NOTE

Thermal Processing Effects on Dietary Fiber Composition and Hydration Capacity in Corn Meal, Oat Meal, and Potato Peels[1,2]

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Cereal Chem. 68(6):645-647

ABSTRACT

The effects of extrusion-cooking and baking on the dietary fiber composition and hydration capacity of corn meal, oat meal, and potato peels were compared. Total nonstarch polysaccharides increased in oatmeal and potato peels with both processes, but the ratio of soluble to insoluble nonstarch polysaccharides was higher in the extruded samples. Uronic acids were not affected by processing; Klason lignin decreased in potato peels only. Values for nonstarch polysaccharides generally increased when resistant starch was not removed by dispersion with dimethylsulfoxide prior to enzymatic digestion. Extrusion increased hydration capacity of corn meal and oat meal; processed potato peels had lower hydration capacities than raw peels.

Consumer interest in the health benefits of dietary fiber has prompted the increased use of high-fiber materials in processed foods (Dreher 1987). However, the effects of food processing on the chemical and physical properties of fiber are not clear. Some researchers have reported that extrusion cooking causes no significant changes in soluble and insoluble fiber (Varo et al 1983, Artz et al 1990), while others have reported reduced fiber (Fornal et al 1987) or increased fiber (Theander and Westerlund 1987).

This situation is further complicated by the lack of agreement on which materials should be considered as fiber and which analytical method for fiber determination should be used. For example, Englyst and Cummings (1988) do not include digestion-resistant starch, lignin, and other nonpolysaccharides in their method for nonstarch polysaccharide determination, hence the values obtained with their method for foods that contain those materials may be lower than the fiber values obtained with other types of fiber analyses.

Changes in fiber content due to processing may be related to the overall composition of the food. Therefore, three food materials (corn meal, oat meal, and potato peels) representing diverse compositions were evaluated for changes in dietary fiber components. Potato peels, while not typically considered as food ingredients, were included because of current research on the suitability of potato wastes as a source of dietary fiber. Two types of thermal processing, baking and extrusion cooking, were studied with respect to their effects on fiber composition and hydration capacity.

MATERIALS AND METHODS

Materials

Enriched, degerminated yellow corn meal (CODE, Pittsburgh, PA) was used as is. Oatmeal (Quaker, Chicago, IL) was ground with a Wiley mill to pass through a U.S. No. 20 sieve. Somerset and Russet Burbank potatoes were abrasion-peeled. Peels were washed with cold water to remove excess starch, freeze-dried, then ground to pass through a No. 20 sieve. Peels from the two varieties were mixed by weight on a 2:1 ratio (Somerset-Russet).

Baking

After duplicate ground samples were adjusted to 20% moisture, 200 g of each were spread in a foil-lined pan (23 × 30 cm) and then baked at 135°C for 1 hr. Samples were cooled to room temperature and then stored in plastic bags.

Extrusion

A laboratory extruder (Model 125-25 BH, C. W. Brabender Instruments, Inc., South Hackensack, NJ) with a zinc-plated screw (3.18 cm, 25:1 length-diameter ratio) with a 3:1 compression ratio was used. The factory-made screw was modified by the addition of a stainless steel cone (5.1 cm long, 45°) attached to the tip of the screw to reduce volume within the die.

Samples were adjusted to 20% moisture and allowed to equilibrate overnight before extrusion. The feeder speed was adjusted to deliver 340 g/min of each material. Extruder screw speed was 70 rpm. Torque (newton meters) was read from a plotter attached to a Plasticorder drive. The barrel temperature profile was 90-105-120-135°C from the feed end to the die end of the barrel. The four heating zones were air-cooled. A horizontal rod die with a circular die nozzle (8 mm in diameter) was heated to 135°C via a metal collar.

During each extruder run, the machine was allowed to equilibrate for 5-10 min until a stable torque was achieved. Extrudates were collected on metal screens to allow excess steam flash-off. Once cool, the samples were transferred to plastic bags. The extruder was shut down and thoroughly cleaned between runs. Duplicate extrusion runs were made for each material.

