Use of Partially Defatted Peanut Flour in Breakfast Cereal Flakes

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ABSTRACT

Extruded breakfast cereal flakes were made by replacing corn cones with nonroasted partially defatted peanut flour (PDPF) and roasted partially defatted peanut flour (R-PDPF) at various levels (10, 20, and 30%). The mixtures were extruded using a corotating twin-screw extruder to produce collets. The collets were flaked and then toasted. The extruded toasted flakes were analyzed for physical, physicochemical, and sensory characteristics. Moisture content, bulk density, hardness (force to break), color, bowl life, water absorption, and water solubility indices were significantly affected by the amount of PDPF and R-PDPF added in the formulation. A sensory panel found extruded toasted flakes made from corn cones and up to 20% R-PDPF were acceptable as control. Peanut flavor intensity was also evaluated. Surprisingly, peanut flavor intensity was the highest for flakes containing 30% PDPF, rather than those containing 30%R-PDPF.

Extrusion is one of many techniques used for manufacturing ready-to-eat (RTE) cereals (Harper 1981). Midden (1989) and Bailey (1991) produced breakfast cereal flakes using a twin-screw extruder. The extrusion process reportedly has numerous processing conveniences over conventional processing methods, including faster processing, lower processing cost, and lower space cost. Four factors that should be monitored in extrusion processing are temperature, cooking time, moisture, and shear (Miller 1994). Overly sheared products absorb moisture quickly and become soggy. They can have a slimy mouthfeel or odd flavors. Rokey (1995) stated that longer cooking time, higher moisture, moderate temperature, and minimum shear are the most important factors in cornflakes acceptability.

Generally, peanuts are considered as an oilseed crop grown primarily for oil production. A high-protein peanut press cake, which is normally used for animal feed, is a byproduct derived from the oil extraction process. Peanut press cake, however, can be used for human food if it is processed from food-grade peanuts under hygienic environments (Lusas 1979). Peanut flour has a relatively high protein content, bland flavor, and light tan color which allow it to be incorporated into a wide range of foods (Prinyawiwatkul et al 1995). The use of peanut flour as a protein supplement in breakfast cereals has been extensively studied. Spadaro et al (1971) used rice grits mixed with defatted peanut flour to make products with higher protein content and desirable cereal-like flavor. Harris et al (1972) developed breakfast cereal flakes that compared favorably with commercial flakes by drum-rolling dough mixtures of defatted peanut, corn, and wheat flour. Extrusion of peanut flour with corn and oats produced breakfast cereals with high protein content, but these products absented peanut flavor (Ayres and Davenport 1977). Suknark et al (1997) recently investigated physical properties of directly expanded extrudates by blending partially defatted peanut flour with different types of starch using single-screw extruder at different conditions.

A peanut flour with very low fat content and strong roasted peanut flavor has only limited application in the food industry, especially in breakfast cereal flakes. A definite need exists for a strongly flavored partially defatted peanut flour for use in reduced-fat food products. In an attempt to produce peanut-flavored flakes, corn cones were also mixed with roasted peanut flour. Roasting process may improve flavor of partially defatted peanut flour and alter the physical properties of products in which it is incorporated. Therefore, the purpose of this study was to evaluate the effects of partial replacement of roasted and nonroasted peanut flours for corn cones to produce breakfast cereal cornflakes, and also to determine the maximum amount of peanut flour that can be substituted to produce acceptable high-protein flakes.

MATERIALS AND METHODS

Raw Materials

Peanuts (*Arachis hypogaea* L. cv Spanish) were obtained from the Birdsong Peanut Corp. (Gorman, TX). Sunlite yellow corn cones (#S 40) were obtained from the J. R. Short Milling Co. (Kankakee, IL); the particle size specification is shown in Table I. Malt (Maltoline ER Light) was purchased from Crompton & Knowles Corp. (Mahwah, NJ). Yellow corn meal (ConAgra Inc., Omaha, NE), white sugar (Domino Sugar Corp., NY), and iodized salt (Morton International, Inc., Chicago, IL) were purchased from a local supermarket.

Preparation of Roasted and Nonroasted Partially Defatted Peanut Flours

Peanuts were blanched in batches of 2.3 kg for 30 sec using a mini-dehuller (Nutana Machine, Saskatoon, Canada) to remove skins. Oil was removed using a dry extruder (InstaPro International, Des Moines, IA) and a continuous horizontal screw press (InstaPro 1500). Peanut press cakes were divided into two lots. One lot of press cakes was roasted in a hot air oven (Despatch Ovens Co., Minneapolis, MN) at 166°C for 8 min, and immediately cooled to room temperature. The other lot was not roasted. The roasted and nonroasted press cakes were milled (Bauer Bros Co., Springfield, OH) and then sieved through a 60-mesh screen. The partially defatted peanut flours were stored at 3°C until used for further product development and analyses.

