to the total protein in the muffin and the protein factors 6.38 (milk), 6.25 (egg and corn), 5.46 (peanut), 5.71 (soybean) and 5.30 (cottonseed). These factors were selected according to the recommendations of Orr and Watt (1957).

Sensory evaluation were conducted using 12 judges (7 males and 5 females) ranging in age from 25 to 52 years. Panelists were selected on the basis of their acceptability of corn muffins, ability to discriminate differences, having normal acuity and dependability to attend panel sessions (Martin, 1973; Prell, 1976). Muffins were served warm (45-50^{0}C) along with butter and grape jelly (in separate containers) to the panelists. All samples were examined under red light (Sylvania 150 PAR-FL-GR floodlight) to mask color differences among the muffins. Panelists were requested to rate their acceptability of the muffins on a hedonic scale ranging from 1 for dislike extremely to 9 for like extremely.

The Gardner Automatic Color Difference Meter, model AC-1, was used to measure the color of baked muffins. External color measurements were conducted on the upper and lower surfaces of the muffin. Muffins were cut crosswise at their widest diameter and the cut surfaces of both halves were used for internal color measurements. Each sample was placed on a flat sheet of optical glass which covered the instrument sample port. Conditions of measurements were: small area of illumination (2.5 cm) and standardization with a medium gray color with the color parameters of L 44.7, a_L + 0.7 and b_L + 1.2. Ten muffins from each treatment were used for color measurements; results were expressed as mean values.

To test the nutritional value of the muffins fortified with peanut proteins and dietary fiber, diets based upon three formulations were prepared. These diets contained the muffins plus 25 grams of a vitamin mixture and 29 grams of a salt mixture per kilogram of diet. The vitamin mixture contained all the necessary vitamins in a corn starch base (Anonymous, 1972). The salt mixture was that of Wesson (1932). Mice of the C57 Bl/Fn strain were divided into three groups of 10 each, placed in individual cages three days after weaning (3 wks old) and allowed to consume the diets *ad libitum*. To minimize spillage of the diets the food jars were modified with a wire screen. Growth and food consumption were recorded for three weeks.

At the end of three weeks on the diet, the mice were sacrificed; proximate analyses were performed on their carcasses and separately on their livers.

Analysis for protein was by microKjeldahl (AOAC, 1970), with 6.25 as the factor to convert nitrogen values to protein. Moisture, lipid and ash were determined gravimetrically. Lipids were extracted into 20 times the sample value of chloroform-methanol (2:1). Carbohydrate was determined by difference.

Results and Discussion

Corn meal and LCP cottonseed flour contained more lipids and less ash than the peanut and soybean flours (Table 2). Oilseed flours were higher in nitrogen content than corn meal. Nitrogen content of the baked muffins increased with increasing fortification level. Muffins fortified with either peanut or LCP cottonseed flour showed slightly higher nitrogen contents than those fortified with soybean flour. Fortification with oilseed flours resulted in corn muffins with about 2 to 3 times as much nitrogen and about twice as much ash (Table 2). The high lipid content of the cottonseed fortified muffins was probably due to the relatively low amounts of water added to the mixture (Table 1) and to the higher lipid content of the flour itself (Table 2). Unfortified corn muffins contained less fat than the cottonseed fortified muffins although corn meal had higher fat content than cottonseed flour (Table 2). This was apparently associated in part to the higher moisture content of the unfortified corn muffins (Table 2).

Several factors are used by research workers to convert nitrogen contents of animal and plant materials to protein values. These factors range from 5.30 to 6.31 (Orr and Watt, 1957). These authors also stated that the use of these factors involves two

Table 1. Ingredients for Unfortified and Fortified Muffins

	Control	Fortification Level		
		I	II	III
Peanut Flour				
Corn Meal, g	69.0	28.7	28.7	28.7
Oilseed Flour, g	-	18.0	26.0	35.0
Water, g	54.8	15.8	32.8	54.8
Soybean Flour				
Corn Meal, g	69.0	28.7	28.7	28.7
Oilseed Flour, g	-	23.0	35.0	46.0
Water, g	54.8	49.2	89.0	116.7
LCP Cottonseed Flour				
Corn Meal, g	69.0	28.7	28.7	28.7
Oilseed Flour, g	-	21.0	31.8	42.5
Water, g	54.8	2.8	7.3	24.3

Other ingredients were: nonfat milk 57.5g, whole egg 28.4g, cooking oil 5.2g, sugar 2.7g, salt 1.6g and baking powder 2.1g.