Proximate Analysis

Moisture was measured as the loss in weight of a 1-g sample after 12 hr at 105°C in an air oven. The 1-g samples were incinerated at 550°C for ash content. AOAC Method 984.13 was used to measure nitrogen content (AOAC 1990); protein was calculated as N × 6.25. Fat was determined by AOAC Method 920.39. The composition of the raw materials is shown in Table I.

Nonstarch Polysaccharides

The colorimetric procedure of Englyst and Cummings (1988) was modified slightly to accommodate differences in the centrifuges used in the two laboratories. The source of α-amylase was porcine pancreatin (P 1625, Sigma Chemical Co., St. Louis,

TABLE I
Proximate Composition of Materials[a]

Material	Moisture (%)	Protein, N × 6.25 (%)	Ash (%)	Fat (%)
Corn meal	8.93	9.26	0.50	1.30
Oat meal	8.30	18.04	1.90	6.50
Potato peels	3.00	10.47	2.48	0.60

[a]Average of two determinations.

[1]Maine Agricultural Experiment Station External Publication No. 1582.
[2]Presented at the AACC 75th Annual Meeting, Dallas, TX, October 1990.
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TABLE II
Processing Effects on Dietary Fiber Components and Hydration Capacity[a]

Material	Total NSP[b] (%, db)	Insoluble NSP (%)	NSP with Resistant Starch (%)	Uronic Acids (%)	Klason Lignin (%)	Hydration Capacity[c]
Cornmeal						
Raw	6.47 ± 0.73 a	6.10 ± 0.10 b	7.07 ± 0.35 a	0.23 ± 0.04 a	0.43 ± 0.16 a	2.67 ± 0.08 a
Baked	6.00 ± 0.50 a	6.06 ± 0.37 b	7.02 ± 0.70 a	0.21 ± 0.03 a	0.28 ± 0.06 a	2.36 ± 0.07 a
Extruded	6.46 ± 0.56 a	5.97 ± 0.27 b	7.31 ± 0.98 a	0.20 ± 0.01 a	0.21 ± 0.05 a	7.77 ± 0.79 d
Oatmeal						
Raw	8.92 ± 0.55 b	5.11 ± 0.10 a	10.56 ± 0.19 b	0.20 ± 0.03 a	0.83 ± 0.00 a	2.78 ± 0.01 a
Baked	9.49 ± 0.38 b,c	5.05 ± 0.43 a	10.20 ± 0.07 b	0.21 ± 0.02 a	1.13 ± 0.09 a	2.92 ± 0.07 a
Extruded	10.15 ± 0.51 c	6.82 ± 0.16 b	10.84 ± 0.40 b	0.21 ± 0.02 a	0.88 ± 0.09 a	4.00 ± 0.72 b
Potato peels						
Raw	30.65 ± 0.28 d	22.97 ± 1.25 c	31.12 ± 0.67 c	4.60 ± 0.39 b	12.98 ± 1.02 c	8.49 ± 0.43 e
Baked	33.18 ± 0.75 e	25.29 ± 0.49 e	32.92 ± 0.91 d	4.72 ± 0.18 b	5.76 ± 0.37 b	7.64 ± 0.19 d
Extruded	34.61 ± 1.01 f	24.00 ± 1.05 d	32.91 ± 0.93 d	4.48 ± 0.17 b	6.68 ± 1.53 b	7.16 ± 0.32 d

[a] Means ± SD within columns followed by different letters are significantly different ($P \leq 0.05$).
[b] Nonstarch polysaccharides.
[c] Averages of triplicate measurements; grams of water per gram of sample.

MO). Total nonstarch polysaccharides (NSP), water-insoluble NSP, total NSP plus resistant starch (resistant starch was not removed by dispersion by dimethylsulfoxide (DMSO)), and uronic acids were analyzed in duplicate for each raw, baked, or extruded material.