Flakes Formulation

The base formula used for making flakes is shown in Table II. The control formula had only corn cones. In the test formula, corn cones were replaced by PDPF and R-PDPF at levels of 10, 20, and 30% of the total mix. All blends contained 10% sugar, 3% malt, and 2% salt. To improve texture, mouthfeel, blistering, and appearance of the final flakes, corn meal (8.5%) was added to the cornflakes formula as suggested by E. Sevatson (Wenger Mfg. Co., *personal communication*).

The process used to produce flaked cereal is shown in Fig. 1. Each blend (13 kg) of dry ingredients was mixed in a dry vertical mixer (Hobart Mfg., Troy, OH) at low speed for 2 min. Liquid malt was added gradually to dry ingredients and mixed for 5 min at medium speed. Mixing continued at low speed for 20 min to ensure homogeneity. All blends were held in tied plastic bags overnight at 3°C. Before extrusion, the mixes were brought to room temperature.

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Extrusion Process

A corotating, intermeshing, twin-screw extruder (TX-52, Wenger Mfg. Co., Sabetha, KS) equipped with a 25.5:1 (nine heads) length-to-diameter ratio extruder barrel was used. A vent was used on the 7th head to depressurize steam to the atmosphere. Chilled water (9°C) was circulated in the barrel in zones 5 and 6 (8th and 9th heads) to avoid puffing of the collets. The feeder, preconditioner, and main twin-screws were operated at 13, 96, and 165 rpm, respectively. Material flow rate was held at 64 kg/hr. In the preconditioner, steam was added at a rate of 0.3 kg/min, and water at a rate of 0.112 kg/min. Retention time in the preconditioner was 240 sec. The exiting temperature of product from the preconditioner was 91°C. Temperatures of zones 1 through 6 of the extruder barrel were held constantly at 60, 100, 100, 90, 60 and 60°C, respectively. The head pressure was ≈425 PSI. Steam was injected into the extruder barrel at a rate of 0.08 kg/min. No water was added at the extruder barrel. A die with four inserts (6-mm round holes) was used. The temperature of collets exiting from the extruder was ≈98°C.

Extrusion was allowed to reach the steady state for at least 5 min between trials, and then collets were collected. The round-shaped collets were later cooled in trays at room temperature. Collet size from each trials was similar at ≈36 beads/100 gm. An effort was made to collect these collets in one layer to keep them separated. Collets were held in air-tight plastic bags for two days at cold storage (3°C) to allow moisture equilibration. Then they were delivered for flaking.

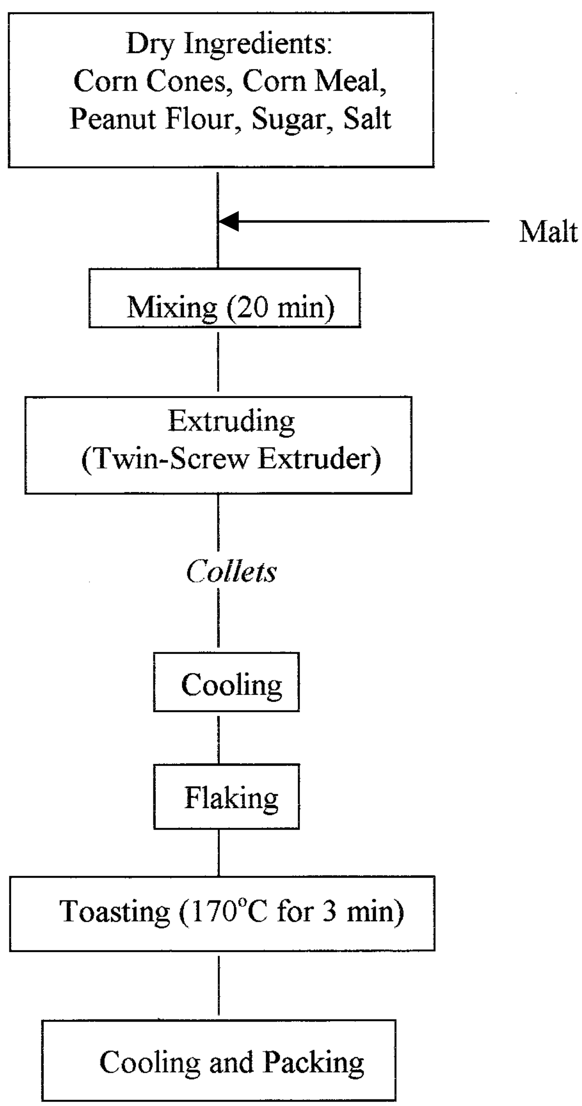

Fig. 1. Processing scheme for extruded breakfast cereal flakes.

