Isolation of Gluten and Starch from Ground, Pearled Wheat Compared to Isolation from Flour[1]

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ABSTRACT

Wheat (16.4% protein) was pearled to remove 11.4% of bran and germ, and the pearled wheat was ground to an average particle size of 200 μm. The ground, pearled wheat (GPW) was compared with conventionally milled flour (70% extraction) as starting material for wet processing. Using the conventional dough-washing method, GPW gave a gluten yield (based on wheat weight) 20–25% higher than that of flour. The gluten from both GPW and flour contained 75.2–76.4% protein (dry matter basis) and were the same Agtron color. Gluten from GPW was only slightly inferior to an equivalent level of gluten from flour in improving loaf volume in breadmaking. No significant difference was noted in the yield and purity of A-starch from GPW and flour.

Of all the cereal grains, wheat is produced in largest tonnage around the world. Wheat is most often dry milled into farina, flour, germ, and bran, and those commodities are converted into food or feed. But dry-milled products are mixtures of proteins, carbohydrates, lipids, phenolics, and cellulose, and their mixed composition limits their conversion to modified products. Wet processing of wheat provides products of singular composition, such as protein, starch, and oil. Wet-processed products from wheat, or their modified forms, may find increased use in foods, textiles, paper, and specialty products.

The two major starting materials for wet processing are the whole wheat kernel or flour. Those processes have been reviewed by several authors (Anderson 1967, 1974; Fellers 1973; Knight and Olson 1984; Wadhawan 1988). Most manufacturers of gluten and starch begin with flour. If the endosperm represents 83% of the kernel, the commercial extraction of approximately 76% flour is 7% lower than ideal, and the difference is the peripheral endosperm that is high in protein (Fellers 1973). Also, milling damages some starch in the hard wheat flour.

Ideally, wheat gluten and starch would be produced starting with whole wheat kernels. Several processes have been proposed. In the Far-Mar-Co process (Rao and Gerrish 1975), tempered wheat is flaked and mixed into a tough hydrated dough. High-pressure water is used to wash the starch bran and germ from the developed gluten, and then the bran and germ are screened from the starch slurry. In the Pillsbury process (Rodgers and Gidlow 1974), spring hard wheat is steeped 8 hr and gently macerated mechanically to remove bran and germ from the endosperm. The endosperm then undergoes conventional processing to separate gluten and a low-grade flour. Neither of these methods is used today, probably due to the high drying costs of low-value streams or to difficulties in obtaining high quality gluten (Zwitserloot 1989).

Abbreviated dry milling of wheat is being adopted to circumvent the problems of wet processing wheat kernels, but little information has been reported (Zwitserloot 1989).

The objective of this study was to demonstrate that optimally ground, pearled wheat (GPW) may be a better raw material than 70% extraction flour from which to isolate gluten and starch.

MATERIALS AND METHODS

Norkan hard red winter (HRW) wheat and a commercial sample HRW wheat were used in the dry- and wet-milling investigations. The Norkan (1988 crop) and commercial wheat (1989) contained 16.4 and 13.8% protein (dry basis), respectively. Baking flour was from Cargill (Wichita, KS, June, 1989). Commercial wheat gluten was from N. B. Love, Brisbane, Australia, and Midwest Grains Products, Inc., Atchison, KS. Moisture, protein, and ash were assayed by AACC Methods 44-15A, 46-13, and 08-01, respectively (AACC 1983). Starch content was determined according to Chiang and Johnson (1977), and damaged starch was determined by AACC Methods 76-30A, 80-60, and 70-75 (AACC 1983). The color of flour and starch was determined on dry powders using a M500 Agron reflectance instrument in the green mode. The instrument was calibrated using disks 68 and 97. Particle size was determined by ASAE Method S319.1 (ASAE 1987).

Dry Milling

The wheat was divided into two samples. One was tempered to 16% moisture overnight and then subjected to conventional flour milling using the Ross experimental mill (Liu et al 1986). The other group was tempered overnight to 12% moisture (Liu et al 1986) and then pearled with a Strong-Scott Laboratory Pearler equipped with a No. 30 grit stone and a 10-mesh screen (Tyler code "Figor"). A 50-g batch of wheat sample required 40 sec to pearl. The pearled wheat was then ground (in a Ross experimental mill) with one pass through a break roll (16 corrugations per inch) and two passes through a smooth roll. The optimum particle size for wet processing of GPW was produced using a break roll gap of 0.02 in. (0.51 mm) and a smooth roll gap of 0.003 in. (0.076 mm).

