# Precooked Bran-Enriched Wheat Flour Using Extrusion: Dietary Fiber Profile and Sensory Characteristics

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**ABSTRACT: The effect of precooking by extrusion processing on the dietary fiber profile of wheat flour substituted with 0%, 10%, 20%, and 30% wheat bran was evaluated. Depending on the level of bran, total dietary fiber (TDF) and soluble dietary fiber (SDF) in uncooked flours ranged from 4.2% to 17.2% and 1.5% to 2.4%, respectively. Precooking by extrusion significantly increased SDF in flours (by 22% to 73%); although in most cases it also led to a significant decrease in TDF. Cookies and tortillas produced from uncooked and precooked flours with 0% and 20% substituted bran were evaluated for consumer acceptability using a 9-point hedonic scale. With a few exceptions, all cookies had scores ranging from 6 to 7 ("like slightly" to "like moderately") for each attribute, including overall acceptability, appearance, texture, crumbliness, and flavor. Tortillas were rated for the same attributes except for crumbliness, which was replaced with chewiness. In most cases, tortilla scores ranged from 5 to 7 ("neither like nor dislike" to "like moderately"). Consumer acceptability scores of cookies from uncooked flour did not change significantly with increase in bran substitution from 0% to 20%. However, consumer scores for tortillas did decrease significantly with increase in bran level. Extrusion precooking of the flours did not improve the consumer acceptability of cookies and tortillas; however, it did improve their dietary fiber profile by increasing the SDF significantly.**

**Keywords: cookies, dietary fiber, extrusion, sensory properties, tortillas, wheat bran**

## Introduction

In recent years, dietary fiber has received increased amounts of attention. Several studies have related consumption of dietary fiber and whole grains with reduction in chronic ailments like high serum cholesterol, cardiovascular disease (Anderson and others 1991; Gordon 1999; Jones 2006), certain forms of cancer (Burkitt and Trowell 1975; Whitehead and others 1986; Gordon 1999; Decker and others 2002), and constipation (Lue and others 1991; Kantor and others 2001). In 2001, the Food and Nutrition Board of the Inst. of Medicine established a recommendation for total dietary fiber (TDF) intake of 38 and 25 g/d for adult men and women, respectively (IOM 2002).

There are various definitions of fiber (Englyst and others 1995). According to the American Assn. of Cereal Chemists, dietary fiber is the edible parts of the plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine and functional fiber (Seiz 2006). Dietary fiber can be divided into insoluble and soluble dietary fiber (SDF). Insoluble dietary fiber (IDF), primarily consisting of cellulose, hemicellulose, and lignin, is the fraction of dietary fiber that is not soluble in water; SDF, primarily consisting of pectin and gums, is the water-soluble fraction (Dreher 1987; Qian and Ding 1996). Both SDF and IDF are associated with several health benefits. Soluble fibers are known to be effective in reducing total blood cholesterol and promoting satiety, and insoluble fibers help in treating constipation and reduce the risk of colon cancer and diverticular disease (Mongaeu and Brassard 1984; Best 1987; Lue and others 1991; Seiz 2006).

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Whole wheat flour and wheat bran are two of the most commonly used and important sources of dietary fiber for the cereal-based foods industry. Wheat bran is rich in insoluble fiber and to some extent water-soluble fiber as well. It comprises crude fiber (10%), pentosans (26.5%), cellulose (21.4%), starch (7.51%), total sugar (5.04%), sucrose (2.98%), and reducing sugars (4.42%) (Pomeranz 1988). Other fiber sources of fiber such as soy hull (Seetharaman and others 1994; Seiz 2006), oat bran (Gualberto and others 1997; Seiz 2006), corn bran (Artz and others 1990a, 1990b), rice bran (Lima and others 2002), and citrus fruits (Seiz 2006) are also used to boost the fiber content in cereal products.

