

MECHANICAL DEBRANNING OF WHOLE-KERNEL WHEAT.

III. COMPOSITION, COOKING CHARACTERISTICS, AND STORAGE STABILITY¹

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ABSTRACT

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Gaines, a soft Western white wheat, was debranned in sequential steps using a CeCoCo abrasive cone pearler. Compositional aspects of the pearled wheat and brans were determined. Tenderness of cooked 73%-yield pearled wheat approached that of rice. Flavor, odor, thiobarbituric acid, and lipid acidity

tests on the pearled wheat during storage indicated good stability. *In vitro* protein digestibilities of abraded brans were high compared with brans from the traditional flour-milling process. The potential use of these novel products in foods is discussed.

Wheat has been relatively unexploited in a debranned whole-kernel form. One exception is bulgur, which has been used since biblical times. Bulgur is prepared by parboiling whole wheat, drying, and partially debranning (3 to 6% bran removal) (1,2,3,4). It is normally cracked to grits to reduce cooking time and toughness. A second exception is WURLD wheat, made by lye-peeling the grain with or without cooking (5,6).

Whole-kernel debranning as a preliminary step in flour milling has had little success in improving flour yields or quality (7,8).

A mechanically pearled or debranned wheat to be used similarly to rice has been produced in Australia. It is called Rycena and was designed primarily for export. In some cases, it was fortified with synthetic, extruded kernels containing lysine, vitamins, and minerals. We have been unable to find any literature on production methods or product characteristics.

Previous papers from this laboratory described bran removal in two types of mills, one in which grains are rubbed one against the other (9), and another in which grains are rubbed against an abrasive surface (10). The present paper gives information on composition and other product characteristics of wheat debranned by a mill of the abrasive type.

MATERIALS AND METHODS

Composition and Cooking Studies

Wheat. Gaines, a Western soft white wheat, was cleaned and sized on a Carter dockage tester. Oversized kernels were removed on a No. 29 screen (round depressed holes of 0.376 cm diameter); they represented 1.8% of the total. Chaff aspirated away, and broken kernels, removed by sieving through a No. 4 screen (0.163 × 0.953-cm slot), amounted to 0.7%. Proximate analysis of the cleaned and sized wheat is presented in Table I.

¹Reference to a company or product name does not imply approval or recommendation of the product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

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Debranning. The CeCoCo barley and wheat polishing mill, Type E², used to debran the wheat (10) has an abrasive Carborundum cone which rotates inside a slotted screen. Wheat was sprayed with water (2% of weight of wheat), tempered from 5 to 10 min, and then passed through the CeCoCo mill with the feed gate width at 0.5 in., a stone-to-screen gap of 0.5 in., and minimum pressure on the exit gate. Wheat was debranned in batches of 5000 g to control tempering time. The first-pass wheat and abraded bran were collected and weighed. The first-pass wheat was then subjected to a second debranning pass, and so forth, until a total of six passes was completed.

Analytical. Thiamine was determined by the AACC thiochrome method (11). The method of Wheeler and Ferrel (12) was used for phytic acid. Lysine and other amino acids were determined by ion-exchange chromatography (Phoenix automatic analyzer) of 6*N* hydrochloric acid digests carried out under vacuum. *In vitro* protein digestibility and dry matter digestibility assays of bran fractions were carried out according to the procedure of Saunders and Kohler (13). Other analyses were by appropriate AOAC methods (14).

Cooking Tests. Test samples were prepared by adding 100 g of dry grains to 500 ml of boiling water, returning to a boil, and then simmering for the desired time. The excess water was removed by draining in a sieve for 3 min, and the cooked product was weighed. A 150-g portion of cooked product was placed in the shear cell of a Lee Kramer shear press, Model SP 12 Imp, equipped with an electronic strip-chart recorder, and the resistance to shear was recorded with time. The 3000-lb ring was used. The descent rate of the shear head was set at 4 (7 sec per in.). Results are reported as areas under the shear curves, values that are directly related to work necessary to shear a sample (15).

Water absorption index was determined by dividing the cooked weight by the uncooked weight.