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Wet Processing

All wet-milling experiments were done in triplicate. GPW or flour (250 g) was mixed with water in a Hobart mixer for 1 min with a paddle and then 3 min with a dough hook. The dough was soaked in 1 L of water. The gluten was isolated from the dough by hand washing with a total of 9 L of water and then freeze-dried (AACC Method 38-10, AACC 1983). The liquid washings were combined and passed through a No. 10 Tyler sieve (with an opening of 1.7 mm) to collect gluten scraps, and then through a Nitex Hc 7-118 sieve cloth (with an opening of 118 μm) to collect bran and germ. The filtrate was centrifuged at 470 $\times g$ for 15 min, and the sediment was collected as the starch fraction. The supernatant was discarded. The dark top layer (B-starch) of the sediment was separated with a spatula from the white bottom layer (A-starch), which was washed with water and centrifuged again. The B-starch layer was removed and combined with the first B-starch layer. All the starch fractions and bran were air dried at room temperature with a fan. Dried gluten, A- and B-starches, and bran samples were crushed with a mortar and pestle and then ground through a cyclone sample mill (UDY, Boulder, CO).

Figure 1 shows the processes used for dry milling and wet processing.

Breadmaking

Absorption and mixing time for the mixture of bread flour and gluten were determined with the mixograph (AACC Method 54-40A, AACC 1983), and breadmaking was performed using pup loaves (AACC Method 10-10B, AACC 1983). In a test loaf, 3 g of a gluten sample was blended with 100 g of flour (14% moisture basis) before the dough was mixed. Loaf volumes were measured on bread immediately out of the oven, and volumes were corrected to an isoprotein basis using the regression line of Finney (1985).

RESULTS AND DISCUSSION

Dry Milling

HRW wheats were used in this investigation, a 1988 Norkan sample with 16.4% protein (Table I) and a 1989 commercially mixed sample of wheat with 13.8% protein, both on a dry moisture basis. We present detailed data here only on the high-protein wheat to clearly present the overall approach. Most of the advantages of the new process were observed for both wheats, although to a somewhat diminished degree with the 13.8% protein wheat.

The pearled wheat represented 88–89% of the original weight after removal of the germ and part of bran, whereas the flour from conventional milling was 68–70% of the wheat weight (Table II). Thus, an increased proportion of the wheat kernel was wet-processed when the starting material was GPW. Furthermore, the GPW contained 7% less damaged starch than the straight-grade flour (Table I). Even though the pearled wheat was 1.4% higher in protein, the increase was attributed to endosperm outer layers.

After pearling, it was necessary to grind the pearled wheat to an optimum particle size for wet processing. Wet processing of GPW was tested with five different particle sizes ranging from 100 to 670 μm. Coarse grinding gave large particles of endosperm, and protein development was inefficient in the dough mixing step. On the other hand, fine grinding by roller milling gave excessive starch damage.

Optimum yields and purity of gluten and starch were obtained when the GPW had an average particle size of about 200 μm. The average particle size in GPW was larger than that in flour (Fig. 2) and, as already stated, the damaged starch in GPW was much lower. The wet-processing data on other particle sizes of GPW are not given.

The two systems for flour milling and GPW production were compared. The latter needed one pearling and two grinding steps, whereas the conventional flour milling needed a total of 13 grinding and sieving steps. Based just on the technical stages of handling, grinding, and sieving, we estimated that the cost for dry milling to produce flour is three times higher than the cost to produce GPW.