Flaking and Toasting Process

Flaking and toasting were conducted at the Wenger Mfg. pilot plant in Sabetha, KS. Collets were flaked using Wenger RS-90 faking rolls. The flaking rolls were operated at constant speed (1,135 ft/min). The gap between the rolls was 0.43 mm. The flakes were toasted in a Wenger 4800 drier/toaster at 170°C for 3 min. Dried flakes were stored in plastic bags at room temperature for other measurements.

Experimental Design

The research design included seven trials, one control, peanut flour and corn cones at ratios of 10:90, 20:80, and 30:70, and two types (roasted and nonroasted) of partially defatted peanut flour. Each trial was performed in triplicate. The run order of all blends was randomized. Twenty-one extrusion trials were completed in one day.

Measurement of Physicochemical Properties

The raw material and extruded flakes were ground in the CRC micromill (The Chemical Rubber Co., Cleveland, OH) to pass through a 60-mesh sieve for analyses. Proximate analyses were performed using official procedures (AOAC 1993), with the exception of protein analysis. Crude protein was determined by the Kjeldahl method (AOAC 1990).

Bulk density was analyzed for all extruded toasted flakes in triplicate using the Winchester bushel meter (Seedburo Equipment Co., Chicago, IL). Samples were filled to overflowing in the measuring cylinder (35.24 L) without tapping, then leveled off with a straightedge, and weighed (calculated wt. of sample/unit volume [g/L]).

Hardness (force-to-break) was determined on 10 extruded toasted flakes from each extrusion run using the texture analyzer (TA.XT2, Texture Technologies Corp., Scarsdale, NY) with the small probe (TA-52). The compression test mode was used. The parameters were pretest speed 5 mm/sec, test speed 1 mm/sec, and distance 5 .0 mm.

Color difference measurements (*L*, *a*, and *b*) were made in triplicate on the extruded toasted flakes using Hunterlab tristimulus colorimeter (Reston, VA). Flakes (7 g) were broken into small pieces and arranged to cover the bottom of a sample cup.

Water absorption (WAI) and water solubility (WSI) indices were determined in triplicate followed the procedure of Anderson et al (1969). WAI is the weight of the gel obtained per gram of dry sample. WSI is the amount of solids recovered by evaporating the supernatant from the water absorption tests, expressed as percentages of dry solids in the sample.

The time (min) for crispness to disappear was recorded as the "bowl life". The disappearance of crispness was determined subjectively by soaking 10 g of samples in cold milk (10°C) and chewing flakes at 1-min intervals until crispness disappeared (Celis et al 1996). The measurements were evaluated in triplicate. Three different (A, B, and C) commercial cornflake products were purchased from local stores and also tested. Commercial cornflakes A and B are processed

TABLE I
Typical Particle Size Specification of Corn Cones[a]

Granulation	Specification
On U.S. No. 20 Sieve (850 µm)	0
40 Sieve (425 µm)	2% max.
80 Sieve (180 µm)	95% min.
Thru 80	4% max.

[a] Data provided by J.R. Short Milling Co., Kankakee, IL.

TABLE II
Breakfast Cereal Flakes Formulation[a]

Ingredients	Percent
Corn cones	76.50
Corn meal	8.50
White sugar	9.96
Malt	3.08
Salt	1.96

[a] Excludes roasted and nonroasted partially defatted peanut flour variables.

by a traditional method that uses whole or parts of grains cooked in batch cookers and takes 8 hr or more to be accomplished. Commercial cornflakes C are produced by extrusion technique.

Amino Acid Analysis

All amino acids, except for tryptophan, cysteine, and proline, were determined by a fluorometric HPLC method using precolumn derivatization with *o*-phthaldialdehyde according to the procedure of Wu and Knabe (1994). Corn cones (2.0 g) and partially defatted peanut flour (0.2 g) were hydrolyzed in 250 mL of 6*N* HCl. The solutions were incubated at 110°C under nitrogen for 24 hr. The protein hydrolysate was analyzed for amino acids.