Many cereal-based foods such as expanded snacks from corn (Artz and others 1990b), breakfast cereals from wheat, oat, and barley (Wang and Klopfenstein 1993; Berglund and others 1994) and baked products such as cookies, bread, crackers, and tortillas (Ranhotra and others 1990; Seetharaman and others 1994) are good carriers of dietary fiber (Dreher 1987). However, incorporation of fiber deteriorates the quality characteristics (such as expansion, loaf volume, spread, and texture) of these products (Dreher 1995). Various types of thermal treatments such as drum drying (Lima and others 2002), jet cooking (Lee and Inglett 2006), autoclaving, roasting, micronizing (Caprez and others 1986), mechanical treatments such as fine-milling (Galliard and Gallagher 1988), and thermomechanical treatments such as extrusion cooking (Caprez and others 1986; Camire and others 1997) have been attempted for changing the physicochemical properties and thus improving the functionality of fibrous ingredients such as wheat bran, rice bran, and corn fiber with some success.




doi: 10.1111/j.1750-3841.2008.00715.x

The thermomechanical nature of extrusion cooking has the added potential of causing a redistribution of soluble and insoluble components of fiber in favor of the former. This would tend to improve the hypocholesterolemic properties of fiber, and therefore enhance or improve the dietary fiber profile. Several researchers (Aoe and others 1989; Ralet and others 1990; Wang and Klopfenstein 1993; Gualberto and others 1997) have shown significant increase in SDF content in extruded wheat bran. Some studies have also reported increase in TDF and SDF content of potato peels using extrusion processing (Camire and Flint 1991; Camire and others 1997). However, contradictory results have been reported as well (Asp and Bjorck 1989). According to Varo and others (1983) and Artz and others (1990b), extrusion cooking causes no significant changes in soluble and insoluble fiber, while reduction in fiber content has also been reported (Fornal and others 1987) because of extrusion cooking. When extruding flours or whole formulations, the effect on nutritional properties of other components also needs to be considered. For example, although extrusion has been shown to increase the TDF content of wheat flour (Theander and Westerlund 1987), it negatively affects the nutritional value of proteins due to Maillard reactions and also leads to loss of heat-labile vitamins (Singh and others 2007).

Apart from improvements in functionality and dietary fiber profile due to thermal/mechanical treatment of fiber-based ingredients, the sensory characteristics of the final product could also be positively affected. A previous study by our research group described the modification of wheat bran-enriched flour by extrusion cooking with the goal of improved functionality in making tortillas and cookies (Gajula and others 2008). The current study focuses on determining the effect of extrusion cooking on dietary fiber profile of flour enriched with wheat bran. The consumer acceptability of cookies and tortillas made with the precooked flours was also studied.

## Materials and Methods

### Flour processing

Commercial hard red winter wheat flour, with moisture, protein, and ash contents of 14%, 11.8%, and 0.5%, respectively, was obtained from Horizon Milling, LLC (Wichita, Kans., U.S.A.). The flour was substituted with 0%, 10%, 20%, and 30% hard red winter wheat bran obtained from the pilot mill in the Dept. of Grain Science and Industry, Kansas State Univ. The wheat flour substituted with 0% to 30% bran was processed in a laboratory scale American Leistritz Micro 18 twin-screw extruder (American Leistritz Extruder Corp., Somerville, N.J., U.S.A.) with barrel temperatures of 30, 32, 34, 36, 38, and 40 °C and screw speed of 200 rpm. The effect of extrusion process parameters (barrel temperature and screw speed) on the efficacy of the precooking treatment was studied in the 1st part of this study (Gajula and others 2008). The results indicated that the process parameters described previously led to better quality flour with 20% to 30% bran substitution. For this reason, the current study focused on just these conditions. The extruder screw profile and barrel temperature zones are shown in Figure 1. Feed moisture content was maintained at 30% (wet basis) for all treatments. The target moisture was achieved by mixing the flour with water in a KSM5 KitchenAid (St. Joseph, Mich., U.S.A.) mixer, taking the initial moisture of the flour into account. The hydrated flour was stored overnight at 4 °C for equilibration before extrusion. The average feed rate and specific mechanical energy (SME) input were 1.6 kg/h and 300 kJ/kg, respectively. The ribbon-like extruded product was dried using a Labconco FTS System Inc. (Kansas City, Mo., U.S.A.) freeze drier. The moisture content of the dried flour ranged between 3.9% and 7.4% (wet basis). The dried product was ground to pass through a 0.5-mm sieve using a Thomas Wiley Model 4 laboratory mill (Arthur H. Thomas Co., Philadelphia, Pa., U.S.A.). For