Lignin

AOAC Method 973.18 was used for the determination of Klason lignin in duplicate (AOAC 1990).

Hydration Capacity

AACC Method 56-20 was performed in triplicate on raw, baked, and extruded samples (AACC 1983).

Statistical Analyses

One-way analysis of variance was used to determine differences among the raw, baked, and extruded materials. Duncan's multiple range test ($P = 0.05$) was used.

RESULTS AND DISCUSSION

Dietary Fiber Composition

The extent of total NSP changes was dependent primarily on the material rather than on the type of processing (Table II). No processing changes were observed for corn meal, which was lowest in NSP. Total NSP increased in extruded oatmeal compared with the raw material, while for potato peels, both forms of processing resulted in significantly higher NSP contents.

Insoluble NSP values followed a similar trend for corn meal and oatmeal. Baked potato peels contained the highest percentage of insoluble NSP, but extruded peels increased significantly in both soluble and insoluble NSP. Increased solubilization of fiber components has been found after extrusion of wheat products (Bjorck et al 1984, Siljestrom et al 1986, Theander and Westerlund 1987). Using a modified detergent-enzyme fiber method, Fornal et al (1987) found reduced cellulose and lignin, which are the major components of insoluble fiber after extrusion, presumably due to dextrinization or other type of thermal decomposition.

The inclusion of resistant starch increased the NSP values in raw and processed corn meal and oatmeal and in raw potato peels, but no resistant starch was apparent in processed potato peels (Table II). Processing had no effect on NSP plus resistant starch values for either corn meal or oatmeal. Baked and extruded potato peels had higher values for NSP with resistant starch than did raw potato peels, but the extruded mean value was significantly lower than the comparable value without resistant starch. The discrepancy may be partly explained by the high standard deviations for these treatments. The increase noted in NSP in baked and extruded potato peels may be due to formation of a form of enzyme-resistant starch that is not dispersible in DMSO. Theander and Westerlund (1987) proposed that 1,6-anhydro-D-glucose units may be liberated from starch during thermal processing and then react with starch or other polysaccharides to form enzyme-resistant complexes that are distinct from other types of resistant starch.

The percent of uronic acids appears to be unaffected by the conditions of thermal processing used in this study. Theander and Westerlund (1987) also found no differences in uronide content for wheat flour extruded at 105–200°C. The effect of extrusion processing on pectin solubility or degree of esterification, which influences solubility and gelling properties, was not determined.

No significant differences in Klason lignin contents were found for either corn meal or oatmeal. However, thermal processing resulted in an approximately 50% decrease in lignin in potato peels. The effects of processing on true lignin is not clear. A portion of the material detected as Klason lignin in potato peels is suberin, a waxy material that may be more thermal-labile than true lignin. Increased recovery of Klason lignin after extrusion of wheat was presumably due to the formation of Maillard reaction products under more severe thermal conditions (Theander and Westerlund 1987).

Hydration Capacity

For corn meal and oatmeal, hydration capacity was not affected by baking but was significantly increased by extrusion (Table II). Hydration capacity dropped significantly in extruded potato peels. These findings were not correlated with the changes in total NSP and resistant starch after extrusion, suggesting that other components, such as starch, may be responsible for changes in hydration capacity. Similar disparities were found in the water-binding capacity of yellow pea hulls and depectinized apple pomace (Arrigoni et al 1986). Artz et al (1990) reported that water-holding capacity decreased with increasing fiber content in extruded blends of corn starch with corn bran isolate due to the greater water-holding capacity of gelatinized starch compared with cellulose and hemicellulose.

ACKNOWLEDGMENTS

Modifications of the extruder were made courtesy of John Riley and Dwight Worcester of the Department of Bio-Resource Engineering; Alvin Reeves, of the University of Maine Aroostock Farm, supplied potatoes; Mark Flint and Jianxin Zhao assisted with extrusion and analyses.

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[Received March 29, 1991. Accepted August 12, 1991.]