Sensory Evaluation

Flakes (10 g) containing 0, 10, 20, and 30% R-PDPF and 30% PDPF were evaluated by 48 untrained panelists. Flakes containing 10 and 20% PDPF were not evaluated because the purpose of this study was to improve the flavor of roasted peanut; only the 30% PDPF sample was evaluated. Additionally, too many samples will make panelists more tired and confused. Texture (crispness), color, flavor, and overall acceptability, were evaluated using a nine-point hedonic scale (1 = dislike extremely, 9 = like extremely) at 1 min after addition of milk as desired. Intensity of peanut flavor also was evaluated using a nine-point scale (1 =none, 9 = strong). The sensory evaluations were conducted in a single session. Samples were coded with three-digit numbers to avoid influencing panelist decisions. The samples were presented one at a time in randomized order. Panelists were supplied with deionized distilled water (≈25°C) for rinsing between samples.

Statistical Analysis

The treatment means were analyzed by the general linear models procedure using the SAS statistical software package (v. 6.09, SAS Institute, Cary, NC). Duncan's multiple range test was used for multiple means comparison.

RESULTS AND DISCUSSION

The proximate composition of peanut flours, corn cones, and corn meal are given in Table III. Partially defatted peanut flour had higher protein, oil, and fiber contents than corn cones. The protein content of peanut flours had high protein (46.8% db), fat (7.8% db), and fiber (3.7% db) content compared with corn cones. Roasting reduced the moisture content of partially defatted peanut flour but did not otherwise affect the composition.

WAI and WSI of peanut flours were higher than those of corn cones (Table IV). This can be explained by the fact that peanut flour has a higher protein content resulting in more hydrophilic groups that could bind more water molecules than corn cones. Additionally, particle size of peanut flour was finer than that of corn cones, resulting in higher WSI. Roasting significantly increased the WAI of partially defatted peanut flour; in contrast, it decreased the WSI of the flour. The effect of roasting on WAI and WSI of PDPF was similar to that reported by Singh and Singh (1991). The yellow color, as indicated by *b* value, was higher in corn cones, and apparently was caused by carotenoid pigments, carotenes, and xanthophylls (Weber 1987). Roasting reduced lightness and increased the red and yellow hues. Roasting also caused hydrolysis of sucrose to glucose and fructose. Then, these reducing sugars reacted with amino acids to produce melanoidin pigments by the Maillard reaction, also perhaps due to caramelization reactions (Whistler and Daniel 1985).

Amino Acid Analysis

Higher amounts of almost all essential amino acids, especially lysine, occurred in PDPF than in corn cones (Table V). However, PDPF contained lower amounts of methionine and histidine. In general, most cereals are lower in total protein content and deficient in lysine for optimal nutritional quality. The available lysine content of peanuts is high compared with levels found in cereals (Johri et al 1988). The protein quality of corn meal is substantially improved by fortification with peanut flour (Bookwalter et al 1978).

Moisture Content

Moisture content in each step of extruded flakes production were recorded (Table VI). These include the mixes before preconditioning and at entering the extruder, collets, and toasted flakes. Moisture contents decreased with the amount of peanut flour added. Product moisture contents correlated with initial feed moisture contents and were thus lowest for the toasted flakes containing

TABLE III
Proximate Composition (%) of Raw Materials Used for Breakfast Cereal Flakes[a]

Samples	Moisture	Protein[b]	Oil	Ash	Fiber[c]	Carbohydrate[d]
Corn cones	13.71 ± 0.08	6.34 ± 0.03	1.09 ± 0.09	0.33 ± 0.03	0.55 ± 0.07	77.98 ± 0.11
Corn meal	13.21 ± 0.12	7.03 ± 0.02	1.63 ± 0.07	0.64 ± 0.04	0.85 ± 0.07	76.64 ± 0.22
PDPF[e]	6.13 ± 0.14	43.93 ± 0.06	7.28 ± 0.17	4.04 ± 0.03	3.45 ± 0.07	35.17 ± 0.07
R-PDPF[f]	4.06 ± 0.34	44.88 ± 0.06	7.46 ± 0.16	4.12 ± 0.05	3.57 ± 0.06	35.91 ± 0.53

[a] Values are means ± standard deviation of triplicate determinations (% as is basis).
[b] N × 6.25 (corn), N × 5.46 (peanut).
[c] Crude fiber, determined by Mid-Continent Laboratories, Memphis, TN.
[d] Determined by difference.
[e] Nonroasted partially defatted peanut flour.
[f] Roasted partially defatted peanut flour.