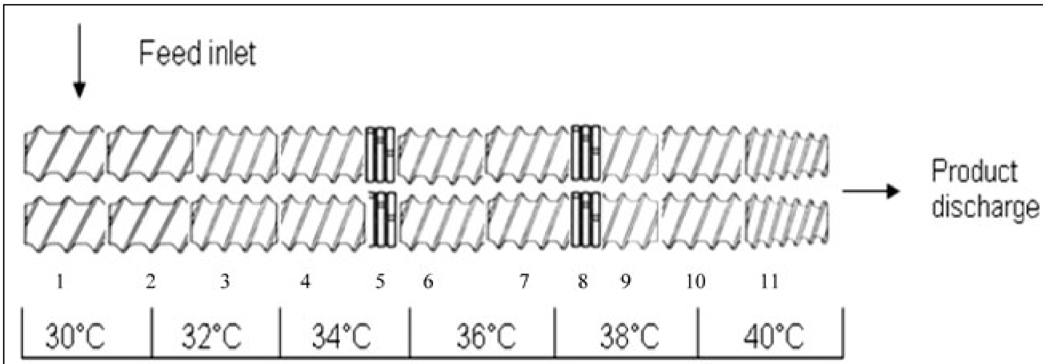


**Figure 1 — Schematic of the laboratory-scale extruder screw profile[a] and barrel temperatures.**

1= SE, 2-30-60; 2 = SE, 2-30-60; 3 = SE, 2-20-60; 4 = SE, 2-15-60; 5 = KB, 4-4-20-30F; 6 = SE, 2-15-60; 7 = SE, 2-10-30; 8 = KB, 4-4-20-30F; 9 = SE, 2-15-60; 10 = SE, 2-15-30; 11 = SE, 2-10-60

SE=screw element
Numbers:
1st –number of flights
2nd - length of flight (mm)
3rd – total element length (mm)

KB = kneading blocks
Letters:
F- Forward
R- Reverse
Numbers:
1st- number of blocks
2nd- length of blocks (mm)
3rd- total element length (mm)
4th-angle of blocks

[a]All screw elements are forward, intermeshing and double flighted, with pitch progressively decreasing from feed to discharge ends.

control studies, uncooked flour was also substituted with 0% to 30% bran that was ground using the same mill to pass through a 0.5-mm sieve.

## Dietary fiber analysis

Megazyme thermostable $\alpha$-amylase (E-BLAAM), protease (E-BSPRT), and amyloglucosidase (E-AMGDF) were obtained from Megazyme Int. Ireland Ltd. (County Wicklow, Ireland). Ethanol (95%) and acetone were obtained from chemical stores at Kansas State Univ., Manhattan, Kans., U.S.A. Standard solutions such as MES-TRIS buffer solution, ethanol (78%), and HCL solution (0.561 N) were prepared to analyze the TDF, SDF, and IDF content. MES-TRIS buffer solution, 0.05 M was obtained by dissolving 19.52 g 2(N-morpholino) ethanesulfonic acid (MES) (M 8250, Sigma-Aldrich, St. Louis, Mo., U.S.A.) and 14.2 g tris (hydroxymethyl) aminomethane (TRIS) (T1503, Sigma-Aldrich Co.) in 1.7 L deionized water, adjusted to pH 8.2 with 6.0 N NaOH, and diluted with water to 2 L. Ethanol, 78% concentration was obtained by diluting 1 L of 95% ethanol with 207 mL water. Similarly, HCL solution (0.561 N) was obtained by adding 93.5 mL of 6 N HCL to approximately 700 mL of water in a volumetric flask, and diluting the resultant solution with 1 L of water.

The total, soluble, and insoluble dietary fiber contents of wheat bran, uncooked flour, and precooked flour substituted with 0%, 10%, 20%, and 30% bran were determined using the AACC approved method 32-21 (AACC 2000) with slight modifications. One gram of sample and 40 mL MES-TRIS buffer solution were added in a 600-mL beaker. The sample was subjected to enzymatic digestion by adding 50 $\mu$L of heat-stable $\alpha$-amylase in a water bath (95 to 100 °C) and shaken continuously. After 35 min, the sample was removed from the water bath and 100 $\mu$L of protease were added, followed by incubation in the water bath at 60 °C with continuous stirring. After another 30 min, the sample was removed from the water bath and 5 mL of 0.56 N HCL were added to adjust the pH to 4.1 to 4.8. Two hundred microliters of amyloglucosidase solution were added to the sample again followed by incubation in the water bath at 60 °C for 30 min with continuous stirring. The enzyme-digested solution was filtered using a celite-containing crucible and the residue was washed twice with 10 mL of water at 70 °C. The residue was then washed with 10 mL of 95% ethanol and acetone, and dried overnight in 103 °C oven. The weight of the dried residue gave the IDF content. Filtrate from the crucible and water washings was precipitated with 4 volumes of 95% ethanol at 60 °C for SDF determination. The precipitate was filtered, washed with 78%, 95% ethanol and acetone, and then dried overnight. The weight of this dried residue gave the SDF content. The TDF content of the sample was obtained from the sum of IDF and SDF values (Berglund and others 1994). IDF, SDF, and TDF for uncooked wheat flour with 10% to 30% bran were calculated from the corresponding data for wheat bran and uncooked flour with 0% bran.