TABLE I

Composition of Wheat and CeCoCo Mill Debranned Wheat; Dry Basis; Average of Duplicate Determinations; 2% Water Sprayed on before Step-1 Milling, Dry Milling in Other Steps

Composition ^a	Original Wheat	After Step 1	After Step 2	After Step 3	After Step 4	After Step 5	After Step 6
Crude fiber, %	3.0	1.6	1.4	1.2	1.3	1.1	1.1
Thiamine, μg/g	3.4	2.9	2.6	1.9	1.7	1.5	1.1
Crude fat, %	1.6	1.5	1.4	1.3	1.1	1.2	1.0
Phytate phosphorus, %	0.20	0.17	0.15	0.14	0.13	0.12	0.13
Ash, %	1.71	1.48	1.27	1.26	1.19	1.20	1.11
Total phosphorus, %	0.28	0.26	0.25	0.21	0.20	0.20	0.19
Lysine ^b , g/16 g N	2.84	2.62	2.53	2.64	2.55	2.68	2.40
Protein (N × 5.7), %	13.7	13.6	13.1	13.1	12.5	12.1	11.8
Glutamic acid ^b , g/16 g N	33.3	34.3	34.6	34.4	35.8	36.1	35.0
Moisture ^c , %	10.0	10.4	10.3	10.2	10.2	10.1	10.1
Yield, % of original wheat	100	89	80	73	66	60	54

^aListed in order of decreasing milling effect.

^bSingle analysis.

^cAs-is basis.

Solids lost in the cooking water were determined by freeze-drying the water and weighing the residue.

As an additional test of cooking completion, ten individual kernels were removed from the cooking water at various times, cooled in water, and sliced in half; the presence and degree of white centers (uncooked portion) were noted.

Storage Stability

Wheat. A second lot of Gaines wheat was cleaned and sized on a Carter dockage tester. Oversized kernels, 9.4%, were removed on a No. 28 screen (round depressed holes of 0.358 cm diameter) and fines, 4%, were removed through a No. 24 screen (0.198 × 1.27-cm slots). The sized and cleaned wheat was milled (four passes) on the CeCoCo mill, yielding 79.8% of debranned wheat. Broken and dust, 1.8%, were removed on the Carter dockage tester (No. 22 screen; 0.154 × 1.27-cm slots). Final yield of debranned wheat was 78%. Crude fiber was reduced from 3.0% (dry basis) in the original wheat to 1.2% (dry basis) in the pearled wheat.

Storage Conditions. Samples at 10.1 and 12.9% moisture were packed in polyethylene bags inside friction-lid cans and stored at 0°, 90°, and 100°F. Samples with initial moisture of 11.2% were packed in cloth bags and stored at 0°, 90°, and 100°F. Samples were evaluated at 0, 1, 2, 4, 6, and 8 months by the following methods:

Odor. Thirty g of each sample was ground and placed in a capped glass jar and allowed to equilibrate. The 0°F, 10.1% moisture sample was selected as the control. Each of the 11 odor panel members was presented with the eight test samples (coded by a single letter code) and the control, and asked, for each sample: "Compared to the control, 1) is the intensity of the odor of the test sample more?, less?, or the same?; 2) does the test sample have a rancid odor, yes?, or no?; and 3) is the odor of the test sample better?, worse?, or the same?"

Thiobarbituric Acid (TBA) Test. The TBA test for oxidative rancidity was run according to the method of Caldwell and Grogg (16) with the following modifications: a) the TBA reagent was made fresh each storage period and stored in the refrigerator when not in use; b) to improve color development, the 7.5 ml of distilled water was added after refluxing; c) 0.5 ml of 10% alkyl dimethyl benzyl ammonium chloride (surface active agent) was added to the petroleum ether extract before refluxing; and d) refluxing was extended to 20 min.

Lipid Acidity. Lipid acidity, a measure of hydrolytic rancidity, was determined on water-saturated n-butyl alcohol extracts of the samples, according to the method of Mechem and Mossman (17).

Flavor. Preparation for the panel involved adding 100 g of pearled wheat to 500 ml of boiling water containing 2 g salt, bringing back to a boil, simmering for 25 min, and draining in a sieve. The triangle test, duplicated, was used: three samples, two of which are identical, are presented to a judge. The judge is asked to identify the like samples, and indicate preference for the like or unlike samples. The panel consisted of 21 laboratory personnel accustomed to flavor panel work. Comparisons were made between the samples held at 0°F (controls) and the 90° or 100°F stored samples; each comparison was at a single moisture.