TABLE IV
Physical and Physicochemical Properties of Raw Materials Used for Preparation of Flakes[a]

			Color[b]		
Samples	WAI[c] (g/g)	WSI[d] (g/100 g)	*L*	*a*	*b*
Corn cones	2.19 ± 0.02h	2.10 ± 0.02h	81.6 ± 0.1f	2.1 ± 0.1g	34.2 ± 0.2f
PDPF[e]	2.33 ± 0.06g	43.10 ± 0.45f	76.0 ± 0.3g	1.2 ± 0.1h	13.0 ± 0.1h
R-PDPF[f]	2.59 ± 0.09f	38.30 ± 0.80g	74.5 ± 0.3h	2.3 ± 0.1f	17.1 ± 0.2g

[a] Values are means ± standard deviations of triplicate runs. Values followed by the same letter in the same column are not significantly different ($P < 0.05$) using Duncan's multiple range test.
[b] *L* = brightness (0 = black, 100 = white); +*a* = red, –*a* = green; +*b* = yellow, –*b* = blue.
[c] Water absorption index is the weight of the gel obtained per gram of dry sample.
[d] Water solubility index is the amount of solids recovered by evaporating supernatant from water absorption tests, expressed as % of dry solids in sample.
[e] Nonroasted partially defatted peanut flour blended by weight with corn cones.
[f] Roasted partially defatted peanut flour blended by weight with corn cones.

30% peanut flours. Additionally, increasing oil contents may also affect the decrease of final moisture of the products. Mohamed (1990) reported the addition of oil up to 3% decreased the product moisture content. This probably caused by increasing the efficiency of heat transfer.

Composition of Flakes

The addition peanut flour increased the protein content from 6.7% in control flakes (no peanut flour added) to 16.6 and 16.9% in flakes containing 30% PDPF and 30% R-PDPF, respectively (Table VII). The oil content of the flakes was 0.93–2.43% and was highest in flakes containing 30% peanut flour. The crude fiber content was slightly increased by the addition of peanut flour. Flakes with higher fiber contents can be associated with important health benefits, including maintenance of gastrointestinal function plus lowering of serum cholesterol levels.

Bulk Density

The addition of PDPF and R-PDPF lowered bulk densities of extruded toasted flakes (Table VIII). The type of peanut flour did not significantly affect the bulk density of extruded toasted flakes. Similar observations were reported by other researchers. Hagen et al (1986) observed the microstructure of textured peanut concentrate and found that it had a high porous structure with thin cell walls and large round-to-elongated air cells. Such morphological features are associated with the very high product expansion, low bulk density, and relatively poor structural integrity of the peanut product. Phillips and Falcone (1988) noted that fat in peanut flour apparently acted as a lubricant and plasticizer, allowing greater expansion and lower density. Suknark et al (1997) also found that the bulk density of extrudates decreased when adding 15–30% partially defatted peanut flour into various types of starch. Additionally, Bhatnagar and Hanna (1997) observed the bulk densities of extruded products blended with corn starch and several oils and found that peanut oil resulted in the lowest bulk density and shear strength, and highest porosity. In this work, therefore, increasing the fat content by fortification with peanut flours would reduce the elasticity of collets as they are flaked, resulting in lower densities. Lowering moisture content of raw material mixture by substitution of peanut flours tended to reduce the bulk density of the flakes. Similar investigations were reported by Camire (1989) and Suknark et al (1997). They noted that as feed moisture increased, bulk density of the extrudates also increased.

Hardness

The greatest force was needed to compress control extruded toasted flakes (Table VIII). PDPF and R-PDPF reduced hardness of extruded toasted flakes. There were no differences according to the type of PDPF used ($P > 0.05$). Products with high bulk density generally require more force to break as reported by Bhattacharya et al (1986) and Prinyawiwatkul et al (1995); thus, extruded toasted flakes with high bulk density would be harder. In the present work, a positive correlation was found between hardness and bulk density ($r = 0.86$). Higher lipid levels can reduce forces for breaking and shearing the product (Bhattacharya et al 1986). The same results were also reported by Suknark et al (1997). They found that the substitution of PDPF for starch at low levels (15–30%) decreased the shear strength. Conversely, shear strength increased as the level of PDPF in the mixture further increased. This can be explained as the small amount of lipid in peanut increasing the expansion, resulting in thinner cell walls, resulting in the low product shear force. Additionally, in this work, decreasing hardness of flakes probably affected by increasing of protein contents in peanut flours. Mohamed (1990) found that the addition of protein content ≤25% resulted in decreased hardness of extruded product. The decrease in hardness could be due to the interference of starch-starch interaction by protein molecules.

