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Selected nutritional, physical and sensory characteristics of pan and flat breads prepared from composite flours containing fababean

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Abstract. Composite flour blends containing wheat (W), fababean (F), cottonseed and sesame flours were formulated to provide the FAO/WHO/UNU protein requirements for the 2–5 year old child, and evaluated in pan and flat bread applications. Water absorption of composite flour doughs was up to 35% greater than the control but gluten strength and slurry viscosities were markedly reduced. Loaf volume and specific volume of pan breads prepared from composite flours were 25–60% less than that of the control bread but flat breads tolerated the protein supplements extremely well. The W/F flat bread, containing 27% of fababean flour, received acceptable taste, texture and colour scores and was only slightly inferior to the control in puffing and layer separation. Additions of cottonseed or sesame flours to the W/F blend failed to improve sensory properties of the flat breads.

Introduction

Bread is one of the most important staple foods, furnishing a major portion of the caloric intake as well as dietary protein for the world population. This is particularly true in the Middle East where cereals, primarily wheat, constitute approximately 50% of total calories and 65% of total protein consumed [22]. In several Middle Eastern countries bulgur and couscous are traditional foods but a thin two-layer, Arab-style flat bread is the predominant food form for populations at most income levels. Although classed as leavened breads, the flat bread doughs contain yeast or starter dough as much for flavour development as for dough expansion. A short period of high temperature during baking causes the dough to rise substantially due to rapid generation of steam. While the loaf will collapse on cooling, the interior of the bread has a soft crumb which adheres to the two distinct layers of the top and bottom crusts.

Although bread wheats and wheat flours are commonly high in protein content relative to other cereals, breads are frequently deficient in certain essential amino acids such as lysine, threonine and tryptophan [10, 14]. Protein supplements from legume or oilseed sources have been used to improve the nutritive value of pan breads [9, 18] and Arabic breads [11]. In order to maintain acceptable bread structures and organoleptic properties, the maximum levels of non-wheat flours in the blends had to be restricted to 15–20%. At this level of blending, the protein efficiency ratios of the flour blends or breads were increased from 1.1 to about 1.7, relative to the value of 2.5 for casein protein controls.

The objective of the present study was to evaluate a wheat-fababean flour blend, in proportions designed to increase the protein nutritive value by 50% over a wheat flour control, in flat and pan bread applications. To improve amino acid balance and functional or sensory properties, additional blends were prepared in which cottonseed or sesame flours replaced a portion of the fababean flour. Nutritional assessments were based on amino acid composition, chemical score, protein content and digestibility, and calculated protein efficiency ratio (C-PER).

Materials and methods

Materials

Samples of the hard red spring wheat cultivar, HY320, were obtained from pedigreed seed stocks at the University of Saskatchewan, Saskatoon, Canada. The cultivar is a common wheat, *Triticum aestivum* s. sp. *vulgare* (Vill. Host) Mackey, with only intermediate protein content, gluten strength and kernel hardness. The wheat grains were tempered overnight to 14.5% moisture content and milled into flour on a Brabender Quadrumat Jr. flour mill at an extraction rate of 73%.

Fababean seed (*Vicia faba minor* L.) of the cultivar, Outlook, was grown on the experimental plots of the University farm in 1987. The brown hulls were removed by abrasive milling on a resinoid disc, abrasive dehuller, followed by air aspiration to remove the approximately 15% of fine hull materials. The dehulled cotyledons were ground in a hammer mill to pass a 60-mesh screen and frozen at $-20\,°C$ until required for analysis. Glandless cottonseed flour (*Gossypium hirsutum* L.) was obtained from Texas A & M University, College Station, TX. Sesame seed, *Sesamum indicum* L., was ground in a Krups coffee mill and the oil extracted with hexane on a 3L Soxhlet unit (Corning Glass Co., Corning, NY) for 24 h. The meal was desolventized at 40 °C in a vacuum oven and reground to pass a 60-mesh screen.