RESULTS

The composition of the original wheat, and the composition and yield of the

pearled wheat after one to six milling passes in the CeCoCo mill, are presented in Table I. The composition of the brans abraded off are shown in Table II.

Figure 1 shows graphically how composition of the wheat changed with increasing passes through the CeCoCo mill. Total phosphorus and phytate

TABLE II
Composition of Bran Abraded from Wheat by a CeCoCo Mill; Dry Basis; Average of Duplicate Determinations; 2% Water Sprayed on before Step-1 Milling, Dry Milling in Other Steps

Composition	Original Wheat	After Step 1	After Step 2	After Step 3	After Step 4	After Step 5	After Step 6
Crude fiber, %	3.0	8.8	3.5	2.2	1.8	1.6	1.4
Thiamine, $\mu\text{g/g}$	3.4	6.0	8.1	7.5	7.4	6.2	4.6
Crude fat, %	1.6	3.5	3.2	3.0	2.9	2.3	2.0
Phytate phosphorus, %	0.20	0.34	0.31	0.27	0.24	0.21	0.20
Ash, %	1.71	3.41	2.96	2.28	2.06	1.75	1.66
Total phosphorus, %	0.28	0.58	0.54	0.44	0.43	0.34	0.27
Lysine ^a , g/16 g N	2.84	3.38	3.21	3.17	2.81	2.50	2.61
Protein (N \times 5.7), %	13.7	15.7	17.5	18.0	16.2	15.2	14.3
Glutamic acid ^a , g/16 g N	33.3	27.9	31.1	31.4	32.5	33.0	34.0
Moisture ^b , %	10.0	13.5	10.0	9.8	9.7	9.5	9.6
Yield, % of original wheat removed each pass	...	11	9	7	7	6	6

^aSingle analysis.

^bAs-is basis.

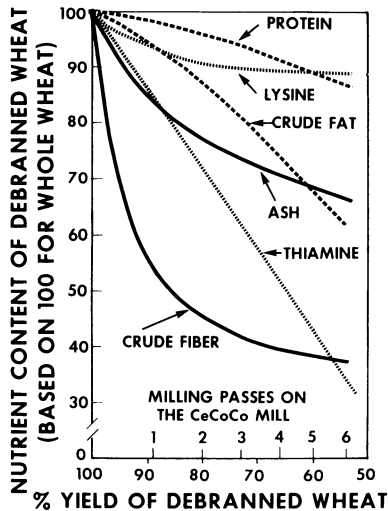


Fig. 1. Change in composition of debranned wheat with degree of CeCoCo milling; 2% water sprayed on wheat 5 to 10 min before first milling pass; dry milling in other passes.

phosphorus followed curves similar to the one for ash content.

The *in vitro* protein digestibilities and dry matter digestibilities of the bran fractions from the first four passes are presented in Table III. Also included in Table III, for comparative purposes, are data on wheat and products from conventional flour milling.

Differences in tenderness (shear resistance) and water absorption, relative to cooking time, for pearled wheats, bulgur, and rice are shown in Fig. 2.

A count of white centers did not indicate any substantial differences in cooking time for the different pearled wheats. All kernels had large white centers at 10 min cooking. At 15 min cooking, 70 to 100% of the kernels had moderate-sized white centers. At 20 min, half the kernels were completely cooked (no white centers). Using this criterion, pearled wheats were completely cooked in 25 to 30 min.

Solids lost in the cooking water ranged from 4 to 5% for all pearled wheat samples when cooked 20 to 30 min. Composition, dry basis, of lost solids from first-pass pearled wheat was: protein 10.6%, crude fat 0.6%, and ash 6.7%; for sixth-pass pearled wheat: protein 6.7%, crude fat 0.3%, and ash 3.8%. Whole wheat cooked for 1 hr lost about 3% solids, and bulgur cooked for 30 min (still incompletely cooked) lost 2.7% solids. After 20 min cooking, Calrose rice had lost 6.7% of its solids to the cooking water. Longer cooking of the rice resulted in excessive water absorption and pasty surfaces.