Color

Increasing PDPF and R-PDPF content reduced lightness of the flakes (Table VIII). The type of peanut flour also contributed. R-PDPF darkened the samples more than nonroasted PDPF, particularly at the high (30%) level of peanut flour. Redness increased as levels of PDPF and R-PDPF increased. Yellowness was decreased by increasing PDPF and R-PDPF content.

WAI and WSI

WAI and WSI of extruded toasted flakes were related to those of the raw materials used for their preparation (Table VIII). WAI of extruded toasted flakes containing 30% peanut flours was higher than the control. Neither adding 10 and 20% peanut flours nor the type of peanut flour affected WAI of the flakes. Other studies also reported the addition of protein ingredients increasing WAI values of the products (Baker and Hin 1984; Bhattacharya et al 1986). An increase of peanut flours increased WSI of extruded toasted flakes. Generally, WSI is related to the quantity of water-soluble molecules. Because flakes with added peanut flour had greater amounts of protein than the control, the added protein increased water solubility of the flakes.

TABLE V
Amino Acid Content (g/100 g of protein) of Partially Defatted Peanut Flour and Corn Cones[a]

Amino Acids[b]	Partially Defatted Peanut Flour	Corn Cones
Arginine	10.86 ± 0.09	2.58 ± 0.02
Histidine	1.57 ± 0.06	1.97 ± 0.30
Isoleucine	3.84 ± 0.07	3.13 ± 0.06
Lysine	3.42 ± 0.11	1.50 ± 0.18
Methionine	1.45 ± 0.11	2.07 ± 0.18
Phenylalanine	5.60 ± 0.06	4.64 ± 0.27
Threonine	2.66 ± 0.10	2.62 ± 0.04
Valine	4.54 ± 0.06	3.75 ± 0.01

[a] Values are means ± standard deviations of duplicate determinations.
[b] Essential amino acids.

TABLE VI
Moisture Content (%) of Extruded Flakes at Different Stages of Processing[a]

	Processing Stage			
Material	Before Preconditioning	Entering Extruder	Exiting Extruder	Final Products
Corn cones only	11.8 ± 0.1	25.6 ± 0.1	19.8 ± 0.3	3.6 ± 0.1
10% PDPF[b]	11.3 ± 0.3	25.2 ± 0.6	19.5 ± 0.2	3.5 ± 0.1
20% PDPF	10.8 ± 0.1	24.9 ± 0.3	19.4 ± 0.3	3.3 ± 0.2
30% PDPF	10.3 ± 0.5	24.6 ± 0.4	19.1 ± 0.2	3.1 ± 0.1
10% R-PDPF[c]	11.0 ± 0.3	24.8 ± 0.3	18.8 ± 0.4	3.4 ± 0.1
20% R-PDPF	10.1 ± 0.1	24.4 ± 0.3	18.6 ± 0.2	3.2 ± 0.1
30% R-PDPF	9.3 ± 0.1	24.2 ± 0.2	18.3 ± 0.1	3.0 ± 0.1

[a] Values are means ± standard deviations from triplicate runs.
[b] Nonroasted partially defatted peanut flour blended by weight with corn cones.
[c] Roasted partially defatted peanut flour blended by weight with corn cones.

TABLE VII
Proximate Composition (%) of Extruded Breakfast Cereal Flakes[a]

Flakes	Protein[b]	Oil	Ash	Fiber[c]	Carbohydrate[d]
Corn cones only	6.74 ± 0.06i	0.93 ± 0.06i	2.28 ± 0.03i	0.73 ± 0.08i	89.32 ± 0.07f
10% PDPF[e]	10.66 ± 0.17h	1.35 ± 0.06h	2.59 ± 0.15h	0.93 ± 0.06h	84.47 ± 0.20g
20% PDPF	13.58 ± 0.21g	1.86 ± 0.12g	2.90 ± 0.06g	1.14 ± 0.05g	80.52 ± 0.76h
30% PDPF	16.60 ± 0.67f	2.37 ± 0.12f	3.10 ± 0.08f	1.44 ± 0.06f	76.49 ± 0.72i
10% R-PDPF[f]	10.86 ± 0.15h	1.38 ± 0.04h	2.65 ± 0.16h	0.95 ± 0.12h	84.16 ± 0.17g
20% R-PDPF	13.87 ± 0.25g	1.92 ± 0.08g	2.95 ± 0.13g	1.18 ± 0.08g	80.08 ± 0.33h
30% R-PDPF	16.98 ± 0.59f	2.43 ± 0.15f	3.16 ± 0.09f	1.48 ± 0.11f	75.95 ± 0.56i

[a] Values are means ± standard deviations of triplicate determinations (% db). Values followed by the same letter in the same column are not significantly different ($P < 0.05$) using Duncan's multiple range test.
[b] N × 6.25.
[c] Crude fiber, determined by Mid-Continent Laboratories, Inc., Memphis, TN.
[d] Determined by difference.
[e] Nonroasted partially defatted peanut flour blended by weight with corn cones.
[f] Roasted partially defatted peanut flour blended by weight with corn cones.