Blends

The proportions of wheat (W), fababean (F), cottonseed (C) and sesame (S) flours in the blends were formulated according to the FAO/WHO/UNU [8] protein requirements of the 2–5 year old child. A report of the Ad-Hoc Working Group on Protein Quality Measurement, CX/VP 87/3 which was prepared by G. Sarwar (Canada) recommended the previous pattern as the reference protein for calculating amino acid scores [Feb. 2–6, 1987]. In addition, this pattern is in close agreement with the NRC [16] protein pattern. Based on an average food intake of 322 g/day and a protein requirement of 16.5 g/day, the protein composition of the diet should be 19.5%, N × 6.25 basis, or 17.8%, N × 5.70 basis. A level of 73% wheat flour and 27% fababean flour provided this dietary protein level.

The FAO/WHO/UNU [8] protein requirement was based on milk protein with 95% protein digestibility. For vegetable protein at approximately 85% digestibility, proportionately higher protein levels were recommended. Therefore, blends of 75 : 15 : 10 of W/F/C and 75 : 17 : 8 of W/F/S provided higher protein contents of 19.8% (N × 5.70) for these encriched protein diets were also evaluated. All blends were prepared in duplicate and the results of all analysis are the means of the two replicates.

Analytical procedures

The samples were analyzed by standard AACC procedures [1] for moisture (Method 44-15A), crude protein (Method 46-13), crude fat (Method 30-25), and total ash (Method 08-03). The protein content of samples was calculated using the nitrogen-to-protein conversion factor of 5.70, based on the recommendations of Sosulski and Imafidon [20]. Total dietary fiber was quantified using the enzymatic gravimetric procedure in the first supplement of AOAC [2] (Method 43.A14).

Starch contents were measured as glucose on the YSI Model 27 Industrial Analyzer (Yellow Springs Instrument Co., Yellow Springs, CO) using a modified Budke [3] procedure. Free sugars were extracted with 80% ethanol prior to starch hydrolysis with Termamyl 120 L (Nova Laboratories Inc., Wilton, CT) at pH 6.0 in a boiling water bath for 30 min, followed by Diazyme L-200 (Miles Laboratories Inc., Elkhart, IN) at pH 4.8 and 60 °C for 30 min. Free sugars in cottonseed ethanol extract were determined by the colorimetric phenol sulphuric method of Dubois et al. [7].

Amino acid compositions of the proteins in the flours, blends and breads were determined on a Beckman model 119 BL analyzer (Beckman Instruments Inc., Palo Alto, CA) following hydrolysis with 6N HCl at 100 °C under nitrogen for 24 h. Sulfur-containing amino acids were determined as cysteic acid and methionine sulfone after preoxidation with performic acid, and tryptophan was quantitated on a $Ba(OH)_2$ hydrolysate [20]. Amino acid (AA) scores were calculated as the ratio of the first limiting amino acid (FLAA) in the product to that of the FAO/WHO/UNU [8] amino acid requirement for the preschool child (2–5 years). Protein efficiency ratios (C-PER) were calculated using the essential amino acid requirement pattern of the FAO/WHO/UNU [8], corrected for protein digestibility [12]. *In vitro* protein digestibility was determined by the multienzyme technique of Hsu et al. [13] using trypsin, chymotrypsin and peptidase.

Dough and bread evaluations

Water absorption of the flours was measured by the centrifuge method of Sosulski [19] while mixograms were determined at 55, 60 and 65% water absorption by AACC method 54-40. The visco/amylograph curves were conducted on 14% slurries by AACC method 22-10 [1].

Pan breads were prepared by a modified AACC [1] straight dough procedure (method 10-10A). The baking formula included 100.0 g (14% moisture basis) of composite flour or wheat flour (control), 4.0 g nonfat dried milk, 4.0 g sucrose, 3.0 g shortening, 0.75 g active dried yeast (db), 1.75 g salt, 0.3 g malt, 0.1 g ammonium phosphate monobasic, 50 ppm $KBrO_3$ and water calculated according to water absorption. The ingredients were mixed in a Grain Research Laboratory (GRL) dough mixer for 3 min and dough fermentation was for 3 h at 30 °C and 80% relative humidity. Baking time was 25 min at 230 °C.