## Cookie preparation

Cookies were prepared using uncooked and precooked wheat flour with 0% and 20% bran as the base ingredient. The other ingredients in the cookie formulation included sugar (90%; United Sugar Corp., Clewiston, Fla., U.S.A.), all-purpose shortening (60%; ACH Food Co. Inc., Cordova, Tenn., U.S.A.), dry eggs (7%; Michael Foods Egg Products, Gaylord, Minn., U.S.A.), salt (1.8%; Morton Salt, Chicago, Ill., U.S.A.), sodium bicarbonate (1.8%; Sigma-Aldrich Co.), and Butter Lemon Vanilla flavor (1.0%; Mothers Murphy's Labs, Greensboro, N.C., U.S.A.). The relative amounts of all materials for the cookie formulation were expressed as baker's percentages. The formulation and the procedures for cookie dough preparation and subsequent baking were adapted from Payne (1995) as described in a previous study by our research group (Gajula and others 2008).

## Tortilla preparation

Tortillas were also prepared using uncooked and precooked wheat flour with 0% and 20% bran as the base ingredient. The other ingredients in the tortilla formulation included all-purpose shortening (11%), salt (1.5%), sodium bicarbonate (1.5%), potassium sorbate (0.5%), sodium propionate (0.5%), sodium stearoyl lactate (0.5%), fumaric acid (0.2%), and cysteine (0.003%). These ingredients, except for the 1st two, were obtained from Sigma-Aldrich Co. The relative amounts of all materials for tortilla formulation were expressed as baker's percentages. The tortilla formulation and procedures for dough preparation, pressing, and subsequent baking, as summarized earlier by our research group (Gajula and others 2008), were adopted from the standard method described by Bello and others (1991). For precooked flours, a few modifications were made to the methodology. These included addition of 15% wheat gluten (MGP Ingredients, Atchinson, Kans., U.S.A.) and water addition level changing from 65% to 71% as bran levels increased from 0% to 30%.

## Color

A hand-held Chroma Meter (Model CR-210, Minolta, Japan) calibrated with standard white plate (Model CR-210; $Y = 94.5$, $x = 0.3129$, and $y = 0.3199$) was used to measure the CIE LAB coordinates for lightness ($L^*$), redness ($a^*$), and yellowness ($b^*$) color value of the test cookies and tortillas. The dimension $L^*$ represents lightness with 100 for white and 0 for black, $a^*$ indicates redness when positive and greenness when negative, and $b^*$ represents yellowness when positive and blueness when negative. Color readings were taken from the center of each cookie and tortilla.

## Consumer acceptability

The consumer acceptability study was reviewed and approved by the Institutional Review Board of Kansas State Univ. A consumer panel consisting of 78 participants (53 female and 25 male) was recruited to rate cookies and tortillas on their overall acceptability and other attributes. All panelists were cookie and tortilla consumers, and were screened for critical conditions such as pregnancy and allergies to wheat. Background information for each panelist, including gender, frequency of consumption of high-fiber products, awareness of health benefits of such products, and willingness to incorporate them in their daily diet, was recorded. A 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely) was used to evaluate the products (Lawless and Heymann 1998). Cookies were rated for overall acceptability, appearance, texture/mouthfeel, crumbliness, and flavor. Tortillas were rated for overall acceptability, appearance, texture/mouthfeel, chewiness, and flavor. The cookies and tortillas were prepared 1 to 3 d prior to testing and stored at room temperature in sealed plastic bags. All the samples were randomized using 3-digit codes. Cookies and tortillas were served, in that order, in 2 subsessions separated by a time gap of approximately 5 min. The order of the treatments served to the consumers within each subsession was kept random. Unsalted crackers and drinking water were provided for palate cleansing in between samples. Prior to serving, each tortilla was sprinkled with 25 g of shredded Colby & Pepper Jack cheese (Kraft Foods, Northfield, Ill., U.S.A.) and heated for 25 s in a microwave oven (Model MA-1572M, Gold Star, Korea). The panelists were provided with quarter sections of tortilla sample thus prepared. The consumer acceptability data were collected using a