Wet Processing

The amount of water needed to form a dough was 3–5% higher

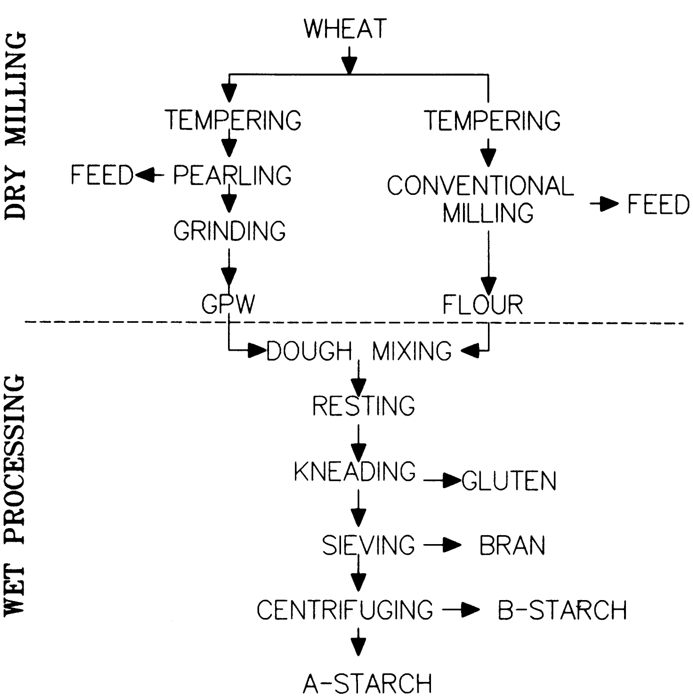

Fig. 1. Schematic flow for fractionation of wheat. GPW = ground, pearled wheat.

TABLE I
Average Composition of Raw Materials of Norkan Wheat (dry matter basis)

Sample	Component	Level (%)
Wheat	Protein	16.4 ± 0.3
	Starch	65.3 ± 1.3
	Ash	1.9 ± 0.1
GPW[a]	Protein	15.2 ± 0.3
	Starch	68.9 ± 0.8
	Damaged starch	1.0 ± 0.2
	Ash	1.6 ± 0.3
Flour	Protein	14.0 ± 0.2
	Starch	79.7 ± 1.3
	Damaged starch	8.3 ± 0.1
	Ash	0.4 ± 0.1

[a]Ground, pearled wheat.

TABLE II
Product Yield (kg) from 100 kg of Norkan Wheat (dry matter basis)[a]

Product	GPW[b] System	Flour System
Dry milled		
Germ and bran	11.4 ± 0.5	30.0 ± 1.0
Endosperm	88.5 ± 0.5	70.0 ± 1.0
Wet processed		
Bran	10.3 ± 0.5	0.4 ± 0.1
Gluten	13.2 ± 0.9 a	10.7 ± 0.8 b
Starch A	32.1 ± 0.3 a	32.1 ± 0.5 a
Starch B	25.8 ± 0.3 a	21.6 ± 1.2 b
Losses (by difference)	7.1	5.3

[a]Different letters indicate a significant difference at $P = 0.05$.
[b]Ground, pearled wheat.

for GPW than for flour. Wet processing of GPW gave a 13.2% yield of gluten, based on the weight of wheat kernels, compared to 10.7% for flour, and 25.8% B-starch, compared to 21.6% for flour. The yields of A-starch were both 32.1% (Table II), and their purities were practically the same (Table III).

Approximately 13% more of the protein available in the wheat kernel was isolated in the gluten starting with GPW than in that from flour. Gluten isolated from the two starting materials had the same protein and starch content within experimental error but differed in ash content by 0.9% (Table III). The gluten was sensitive to oxidation, and its color varied with time of storage in the freezer before drying.

The yield of total starch from GPW was about 12% higher, based on wheat, than that from flour. However, the B-starch from GPW was contaminated with extra bran, as indicated by its twofold higher level of ash and protein compared to the B-starch from flour.

The total solids unaccounted for in the wet processing were 8.9% for the GPW system and 7.8% for the flour system.

TABLE III
Composition (%) of Products Isolated, Starting from Ground, Pearled Wheat (GPW) and Flour from Norkan Wheat (dry matter basis)

Component	Starting Material[a]	
	GPW	Flour
Bran		
Protein	13.9 ± 0.3	Trace amount
Ash	4.5 ± 0.1	Trace amount
Gluten		
Protein	75.2 ± 1.7 a	76.4 ± 1.7 a
Starch	7.3 ± 0.5 a	7.1 ± 0.3 a
Ash	1.3 ± 0.1 a	0.4 ± 0.1 b
Color	44.3 ± 3.8 a	44.3 ± 2.9 a
A-Starch		
Protein	0.6 ± 0.1 a	0.6 ± 0.1 a
Starch	94.3 ± 1.0 a	96.0 ± 2.4 a
Ash	0.2 ± 0.1 a	0.1 ± 0.1 a
Color	90.2 ± 2.3 a	92.0 ± 2.3 a
B-Starch		
Protein	1.6 ± 0.2 a	0.9 ± 0.2 b
Starch	82.5 ± 2.1 a	83.2 ± 2.2 a
Ash	0.4 ± 0.1 a	0.2 ± 0.1 a
Color	69.4 ± 2.0 a	69.3 ± 1.8 a

[a]Different letters indicate a significant difference at $P = 0.05$.