The baking formula for flat bread included 100.0 g (14% moisture basis) composite flour or wheat flour (control), 2.0 g active dried yeast (db), 1.5 g salt and water calculated according to absorption. The ingredients were mixed in the GRL mixer for 3 min, followed by dough fermentation for 1 h at 30 °C and 85% relative humidity. The fermented doughs were cut into 145 g pieces that were proofed for 45 min at 32 °C and 90% relative humidity before flattening on a circular dough molder [17] to 3 mm thickness. The flat dough pieces were held in a proofing cabinet for 15 min at 30 °C and 95%

Table 1. Composition of wheat (W), fababean (F), cottonseed (C) and sesame (S) flours and their composite flour blends (% dry basis)

	W	F	C	S	W/F	W/F/C	W/F/S
Proportion	100	100	100	100	73:27	75:15:10	75:17:8
Starch	75.3	42.9	1.9	2.7	66.4	63.3	64.2
Protein[a]	13.6	29.1	53.2	59.9	17.8	19.8	19.9
TDF[b]	3.4	16.7	14.6	19.8	6.8	6.6	7.0
Lipid	1.0	1.1	1.4	2.7	1.0	1.0	1.1
Ash	0.5	2.7	8.3	7.6	1.1	1.6	1.5
Total	93.8	92.5	79.4	92.7	93.1	92.3	93.7

[a] N × 5.70.
[b] Total dietary fiber.

relative humidity and baked for 4 min at 325 °C. All bakes were performed in duplicate.

Loaf volumes were determined by rapeseed displacement. Specific volume was calculated from loaf volume and loaf weight, both of which were measured 1 h after baking.

The sensory properties, including taste, texture, crumb color, crust color, and puffing or layer separation for flat bread, were scored by an expert panel of 4 bakers on a scale of very good (VG), good (G), fair (F) and poor (P) according to Sosulski and Wu [21].

Results and discussion

Composition of flours and blends

Starch and protein were the principal components in wheat flour but fababean flour had three major components of starch, protein and total dietary fiber (Table 1). The cottonseed and sesame flours were rich in protein with high levels of dietary fiber and ash, and almost no starch. The total measured constituents in cottonseed flour was only 79.4% as compared to 93–94% in the other flours. Analysis for soluble sugar content of this flour resulted in a value of 11.3% [db]. Research by Lusas and Jividen [15] on glandless cottonseed flour indicated that 13.7% was sugar.

The three composite flour blends were similar in composition (Table 1). The W/F blend contained slightly more starch but less protein and ash than W/F/C or W/F/S.

Compared to wheat flour, fababean flour was rich in lysine and threonine, but much lower in methionine, cystine and tryptophan (Table 2). Cottonseed flour was intermediate in lysine and methionine contents but low in

Table 2. Amino acid composition of protein in flours and composite flours and their nutritional indices (g/16 gN)

Amino acids (AA)	Flours				Composite flours			FAO pattern[a]
	W	F	C	S	W/F	W/F/C	W/F/S	
Lys	2.2	6.6	4.6	3.1	3.4	3.2	3.1	5.8
Met	1.7	0.9	1.3	3.1	1.5	1.6	1.7	2.5
Cys	2.1	1.2	1.9	2.0	1.9	2.0	2.0	–
Thr	2.7	3.5	2.2	3.5	3.0	2.8	2.9	3.4
Trp	1.6	1.0	0.8	1.1	1.5	1.4	1.5	1.1
His	2.2	2.5	2.9	2.7	2.4	2.4	2.4	1.9
Ile	3.4	3.8	3.0	3.5	3.5	3.4	3.5	2.8
Leu	7.1	7.5	6.0	6.8	7.3	7.0	7.2	6.6
Phe	5.2	4.2	5.5	4.9	5.0	5.1	5.1	6.3
Tyr	2.6	3.1	3.3	4.2	2.8	2.8	2.8	–
Val	4.3	4.8	4.4	4.9	4.5	4.4	4.5	3.5
Ala	3.2	4.2	4.3	4.7	3.5	3.4	3.5	–
Arg	3.4	9.5	12.1	12.5	5.0	5.2	5.3	–
Asp	4.3	11.1	10.6	8.8	6.1	6.0	5.9	–
Glu	32.9	18.5	22.6	21.0	29.5	29.7	29.7	–
Gly	3.8	4.1	4.2	4.8	3.9	3.9	3.9	–
Pro	11.3	4.3	3.5	3.2	9.6	9.5	9.5	–
Ser	5.2	5.2	4.8	4.7	5.2	5.3	5.2	–
Total AA	99.2	96.0	98.0	99.5	99.6	99.1	99.7	–
Total EAA	35.1	39.1	35.9	39.8	36.8	36.1	36.7	33.9
AA Score[a]	38	84[d]	65	53	59	55	53	100
FLAA[b]	Lys	Met	Thr	Lys	Lys	Lys	Lys	–
PD[c]	86.5	77.4	79.7	82.8	83.7	84.7	84.8	–
C-PER	1.2	1.7	1.5	1.8	1.9	1.8	1.8	–