**Table 1 — Dietary fiber content[A] of uncooked and precooked wheat flours with 0% to 30% bran.**

| | Uncooked flour[B] | | | Precooked flour | | |
|---|---|---|---|---|---|---|
| Bran level (%) | IDF[C](%) | SDF[C] (%) | TDF[C] (%) | IDF (%) | SDF (%) | TDF (%) |
| 0 | 2.7 ± 0.7 | 1.5 ± 0.1 | 4.2 ± 0.6 | 1.7 ± 0.0[d] | 2.6 ± 0.1[c] | 4.3 ± 0.1[d] |
| 10 | 6.7 | 1.8 | 8.5 | 5.0 ± 0.3[c] | 2.2 ± 0.1[d] | 7.2 ± 02[c] |
| 20 | 10.8 | 2.1 | 12.9 | 8.2 ± 0.5[b] | 3.5 ± 0.2[b] | 11.7 ± 0.5[b] |
| 30 | 14.8 | 2.4 | 17.2 | 9.9 ± 0.4[a] | 3.7 ± 0.1[a] | 13.6 ± 0.3[a] |

[A]Mean, $n = 3$; means with same superscript in the same column are significantly different ($P < 0.05$). All percentages are on dry weight basis.
[B]IDF, SDF, and TDF for uncooked wheat flour with 10% to 30% bran were calculated using data from wheat bran (43.0% IDF and 4.6% SDF) and uncooked flour with 0% bran substitution.
[C]IDF = insoluble dietary fiber; SDF = soluble dietary fiber; TDF = total dietary fiber.

**Table 2 — Color values[A] for (a) cookies and (b) tortillas from uncooked and precooked wheat flours with 0% and 20% bran.**

| Bran level (%) | Flour type | $L^*$ | $a^*$ | $b^*$ |
|---|---|---|---|---|
| (a) Color – Cookies | | | | |
| 0 | Uncooked | 77.0 ± 0.7[a] | 1.2 ± 0.7[c] | 25.3 ± 2.4[a] |
| 0 | Precooked | 71.3 ± 0.9[b] | 0.6 ± 0.1[d] | 21.9 ± 0.3[b] |
| 20 | Uncooked | 61.5 ± 0.4[c] | 5.4 ± 0.1[b] | 20.2 ± 0.3[c] |
| 20 | Precooked | 58.7 ± 0.3[d] | 5.8 ± 0.0[a] | 21.1 ± 0.2[b] |
| (b) Color – Tortillas | | | | |
| 0 | Uncooked | 72.7 ± 0.5[a] | 0.4 ± 0.1[d] | 18.8 ± 0.7[b] |
| 0 | Precooked | 68 ± 1.2[b] | 1.3 ± 0.3[c] | 21.5 ± 0.5[a] |
| 20 | Uncooked | 61.4 ± 1.0[c] | 3.8 ± 0.2[b] | 15.6 ± 0.5[d] |
| 20 | Precooked | 53.3 ± 0.7[d] | 5.5 ± 0.1[a] | 16.8 ± 0.2[c] |

[A]Mean, $n = 6$; means with same superscript in the same column are significantly different ($P < 0.05$).

computerized data collection system, Compusense® (Version 4.6; Compusense Inc., Guelph, Ontario, Canada).



### Experimental design and statistical analyses

The effect of bran substitution and extrusion precooking on the dietary fiber profile of wheat flour was investigated using a 4 × 2 complete factorial design, with 4 levels of bran substitution (0%, 10%, 20%, and 30%) and 2 levels of processing (no precooking and LTLS extrusion precooking). The IDF and SDF contents measured for wheat bran, uncooked flour with 0% bran, and all the precooked flours were averaged from triplicate tests. Color values were averaged based on 6 samples from each treatment. Consumer acceptability tests were conducted on cookies and tortillas prepared from uncooked and precooked flours with 0% and 20% bran levels only. Data were analyzed using general linear models procedure (PROC GLM) in SAS® (version 9.1.3; SAS Inst. Inc., Cary, N.C., U.S.A.). Analysis of variance (ANOVA) was performed on all data. Fisher's least square difference (LSD) was used as a posthoc mean separation technique for treatments when ANOVA indicated significant differences among the samples. The consumer ranking data were analyzed by Friedman's chi-square test (Lawless and Heymann 1998). All statistical analyses were performed at a 5% level of significance.