Table 2. Proximate Analysis (Wet Basis) of Corn Meal, Oilseed Flours, and Fortified and Unfortified Baked Corn Muffins.

		Moisture %	Nitrogen %	Lipid %	Ash %
Flour					
Corn		10.6	1.0	4.0	0.4
Peanut		7.5	9.1	1.5	4.4
Soybean		7.6	7.7	0.1	2.9
LCP Cottonseed		7.6	8.8	3.1	1.2
Muffin					
Fortification level					
Peanut	I	44.4	2.5	3.5	3.9
	II	43.3	3.0	3.7	3.9
	III	41.0	3.3	3.8	3.9
Soybean	I	45.8	2.3	4.4	4.8
	II	42.4	2.9	4.4	4.2
	III	41.2	3.1	3.3	4.2
Cottonseed	I	45.6	2.5	6.5	4.1
	II	43.1	3.0	5.3	4.1
	III	39.8	3.5	4.8	4.1
Unfortified	None	50.1	1.2	4.1	2.1

Table 3. Average Baking Loss, Weight, Nitrogen and Protein Contents of Fortified and Unfortified Baked Corn Muffins.

Fortification level		Baking Loss %	Wt g	Nitrogen g/muffin	Total Protein[1] g/muffin
Peanut	I	9.8	36.1	0.92	5.67
	II	16.6	38.1	1.15	7.15
	III	25.4	40.3	1.35	8.22
Soybean	I	24.8	37.3	0.87	5.39
	II	35.6	40.3	1.15	7.11
	III	40.3	43.1	1.35	8.26
Cottonseed	I	1.9	36.8	0.91	5.59
	II	4.4	39.5	1.17	7.10
	III	12.5	42.2	1.47	8.84
Unfortified	None	24.8	41.6	0.50	3.14

[1]Calculated from nitrogen content and a proportional factor based on the relative contribution of protein sources to the total protein in the cooked muffin, using protein factors of: milk:6.31; egg:6.25; corn meal: 6.25; and peanut:5.46; soybean:5.71; or cottonseed:5.30.

Table 4. Gardner Color Values of Unfortified and Fortified Baked Corn Muffins.[1]

		External		Internal	
		Upper half	Lower half	Upper half	Lower half
Unfortified	L	47.9	29.5	65.9	66.8
	a_L	10.9	10.1	0.9	0.5
	b_L	20.1	9.3	17.0	17.9
Peanut	L	47.6	29.0	63.5	62.7
	a_L	10.8	10.2	2.1	1.9
	b_L	19.1	8.2	16.7	16.7
Soybean	L	41.1	30.8	65.0	66.3
	a_L	10.2	9.7	0.6	0.7
	b_L	16.2	8.3	17.7	18.2
Cottonseed	L	31.7	27.3	44.9	45.0
	a_L	9.5	7.5	-2.3	-2.2
	b_L	9.4	5.8	16.2	16.1

[1]Total protein per muffin: 3.14g unfortified, 8.22g peanut, 8.26g soybean, and 8.84g cottonseed.

assumptions: a) that all nitrogen present is protein nitrogen, and b) the protein on which the particular factor for a food was based has the same nitrogen content as other proteins that may be present in the food. Neither of these assumptions is entirely valid. This is of particular importance and is critical for formulated foods that contain several sources of protein. For such foods, amino acid analysis should be conducted and the correct factors calculated. In the present study, no attempts were made to determine the amino acid profiles of the fortified and the unfortified corn muffins. Although the proportional factor used in the present study (Table 3) is not a substitute for the amino acid profile factor, it should be considered appropriate to use since it allowed for the contribution of milk and egg protein.