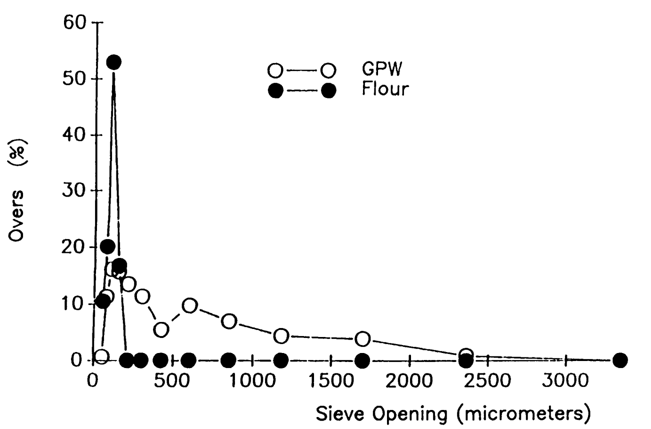

Fig. 2. Particle size distribution of raw materials for the wet process. GPW = ground, pearled wheat.

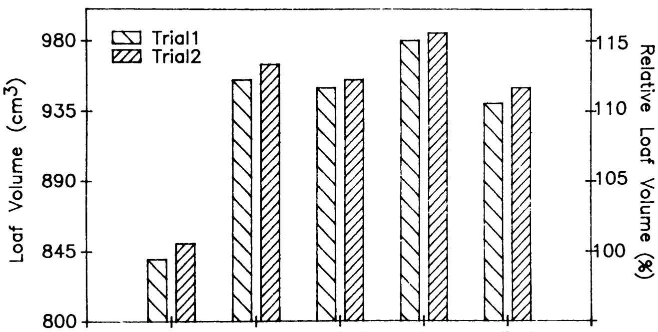

Fig. 3. Loaf volume response of different gluten sources added to the control, calculated on an isoprotein level in flour of 15.9%. 1, Blank, no gluten added; 2, commercial gluten A added; 3, commercial gluten B added; 4, flour gluten added; 5, gluten from ground, pearled wheat added. Different letters indicate a significant difference at $P = 0.05$.

Quality of Gluten

All gluten samples increased loaf volume in breadmaking (Fig. 3), when added at a 3% level to a flour with an initial protein level of 13.2%. When the loaf volumes were normalized to an isoprotein basis of 15.9% in the flour (Finney 1985), the gluten isolated from GPW gave slightly less improvement in loaf volume than the gluten from flour (Fig. 3). However, the two gluten samples gave identical dough absorptions, mixing times, and crumb grain in the baked bread. Two commercial gluten samples were equal to GPW gluten in improving the performance of the flour. This result is somewhat surprising, since commercial gluten usually has approximately 60% efficiency compared to freeze-dried gluten.

Normal vs High-Protein Wheat

A commercial sample of HRW wheat (13.8% protein, dry moisture basis) was pearled (with 10% loss of bran) and ground to approximately the same granulation as the GPW from the high-protein wheat. The normal-protein wheat was also ground to 70% extraction flour. Wet processing of the normal-protein GPW and flour gave the following results; 16% more gluten isolated from the GPW than from flour (based on the weight of wheat), 12% more protein isolated from GPW (based on kernel protein), and less A-starch from the GPW (31.5% based on wheat) than from the flour (34.0%), but more B-starch from GPW (27.4%) than from the flour (21.1%). The A-starch from normal-protein GPW contained somewhat higher ash and protein than that isolated from the normal-protein flour.

The results in this investigation were obtained using bench-scale batch processing. In future work, the difference between wet processing of GPW and of flour from other classes of wheat with various protein levels should be examined on continuous pilot-scale equipment.

CONCLUSION

GPW is preferred over conventional milled wheat flour to prepare gluten and starch. The dry milling of GPW is simpler and less costly compared to milling of wheat flour, and a higher yield of gluten protein is obtained from GPW. GPW also gave the same yield of A-starch as wheat flour, and the starch had better purity.

ACKNOWLEDGMENT

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