## Results and Discussion

### Effect of extrusion processing on dietary fiber content

The total insoluble and soluble dietary fiber contents of the uncooked and precooked flours are shown in Table 1. The IDF and SDF contents of wheat bran were 43.0% and 4.6%, respectively. IDF and SDF of the uncooked flour without bran substitution were 2.7% and 1.5%, respectively. Ranhotra and others (1990) reported similar dietary fiber profiles for wheat bran (41.93% IDF and 2.10% SDF) and wheat flour (1.42% IDF and 1.09% SDF). The dietary fiber profile of uncooked flours with 10%, 20%, and 30% bran was calculated based on IDF and SDF data for bran and unsubstituted, uncooked flour. For precooked flours, the IDF, SDF, and TDF increased significantly as bran substitution increased from 0% to 30%, as expected. Extrusion precooking increased SDF by 22% to 73% and decreased IDF by 24% to 37%, respectively, depending on the bran level. These results indicated that the thermomechanical treatment undergone by the wheat flour and bran during extrusion led to redistribution of part of the IDF fraction to SDF, leading to an increase in the latter. However, in most cases the decrease in IDF was higher than the accompanying increase in SDF. This implied that a portion of the IDF was being fragmented to lower molecular weight fragments and possibly converted to sugars due to extrusion treatment. This would explain the observation that the TDF of precooked flours was up to 21% lower as compared to that for uncooked flours with the same bran level. Similar changes in the dietary fiber profile of various extruded products have been reported by numerous studies. SDF increased due to extrusion processing of wheat flour (Siljestrom and others 1986; Wang and Klopfenstein 1993), barley (Berglund and others 1994), sugar beet fiber with corn meal (Lue and others 1991), wheat bran (Caprez and others 1986; Aoe and others 1989; Ralet and others 1990; Wang and others 1993; Gualberto and others 1997), soy fiber (Qian and Ding 1996), and potato peels (Camire and Flint 1991; Camire and others 1997). The increase in SDF was usually at the expense of IDF due to fragmentation or other type of thermomechanical decomposition of cellulose and lignin that are major components of insoluble fiber. These above-mentioned studies have reported conflicting results with regard to TDF, which either remained unchanged (Siljestrom and others 1986), decreased (Lue and others 1991), or even increased (Camire and Flint 1991; Camire and others 1997) in some cases. Increase in TDF due to extrusion was attributed to formation of resistant starch. As discussed previously, decrease in TDF could be due to fragmentation of IDF to sugars or lower molecular weight fragments, which are not detected as SDF by enzymatic assay methods.

It is important to note that most of the above-mentioned extrusion studies were carried out under conditions of relatively low moisture (for example, water addition of 6.1% to 17.5% dry basis in the case of Ralet and others [1990]), high screw speed (for example, up to 450 rpm in the case of Gualberto and others [1997]), and high barrel temperatures (for example, up to 160 °C in the case of Aoe and others [1989]). The extrusion conditions in the current study were relatively milder (higher moisture and lower screw speed and barrel temperature) due to the processing of composite flours and the need for minimizing degradation of the starch and protein fractions, which are critical for making any baked product.

### Color

The color parameters ($L^*$, $a^*$, and $b^*$) for the experimental cookies and tortillas are shown in Table 2. Increase in bran level from 0%

to 20% led to a significant increase in the darkness of both products. Also, cookies and tortillas made from precooked flours were significantly darker than those made from uncooked flours. Most differences in redness ($a^*$) and yellowness ($b^*$) values were also statistically significant. In general, the change in redness was more pronounced than in yellowness. Increase in redness and decrease in yellowness were observed as bran level increased from 0% to 20%. Tortillas from precooked flours were redder and yellower in color than those from uncooked flours. The same was observed for cookies with 20% bran, although the trend was reversed for those with 0% bran, indicating interactions between wheat bran level, precooking, and the 2 baking processes. Overall results indicated that both precooking and increased bran level in flour led to products that were substantially darker and redder in appearance, with only 1 exception. The wheat bran had a reddish brown color; thus higher levels of wheat bran substitution led to darker and redder products. Also, extrusion cooking probably might lead to Maillard browning reactions causing darker color for the precooked flours and their products. Similar reasons were attributed for change in color in cookies and tortillas substituted with corn (Artz and others 1990a; Seetharaman and others 1994; Soto-Mendivil and Vidal-Quintanar 2001) or wheat bran (Jeltema and others 1983).