The odor panel work did not indicate any major differences between the control (0° F storage, 10.1% moisture, sealed container) and samples stored under other conditions, except for the sample stored in a cloth bag at 0° F. Throughout the 8-month storage test, the panel consistently indicated a more intense and undesirable odor (but not rancid) in this sample. It is assumed that this was because of pick-up of an off-odor from the cold room where the sample was stored.

The thiobarbituric acid values corroborate a lack of oxidative rancidity in all samples throughout storage. Values (absorbance at 532 nm) did not increase with

TABLE III

In Vitro Protein Digestibilities (PD) and Dry Matter Digestibilities (DMD) of Bran Abraded from Wheat, Compared to Products from the Roller-Milling Process and Whole Wheat (13)

Product	PD %	DMD %
Bran from pearled wheat ^a		
First pass	93.7	65.2
Second pass	95.9	82.8
Third pass	96.8	87.9
Fourth pass	96.2	89.5
Roller-mill products		
Bran	71.5	34.8
Shorts	79.1	48.4
Red dog	89.5	73.1
Flour	96.7	91.3
Whole wheat, Wiley mill 20-mesh	91.0	85.0

^aAverage of duplicate determinations.

storage time; they generally ranged from 0.01 to 0.05. Caldwell and Grogg (16) found that an oat cereal invariably smelled rancid at an absorbance of 0.25, or higher; oatmeal cookies at 0.55, and higher. The threshold value for pearled wheat is not known but, apparently, was not approached in 8 months under the conditions of this experiment.

Lipid acidities were stable or increased slightly (by a maximum of 25%) in all samples, except 13% moisture samples held at 90° or 100°F. In these samples, lipid acidity increased from 27 μeq per g of sample to 44 and 60 μeq per g of sample, respectively, at 8 months. For comparative purposes, a 13% moisture straight-grade flour stored at 100°F in a sealed container increased in lipid acidity from 8 μeq per g flour to 18 at the end of 6 months (17).

Figure 3 shows that significant differences in flavor developed between 6 and 8 months of storage for samples held at 100°F. In the 13% moisture materials, there was a significant preference (67%) for the 0° F sample at 8 months by those who correctly identified the odd sample in the triangle. In the 10% moisture materials, there was no significant preference at 8 months, though more judges were inclined to favor the 100° F sample. Results with the bag samples are not included because the panel appeared confounded by the off-odor picked up by the 0° F control sample in the cold room (mentioned above). Samples stored at 90° F were tested only after 6 and 8 months of storage (Fig. 3). The flavor of the 13% moisture, 90° F sample was significantly different from the 0° F control at both 6 and 8 months, but there were no significant preferences between the control or test samples. While flavor of the 10% moisture, 90° F sample was not significantly different from the 0° F control at 6 months, it was significantly different at 8 months; there were, however, no significant preferences. Overall, it appears that no gross flavor deterioration occurred at either 90° or 100° F for 6 to 8 months, even though some significant flavor changes did occur.

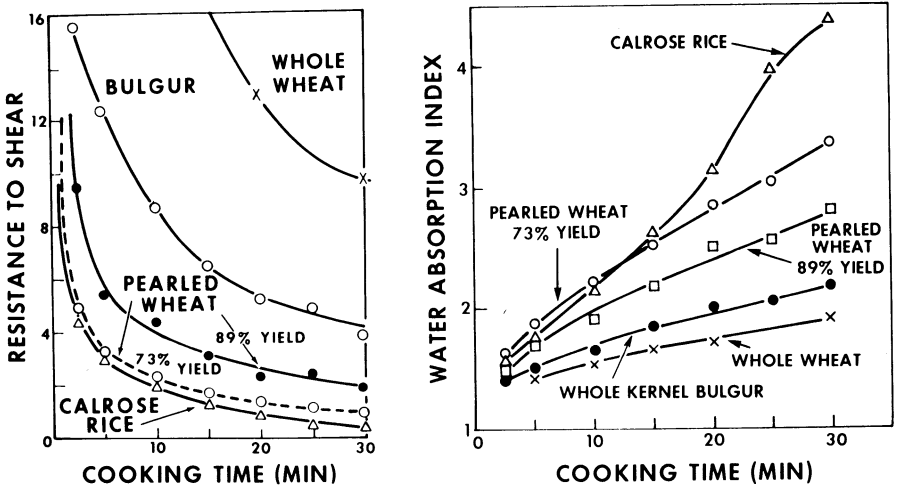


Fig. 2. Water absorption index and tenderness (resistance to shear) of wheat and rice products; 100 g of products was placed in 500 ml of boiling water, returned to a boil, and simmered.