TABLE VIII
Physical and Physicochemical Properties of Extruded Breakfast Cereal Flakes[a]

					Color[b]		
Flakes	Bulk Density (g/L)	Hardness (N)	WAI[c] (g/g)	WSI[d] (g/100 g)	*L*	*a*	*b*
Corn cones only	265e	3.07e	5.78 ± 0.20f	14.19 ± 0.18g	56.8 ± 0.2e	9.7 ± 0.1g	29.4 ± 0.1e
10% PDPF[e]	256f	2.76f	5.85 ± 0.12f	15.00 ± 0.48f	52.2 ± 0.8f	10.8 ± 0.4f	25.4 ± 0.4f
20% PDPF	248f,g	2.41g	5.93 ± 0.10e,f	15.61 ± 0.24e,f	49.1 ± 0.7g	11.2 ± 0.2e	22.7 ± 0.2g
30% PDPF	241g,h	2.05h	6.11 ± 0.08e	16.08 ± 0.54e	47.8 ± 0.2h	11.4 ± 0.1e	21.0 ± 0.1h
10% R-PDPF[f]	254f	2.65f,g	5.90 ± 0.11f	14.81 ± 0.53f	51.6 ± 0.5f	10.7 ± 0.3f	25.0 ± 0.4f
20% R-PDPF	245f,g	2.32g	5.95 ± 0.07e,f	15.52 ± 0.18e,f	48.4 ± 0.5g,h	11.5 ± 0.2e	22.7 ± 0.3g
30% R-PDPF	236h	1.99h	6.14 ± 0.08e	15.89 ± 0.38e	46.6 ± 0.6i	11.6 ± 0.1e	21.1 ± 0.5h

[a] Values are means ± standard deviations of triplicate runs. Values followed by the same letter in the same column are not significantly different ($P < 0.05$) using Duncan's multiple range test.
[b] L = brightness (0 = black, 100 = white); $+a$ = red, $-a$ = green; $+b$ = yellow, $-b$ = blue.
[c] Water absorption index is the weight of the gel obtained per gram of dry sample.
[d] Water solubility index is the amount of solids recovered by evaporating supernatant from water absorption tests, expressed as % of dry solids in sample.
[e] Nonroasted partially defatted peanut flour blended by weight with corn cones.
[f] Roasted partially defatted peanut flour blended by weight with corn cones.

TABLE IX
Bowl Life of Experimental Flakes and Commercial Cornflakes

Flakes	Bowl Life (min)[a]
Corn cones only	9.0e[b]
10% PDPF[c]	8.0f
20% PDPF	7.0g
30% PDPF	6.0h
10% R-PDPF[d]	8.0f
20% R-PDPF	7.0g
30% R-PDPF	6.0h
Commercial cornflakes A	4.0i
Commercial cornflakes B	4.0i
Commercial cornflakes C	3.0j

[a] Subjective determination of time for disappearance of crispness of extruded toasted flakes.
[b] Values followed by the same letter in the same column are not significantly different ($P < 0.05$) using Duncan's multiple range test ($n = 3$).
[c] Nonroasted partially defatted peanut flour blended by weight with corn cones.
[d] Roasted partially defatted peanut flour blended by weight with corn cones.

Bowl Life

The time that RTE breakfast cereal flakes retains crispiness after wetting with milk is critically important. Flakes containing peanut flours took less time to become soggy than the control (Table IX). This was related to structural integrity, hydration capacity, solubility, and density of the flakes. Flakes containing 30% PDPF disintegrated easily after a short time. Only experimental flakes containing corn cones took longer time to become soggy than commercial cornflakes C, which are produced by extrusion processing. The hardness of the experimental flakes was due to limitations of the equipment to produce good quality flakes as commercial products. Because no forming extruder was used in this study, apparently shortening the extrusion cooking cycle resulted in less development of the matrix constituents. The forming extruder allows previously sheared dough to relax before being forced through the final die (Bailey et al 1991). Furthermore, a cooling reel to cool the bead to ≈38–63°C, and a tempering screw to assist in maintaining the temperature and moisture of the collets were not available in this study, making it difficult to make flakes with good texture. Finally, commercial cornflakes A and B took longer time to retain crispness after soaking in milk than commercial cornflakes C, which was probably due to the extrusion process that provided both thermal and mechanical degradation.