## Consumer acceptability

**Cookies.** Table 3 shows the consumer acceptability ratings for various sensory attributes of cookies. The ANOVA results indicated that overall acceptability, appearance, and flavor were significantly affected by the treatments, while texture and crumbliness were not significantly affected. Previous studies have shown that addition of fibrous ingredients such as corn, rice, oat, and wheat bran to the formulation beyond a certain level (6% to 20%) decreases the organoleptic characteristics of cookies and biscuits (Vratanina and Zabik 1978; Artz and others 1990a; Sekhon and others 1997; Soto-Mendivil and Vidal-Quintanar 2001; Haque and others 2002). However, chemical or physical treatment of fiber prior to their addition into the formulation could improve the sensory properties of the final product (Galdeano and Grossman 2006). This was attributed to the destructuring and improvement of hydration properties of the fiber due to the pretreatment. Our study indicated mixed results with regard to effects of bran level and pretreatment on consumer acceptability of cookies. Increase in bran level from 0% to 20% did not significantly affect any of the attributes of cookies from uncooked flour; however, for precooked flour similar increase in bran level decreased the overall acceptability, appearance, and flavor. The decrease in appearance ratings corresponded with the color measurements discussed previously, which indicated that higher bran levels led to darker and redder products. Precooking of flour with 0% bran did not significantly affect any attributes, while precooking of flour with 20% bran significantly lowered the overall acceptability and flavor of the cookies. While extrusion treatment might have led to some improvement in the functionality of fiber as was originally hypothesized, at the same time it led to degradation of the starch and protein fractions of the flour as well. This led to an overall deterioration in the quality of the flour and the resultant cookies. The 1st part of this study (Gajula and others 2008) described in detail the effect of extrusion precooking on the rheological and functional properties of the flours, and baked product quality attributes such as cookie spread and tortilla rollability. Cookies made from uncooked flour with 20% bran substitution received the highest mean hedonic scores for all 5 attributes. However, cookies from all 4 treatments were acceptable to consumers, receiving hedonic scores ranging from 6 to 7 ("like slightly" to "like moderately") for all attributes with the exception of cookies made from precooked flour with 20% bran that had crumbliness and flavor ratings slightly below 6. The ranking results mirrored the consumer attribute ratings and showed that all the cookies were preferred equally with no significant differences ($P < 0.05$).

In general, male ($N = 25$) consumers had higher overall acceptability scores than female ($N = 53$) consumers for all treatments except the precooked flour cookies with 20% bran substitution. Both female and male consumers who were frequent consumers (more than once a week) gave higher scores to the cookies from precooked flours. Of the 78 panelists, 76 were aware of health benefits linked to fiber-enriched products and were willing to use them in their daily diet.

**Tortillas.** Table 4 shows the consumer acceptability ratings for various sensory attributes of tortillas. The ANOVA results indicated that all the attributes (overall acceptability, appearance, texture, chewiness, and flavor) were significantly affected ($P < 0.05$) by the treatments. Just like cookies, previous studies on tortillas have shown that addition of fibrous ingredients from sources such as corn, oat, pea, soy, and sugar beet to the formulation beyond a certain level (12% to 25%) decreases the sensory properties (Seetharaman and others 1994; Soto-Mendivil and Vidal-Quintanar 2001). Dreher (1995) also reported adverse effects of bran inclusion on tortilla sensory characteristics, such as appearance, texture, and chewiness. As observed for cookies, results were mixed with regard

**Table 3—Consumer acceptability (9-point hedonic scale) results[A] for cookies from uncooked and precooked flours with 0% and 20% bran.**

| Bran level (%) | Flour type | Overall | Appearance | Texture | Crumbliness | Flavor |
|---|---|---|---|---|---|---|
| 0 | Uncooked | $6.7 \pm 1.6^a$ | $7.0 \pm 1.5^{ab}$ | $6.4 \pm 1.8^a$ | $6.1 \pm 1.8^a$ | $6.3 \pm 1.6^a$ |
| 0 | Precooked | $6.7 \pm 1.5^a$ | $6.7 \pm 1.3^{bc}$ | $6.5 \pm 1.7^a$ | $6.1 \pm 1.7^a$ | $6.4 \pm 1.6^a$ |
| 20 | Uncooked | $6.9 \pm 1.4^a$ | $7.2 \pm 1.6^a$ | $6.4 \pm 1.5^a$ | $6.2 \pm 1.6^a$ | $6.8 \pm 1.5^a$ |
| 20 | Precooked | $6.0 \pm 1.5^b$ | $6.4 \pm 1.4^c$ | $6.3 \pm 1.4^a$ | $5.9 \pm 1.5^a$ | $5.7 \pm 1.7^b$ |

[A]Mean, $n = 78$; means with same superscript in the same column are significantly different ($P < 0.05$).