[a] Amino acid score is based on FAO/WHO/UNU (1985) pattern for pre-school child (2–5 years).
[b] FLAA – first limiting amino acid.
[c] Protein digestibility, %.
[d] Assuming the sparing effect of Cys on Met requirement was 50%.

threonine and tryptophan comparing to wheat and fababean flours. Sesame flour had a low lysine level but contained the most methionine and cystine. Relative to the FAO/WHO/UNU [8] requirements for the 2–5 year old child, the amino acid score for wheat flour was only 38 as compared to 84, 65 and 53 for the fababean, cottonseed and sesame flours, respectively (Table 2). Note that lysine was the first limiting amino acid in wheat and sesame flours but methionine and threonine, respectively, were most limiting in fababean and cottonseed flours. Protein digestibility in wheat flour greatly exceeded that of fababean flour, with cottonseed and sesame flours having intermediate digestibilities. Thus, the C-PER for wheat was about two-third of the values for fababean and sesame flours. The low C-PER for cottonseed flour was due, in part, to the lower total EAA value.

The three composite flours were quite uniform in composition of esential and nonessential amino acids (Table 2). However, the amino acid score of the W/F flour was about 9% higher than the computed values for W/F/C and W/F/S composites, based on the contents of the first limiting amino acid, lysine. The protein digestibilities of the three composites were uniformly 84–85% and C-PER values ranged from 1.8 to 1.9.

Rheological properties of doughs

The water absorption values for wheat, W/F, W/F/C and W/F/S flours were 68, 80, 90 and 93%, respectively. Because of the wide differences in absorption, the mixograph curves were developed at three moisture levels: 55%, 60%, and 65% (Table 3). As dough moisture level was increased, the time to reach peak height increased but peak height and curve area decreased for each flour. Wheat flour gave the strongest mixograph curve and W/F, which contained the least wheat flour, and W/F/C showed the weakest dough strength (Fig. 1). D'Appolonia [5, 6] and Sathe et al. [18] had previously shown that water absorption increased and dough strength decreased when legume flours or protein concentrates were incorporated into bread formulations.

The visco/amylograph curves for 14% slurries of the composite flours demonstrated that the legume and oilseed flours reduced the slurry viscosities quite markedly, especially in the W/F/C flour (Table 3), The W/F/C flour slurry also exhibited low pasting and peak temperatures.

Composition of pan and flat breads

The starch and protein contents of the breads (Table 4) were only slightly lower than in the blends (Table 1) because dilution with other dough ingredients was minimal. Also, the total dietary fiber, lipid and ash contents of wheat breads were higher than in the original wheat flour due to the added ingredients and baking effects.

Lysine contents of the proteins in the pan and flat breads were similar to those of the original flours and blends (Table 5). However, methionine, threonine and tryptophan concentrations appear to have been adversely affected by the heat during baking. Where the recoveries of total amino acids and total essential amino acids in the original flours and blends averaged 98.8% and 36.8%, respectively, (Table 2) the corresponding values for the baked breads were 94.4% and 33.2% (Table 5). Also, the amino acid score

Table 3. Rheological properties of control and composite flours

Composite flour	Mixograph curves 55%[a]			60%			65%			Visco/Amylograph curves		
	Time (min)	Height (cm)	Area (cm^2)	Time (min)	Height (cm)	Area (cm^2)	Time (min)	Height (cm)	Area (cm^2)	Pasting temp. (°C)	Peak viscosity (BU)	Peak temp. (°C)
W	2.0	10.4	113.1	2.5	10.3	98.6	2.5	9.6	83.2	63.0	640	94.5
W/F	1.8	10.4	82.7	2.5	7.9	67.8	2.8	7.7	65.1	63.0	380	91.5
W/F/C	2.2	9.0	77.9	2.3	8.6	73.0	2.7	7.3	62.5	61.5	210	90.0
W/F/S	1.7	10.4	89.8	2.0	8.6	78.8	2.7	8.3	74.8	66.0	340	93.0

[a] Water absorption at 14% mb.