Corn muffins fortified with either peanut or soybean flour were lighter in color (higher L values) than those fortified with LPC cottonseed flour (Table 4). The interior of the cottonseed-fortified muffins was green as indicated by the negative a_L values. These muffins would be less acceptable to the consumer due to their external brown color and internal greenish yellow hue. The colors of peanut and soybean-fortified muffins were similar to the conventional corn muffins and thus would be readily acceptable to the consumer. No differences were found in the acceptability ratings of fortified muffins due to either increased protein concentration or to fortification with peanut or soybean flour (Table 5). Cottonseed-fortified muffins received lower acceptability ratings than the other sources of oilseed flours. From the results shown in Tables 4 and 5, peanut-fortified muffins were selected for further study.

Table 5. Sensory Acceptability Ratings[1] of Corn Muffins as Influenced by Fortification Source and Concentration of Protein.

Concentration g/muffin	Fortification Source			
	Peanut	Soybean	Cottonseed	Mean
5.55 ± .14	6.9	7.2	5.7	6.6y
7.12 ± .02	7.1	7.4	5.8	6.8y
8.44 ± .31	6.8	7.1	5.9	6.6y
Mean	6.9a	7.2a	5.8b	

Means within each group having no common postscript letter are significantly different at the 0.05 probability level by Duncan's New Multiple Range Test.

[1]1 = Extremely unacceptable, 9 = Extremely acceptable
Unfortified corn muffins (3.1g protein/muffin) received a sensory rating of 6.7.

Table 6. Sensory Acceptability Ratings[1] of Peanut-Fortified Corn Muffins as Influenced by Protein and Dietary Fiber Concentrations (g/Muffin)

Protein	Dietary Fiber			
	1.2	2.4	3.6	Mean
7.15	6.1	6.8	6.4	6.4y
8.22	6.6	6.4	5.9	6.3y
Mean	6.4a	6.6a	6.2a	

Means within each group followed by the same letter are not significantly different at the 0.05 probability level by Duncan's Multiple Range Test.

[1]1 = extremely unacceptable, 9 = extremely acceptable
Unfortified corn muffins (3.1g protein/muffin) received a sensory rating of 6.7.

Recent thoughts on the influence of dietary fiber in providing protection against several gastrointestinal diseases (Burkitt, 1977) have generated interest in the effects of fiber on the sensory quality of foods. Three levels of dietary fiber were added to peanut-fortified muffins. Levels of 1.20 and 2.40 g per muffin approximate the amount of fiber in 1.0 oz servings of 40% bran and 100% bran cereals, respectively (Gravani, 1976). Muffins containing dietary fiber at the highest concentration (3.60 g/muffin) were almost as acceptable to the sensory panel as those containing lesser concentrations (Table 6). Muffins fortified with peanut flour at both conentrations received similar acceptability ratings. This is in agreement with the results obtained in Table 5. Levels of proteins used in the present study were selected on the basis of the recommended allowances of 46 g and 54 g of protein for adult female and male (Anonymous, 1974) and the recommendation that the breakfast meal should provide about 25% of the RDA nutrients (Franta, 1976; Gravani, 1976). Since two muffins are usually consumed for a breakfast meal, the highest level of peanut flour fortification used in the present study would provide 30 and 36% of the RDA requirement for the adult male and female, respectively. Muffins fortified with peanut flour to the highest level (8.22 g per muffin) were selected for further sensory evaluation and nutritional studies.

Sensory food action ratings of protein and fiber-fortified muffins are shown in Table 7. In this evaluation panelists were informed as to which samples were fortified and how much protein, fiber and calories were provided by each muffin. Similar action ratings were awarded to the fortified and the non-fortified muffins. Ratings ranged from "I like this and would consume it now and then" to "I would consume this frequently." Results shown in Tables 6 and 7 indicate the need for a better fiber-fortified muffin. The action rating for the non-fortified muffins was probably due to the sensory panel's familiarity with the flavor and texture of corn muffins. Similar results were obtained for protein-fortified and non-fortified wheat doughnuts (Lawhon *et al.*, 1975).