**Table 4—Consumer acceptability (9-point hedonic scale) results[A] for tortillas from uncooked and precooked flours with 0% and 20% bran.**

| Bran level (%) | Flour type | Overall | Appearance | Texture | Chewiness | Flavor |
|---|---|---|---|---|---|---|
| 0 | Uncooked | $7.0 \pm 1.3^a$ | $7.2 \pm 1.2^a$ | $6.8 \pm 1.5^a$ | $6.5 \pm 1.6^a$ | $6.8 \pm 1.2^a$ |
| 0 | Precooked | $6.3 \pm 1.7^b$ | $6.4 \pm 1.8^b$ | $6.1 \pm 1.7^b$ | $5.9 \pm 1.6^{bc}$ | $6.3 \pm 1.7^{ab}$ |
| 20 | Uncooked | $6.0 \pm 1.4^b$ | $5.2 \pm 1.3^c$ | $6.0 \pm 1.5^b$ | $6.0 \pm 1.6^{ab}$ | $6.0 \pm 1.4^{bc}$ |
| 20 | Precooked | $5.8 \pm 1.8^b$ | $4.8 \pm 1.7^c$ | $5.6 \pm 1.9^b$ | $5.5 \pm 1.8^c$ | $5.8 \pm 1.8^c$ |

[A]Mean, $n = 78$; means with same superscript in the same column are significantly different ($P < 0.05$).

S: Sensory & Food Quality

to the effects of bran substitution and extrusion pretreatment on consumer acceptability of tortillas. Increase in bran level from 0% to 20% in uncooked flour significantly reduced the overall acceptability and all other attributes for tortillas except for chewiness. However, when tortillas made from precooked flour were compared, similar increase in bran level did not significantly affect overall acceptability, texture, and chewiness. Precooking of the flour without any bran substitution led to diminished consumer acceptability of tortillas for all attributes, with the exception of flavor. Precooking the flour with 20% bran also led to decreases in all consumer acceptability attributes, although most of these differences were not statistically significant ($P < 0.05$). The negative effect of extrusion precooking was attributed to the degradation of the starch and protein fractions and an overall deterioration in the rheological properties of the flours (Gajula and others 2008) as described previously. Along with other attributes, appearance played a major role in determining the overall acceptability. The color measurements discussed previously underscored this point, as darkness and redness increased with precooking or increase in bran level. Tortillas containing precooked flour with 20% bran scored the lowest mean hedonic score (< 5) for appearance, indicating that consumers did not like the darker appearance of this product. The tortillas made with uncooked flour without any bran substitution was most acceptable to the consumers, receiving the highest mean hedonic scores for all 5 attributes. The precooked flour tortilla containing 20% bran had a mean overall acceptability score of 5.8, and was least acceptable to the consumers. Except for precooked flour tortillas containing 20% bran, all products had mean hedonic scores of 6 or more for overall acceptability and most of the other attributes, which indicated liking by the consumers.

The ranking results also indicated that the tortillas from uncooked flour with 0% bran were liked the most, while tortillas from precooked flour with 20% bran were the least liked. Most rankings were significantly different ($P < 0.05$). Male consumers had higher overall acceptability scores than female consumers for all treatments. Both female and male panelists who consumed tortillas frequently gave higher acceptability scores for all treatments.



## Conclusions

Cookies and tortillas prepared from flours with 0% or 20% wheat bran substitution were found to be acceptable by consumers, with most hedonic scores ranging between 6 and 7 on a 9-point hedonic scale. Consumer acceptability of products made from flour with 20% bran was similar to or poorer than those from flour with 0% bran. Extrusion precooking of the flours did not improve the consumer acceptability of cookies and tortillas; however, it did improve their dietary fiber profile by increasing the SDF significantly. With 20% bran substitution, up to 2.24 and 2.75 g of TDF and 0.54 and 0.66 g of soluble fiber could be provided per serving of the cookies and tortillas, respectively.

## Acknowledgments

This study was supported by check-off funds from the Kansas Wheat Commission. The authors would like to thank Mr. Eric Maichel, Mr. Dave Krishock, and Dr. Yong-Cheng Shi of the Dept. of Grain Science and Industry at Kansas State Univ. for providing technical assistance and lab facilities. We also appreciate Horizon Milling (Wichita, Kans., U.S.A.) for donating the flour ingredients. This article is contribution nr 07-248-J from the Kansas Agricultural Experiment Station, Manhattan, Kans., U.S.A.

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