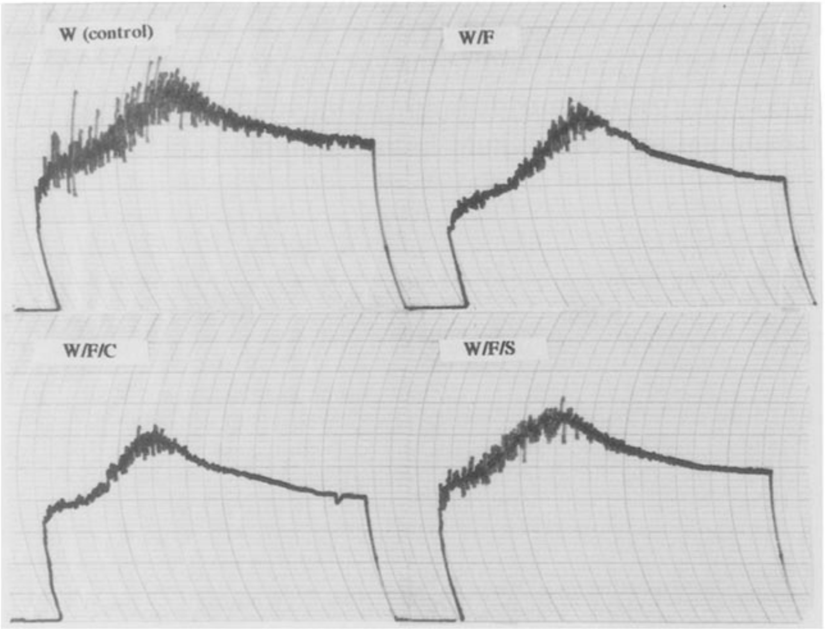

Fig. 1. Mixograms (35 g based on 14% mb at 65% water absorption) of control and composite flour blends.

for wheat flour was 38 and the scores for the pan and flat breads dropped to 35 and 31, respectively. The amino acid scores for pan breads tended to be higher than for most flat breads, especially for W/F bread. The C-PER values reflected these effects, baking in general decreased the values but the blend values were still essentially twice those of the wheat controls.

Table 4. Composition of pan and flat breads prepared from wheat and composite flours (% dry basis)

Constituent	Pan bread				Flat bread			
	W	W/F	W/F/C	W/F/S	W	W/F	W/F/C	W/F/S
Starch	72.7	65.7	61.5	62.2	74.0	66.1	62.4	63.0
Protein[a]	13.9	17.5	20.4	20.6	14.1	17.6	20.5	20.9
TDF[b]	4.1	6.0	6.8	7.7	4.3	5.8	6.2	7.0
Lipid	1.3	1.1	1.3	1.2	0.7	0.8	0.8	0.8
Ash	2.4	2.8	3.3	3.1	2.2	2.6	3.2	2.9
Total	94.4	93.1	93.3	94.8	95.3	92.9	93.1	94.6

[a] N × 5.70.

[b] Total dietary fiber.

Table 5. Amino acid composition of proteins in pan and flat breads and their nutritional indices (g/16 gN)