The data for the capacity of the various muffins to support growth are presented in Table 8. No statistical differences were observed in the body weights of the mice after 3 weeks feeding with the 3 different diets. However, the mice consuming the conventional corn muffin ate more of the diet than those eating either of the modified muffins. The inability of the protein manipulation to increase growth rate can be related to several factors. First, only a poor protein source would stunt growth in the short time these mice were exposed. A great increase in growth cannot be expected since these animals are growing maximally and it is doubted that they can be forced beyond this normal rate (Kennedy, 1950). It is significant that the young mice were able to maintain their growth rate on less of the modified diet with added peanut protein.

The presence of protein from corn, peanut, egg, and milk would tend to produce a complete amino acid mixture, capable of supplying the substrates for the growing organism. Corn meal-peanut flour blends have been shown to be capable of PER's of up to 1.4, and a PER of 2.0 was produced with lysine supplementation (Brookwalter *et al.*, 1977) in comparison to a PER of 0.3 for corn flour. This blending of proteins to maximize the amino acid pattern has been shown to be of great value in achieving protein products of increased nutritional quality (Sarwar *et al.*, 1975).

Whole body proximate analyses are presented in Table 9. No differences were apparent in lipid or ash content; however, mice consuming the protein fortified muffin diet had lower body protein and slightly higher body water than those eating the conventional corn muffin diet. The apparent lower level of protein may be related to the hydration of the mice and may not represent a decreased lean body mass.

Table 7. Food Action Ratings[1] of Corn Muffins Fortified with Protein and Dietary Fibers.

Type of Muffin	Concentration (g/Muffin) Protein	Diet Fibers	Mean Rating
Fortified	8.22	1.2	6.3a
Fortified	8.22	2.4	6.1a
Control	3.14	0.0	6.7a

Means followed by the same letter are not significantly different at the 0.05 probability level by Duncan's Multiple Range Test.

[1] 1 = I would consume this product if I were forced to do so, 9 = I would consume this product at every opportunity I had.

Table 8. Body Weights and Food Consumption of Mice During Trials.

Muffin Diet g/muffin Protein	Fiber	Body Weight (g) Initial	Final	Food Consumption g/total	Diet Efficiency[1]
8.22	1.20	10.2 ± 0.3	17.9 ± 0.8	54.6 ± 6.3*	.141
8.22	2.40	9.8 ± 0.6	18.3 ± 0.4	54.6 ± 2.1*	.156
3.14	0.00	9.8 ± 0.6	17.1 ± 0.5	73.5 ± 2.1	.099

*Significantly lower than unfortified muffins ($p \leq 0.01$).

[1] Diet efficiency = total gain/total food consumption.

Table 9. Proximate Analyses of Mice Carcass and Liver as Influenced by Muffin Diet.

Muffin Diet g/Muffin Protein	Fiber	Moisture %	Protein %	Lipid %	Ash %	Carbohydrate %
Carcass						
8.22	1.20	70 ± 3	16 ± 1*	8.1 ± 0.9	2.0 ± 0.4	3.9
8.22	2.40	66 ± 2	18 ± 2*	8.1 ± 0.5	1.9 ± 0.2	6.0
3.14	0.00	65 ± 2	22 ± 1	8.0 ± 0.7	2.3 ± 0.2	2.7
Liver						
8.22	1.20	71 ± 1	11 ± 1	5.5 ± 0.1*	0.9 ± 0.1	11.4
8.22	2.40	73 ± 1	10 ± 1	5.7 ± 0.6*	0.8 ± 0.1	10.6
3.14	0.00	73 ± 1	11 ± 1	7.2 ± 0.6	0.9 ± 0.1	8.6

*Significantly lower than unfortified muffins ($p \leq 0.01$).

Since the liver is a central metabolic organ, a separate analysis was performed to determine its constituents. Cursory examination revealed that all livers appeared normal. These data were confirmed when analyses were carried out. All groups were similar in composition except that the lipid content of livers from mice consuming the conventional muffin was higher than that of mice consuming the protein fortified muffin diet (Table 9). Conversely, carbohydrate content was highest in the livers of mice consuming diets based upon the modified muffins. Further study to more clearly elucidate the effects of protein and fiber supplementation on nutritional status is needed. Results of this study indicate that peanut and soybean flour could supplement corn muffins without adversely affecting sensory quality.

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