Sensory Evaluation

Extruded toasted flakes were rated acceptable (average > 5.0) for all attributes evaluated (Table X). No significant difference was found in sensory ratings for crispness of extruded toasted flakes. The samples containing 30% peanut flour were rated less acceptable than those containing higher percentages of corn cones. Some panelists commented that almost all of the samples were too hard due to limitations of the experiment described earlier. The addition of peanut flour significantly reduced the color acceptability of extruded toasted flakes. Mean scores for color acceptability of extruded toasted flakes containing peanut flour were 5.87–7.02, which is between "neither like nor dislike" to "like moderately", indicating that inclusion of 10–30% R-PDPF did not cause the color to be unacceptable.

Flakes containing 10 and 20% R-PDPF provided flavor and overall acceptability compatible with that of the control. Flavor acceptability was difficult to evaluate because some panelists liked the peanut flavor very much, while others disliked it.

Improvement of Peanut-Flavored Flakes

Flakes containing 30% nonroasted PDPF had the highest peanut flavor intensity score (Table X). The intensity of peanut flavor was 1.31–5.33, which is relatively mild. The mild peanut flavor in extruded toasted flakes probably is the result of the 8% oil in PDPF.

TABLE X
Sensory Evaluation of Extruded Breakfast Cereal Flakes

Flakes	Sensory Scores[a]				
	Crispness[b]	Color[b]	Flavor[b]	Overall Acceptability[b]	Flavor Intensity[c]
Corn cones only	7.10e	7.96e	6.44ef	6.73e	1.31h
10% R-PDPF[d]	6.69e	7.02f	6.73e	6.81e	2.33g
20% R-PDPF	7.08e	6.33g	6.08ef	6.19ef	2.89fg
30% R-PDPF	7.10e	5.89g	5.71fg	5.89f	3.46f
30% PDPF[e]	7.04e	5.87g	5.23g	5.58f	5.33e

[a] Values followed by the same letter in the same column are not significantly different ($P < 0.05$) using Duncan's multiple range test ($n = 48$).
[b] Value represents mean scores from a nine point hedonic scale: 1 = extremely dislike, 9 = extremely like.
[c] Intensity of peanut flavor. Value represents mean scores from a nine point hedonic scale: 1 = none, 9 = strong.
[d] Nonroasted partially defatted peanut flour blended by weight with corn cones.
[e] Roasted partially defatted peanut flour blended by weight with corn cones.

Because much of the flavor is in the oil, defatted peanuts are less flavor-intensive (Woodroof 1983). Additionally, extrusion tends to reduce flavors of products because of chemical degradation due to oxidation, hydrolysis, and other reactions. Much of the flavor is normally lost to the atmosphere as the extrudate exiting at the die (Maga 1989). Spadaro et al (1971) reported that the use of 15% full-fat roasted peanuts produced an extruded product with peanut aroma; however, this aroma dissipated as the product cooled after extrusion. Prinyawiwatkul (1993) also found that peanut aroma is not evident in cooled extruded products made with corn starch and peanut flour.

R-PDPF did not improve peanut flavor in the flakes. This is probably because pyrazine compounds, the major flavor precursors of roasted flavor, are heat sensitive and rapidly vanished during the extrusion process, resulting in the mild flavor of extruded toasted flakes made with R-PDPF. In addition, flavor compounds are bound to macromolecules such as starch and protein in the reactor zone of the extruder (Camire and Belbez 1996).

CONCLUSIONS

This study showed that breakfast cereal flakes could be made from combinations of corn cones blended with partially defatted peanut flour (PDPF) or roasted partially defatted peanut flour (R-PDPF) at different levels up to 30% using twin-screw extrusion. Supplementation with peanut flours improved the nutritional characteristics of corn cones breakfast flakes. However, protein and fat content in peanut flours also affected the density of those extruded flakes, resulting in shorter bowl life. An addition of extruded toasted flakes with ≤20% R-PDPF were considered as acceptable as those without peanut flour. The peanut flavor intensity score of extruded toasted flakes with 30% PDPF was rated as strongest. An effort to enhance peanut flavor intensity using R-PDPF was impractical because flavor compounds were lost or bound to macromolecules during extrusion. The use of PDPF as protein supplement incorporated with corn meal or some other types of starch to produce other RTE breakfast cereals or snacks should be further studied.

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