Amino acids (AA)	Pan bread				Flat bread				FAO pattern[a]
	W	W/F	W/F/C	W/F/S	W	W/F	W/F/C	W/F/S	
Lys	2.0	3.4	3.2	3.0	1.8	3.1	2.9	3.0	5.8
Met	1.6	1.2	1.2	1.5	1.3	1.3	1.3	1.6	2.5
Cys	2.0	1.8	1.7	1.8	1.9	1.9	1.9	2.0	–
Thr	1.7	2.3	1.9	1.9	1.8	2.2	2.1	2.5	3.4
Trp	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.3	1.1
His	2.2	2.4	2.3	2.2	2.1	2.3	2.3	2.1	1.9
Ile	3.3	3.6	3.2	3.1	3.2	3.6	3.6	3.2	2.8
Leu	6.8	7.1	6.6	6.5	6.6	7.1	6.5	6.5	6.6
Phe	4.4	4.4	4.2	4.2	4.3	4.2	4.4	4.1	6.3
Tyr	2.7	3.7	3.7	3.5	2.4	3.1	3.2	3.2	–
Val	4.2	4.4	3.8	4.2	4.1	4.6	4.6	4.7	3.5
Ala	3.2	3.5	3.2	3.8	3.2	3.7	3.8	3.6	–
Arg	3.7	6.3	7.1	5.6	3.8	6.2	6.5	6.4	–
Asp	5.5	8.2	7.9	8.0	5.4	8.2	8.1	7.8	–
Glu	30.2	26.7	26.8	28.3	32.1	27.3	26.4	27.5	–
Gly	3.5	3.6	3.5	3.8	3.6	3.9	3.9	4.0	–
Pro	10.5	7.4	6.8	6.4	10.4	7.9	7.3	6.8	–
Ser	4.8	5.0	4.6	5.0	4.8	5.0	4.8	4.7	–
Total AA	93.3	96.0	92.8	93.9	93.9	96.8	94.8	95.0	–
Total EAA	31.9	35.3	32.9	33.0	30.6	34.6	34.0	34.2	33.9
AA Score[a]	35	59	54	51	31	54	51	51	100
FLAA[b]	Lys	Lys	Lys	Lys	Lys	Lys	Lys	Lys	–
PD[c]	86.0	84.6	85.1	85.1	86.9	85.1	85.1	85.1	–
C-PER	0.8	1.7	1.4	1.5	0.7	1.5	1.5	1.6	–

[a] Amino acid score is based on FAO/WHO/UNU (1985) pattern for pre-school child (2–5 years).
[b] FLAA – first limiting amino acid.
[c] Protein digestibility, %.

Baking quality

The loaf weights of pan and flat breads which contained W/F and W/F/C flours were greater than control (W) weights, apparently due to the greater water absorption in the doughs (Table 6). It appeared that W/F/S breads failed to retain the extra water required for optimum dough development.

In the pan breads, loaf volumes and specific volumes were reduced quite markedly by the protein supplements in the blends (Table 6). The W/F bread, which was reduced in volume by about 25% over the control, was superior to the other composite breads in both parameters. The W/F bread was rated as 'Good' in taste and texture, and had acceptable crumb and

Table 6. Physical and sensory characteristics of pan and flat breads prepared from composite flours

Composite flour	Loaf weight (g)	Loaf volume (cc)	Specific volume (cc/g)	Taste (score[a])	Texture (score[a])	Crumb color	Crust color	Puffing and layer separation (score[a])
Pan bread								
W (control)	140.7	700	4.98	VG	VG	White	Brown	–
W/F	148.0	530	3.58	G	G	Cream	Brown	–
W/F/C	149.1	455	3.05	F	G	Beige	Brown	–
W/F/S	141.7	430	2.83	G	G	Cream	Brown	–
Flat bread								
W (control)	121.3	625	5.15	VG	VG	White	White	VG
W/F	124.3	580	4.67	VG	VG	Cream	Cream	G
W/F/C	124.1	655	5.28	F	G	Green/brown	Green/brown	VG
W/F/S	118.8	490	4.12	G	G	Cream	Cream	P

[a] VG = very good, G = good, F = fair, P = poor.

crust colors. The W/F/S bread received the same organoleptic ratings as W/F, but W/F/C appeared less satisfactory in taste and color.

D'Appolonia [5] and Fleming and Sosulski [9, 10] reported similar reductions in loaf and specific volume, and bread characteristics, in fababean-supplemented breads. In their investigations, additions of vital gluten and dough conditioners were necessary to restore bread quality.

It appeard that flat breads were more tolerant of the protein supplements than pan bread. The loaf and specific volumes of W/F flat bread were reduced less than 10% relative to the control (W) flat bread (Table 6). Also taste, texture and color ratings were as acceptable as the control. Puffing and layer separation for the W/F bread was given only a 'Good' rating. The W/F/C flat bread was excellent in volume and puffing, but was down-graded for taste and color. The W/F/S flat bread exhibited the poorest volume and puffing score. Previously, Hallab et al. [11] reported that chickpea flour could be incorporated up to 20% into white Arabic bread without adverse effects on organoleptic properties but only 10% soybean flour could be added and still be rated as being organoleptically acceptable.

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