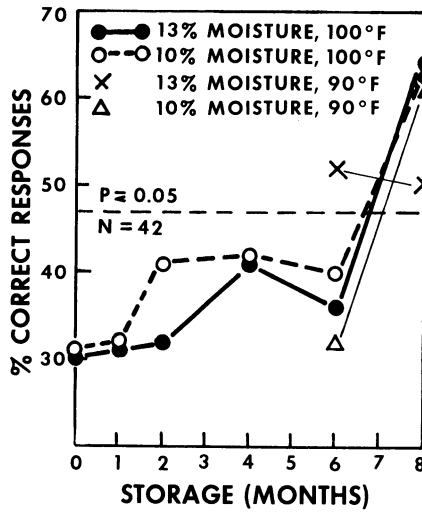


Fig. 3. Effect of storage time on development of flavor differences between 0° F-held control samples and 90°- or 100° F-held test samples; triangle test.

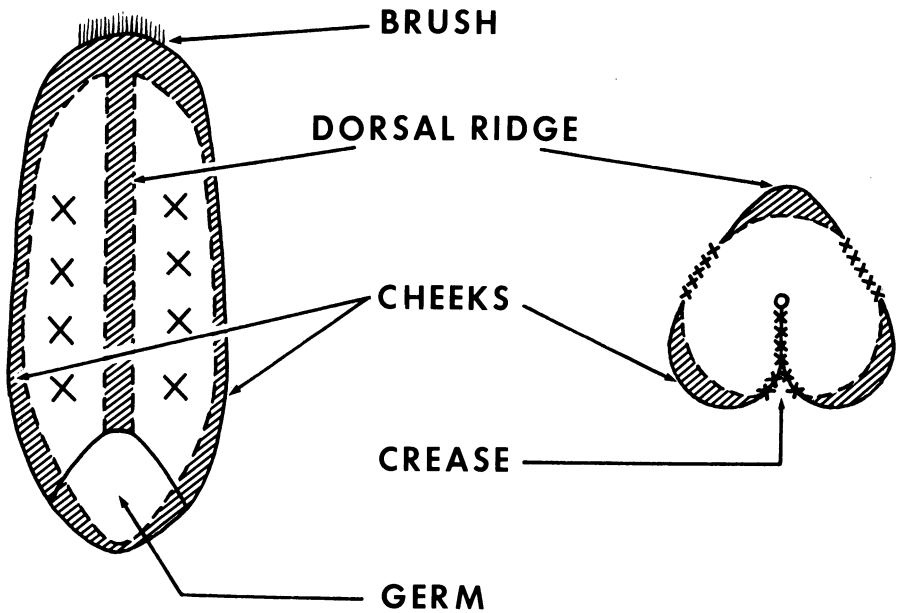


Fig. 4. Location of heaviest abrasive action (hatched area) on Gaines soft white wheat during pearling in the CeCoCo mill. X = areas where residual bran is usually present including bran layers out to and including cross cells; 73% hypothetical yield.

DISCUSSION

The objective of debranning wheat in the present work was to produce a storage-stable, high-yield product in whole-kernel form—one that could be cooked like rice in a relatively short time and have desirable texture and flavor. Results of odor, thiobarbituric acid, lipid acidity, and flavor tests indicate that moderately debranned wheat (78% yield) has good storage stability. On the other hand, Boles and Ernst (18) evaluated samples of our pearled wheat and found them to be preferentially attractive to adults of the rice weevil and the red flour beetle; they also stimulated reproduction of these insects to a greater extent than WURLD wheat, cracked bulgur, Gaines variety whole wheat, or white flour (18).

From the standpoint of fiber or ash reduction, CeCoCo mill pearling is decidedly inefficient compared to roller milling. For example, crude fiber contents of 75, 85, 90, 95, and 100% extraction flours from roller milling are 0.15, 0.30, 0.80, 1.40, and 2.00%, respectively (19), compared to the higher crude fiber contents for pearled wheats (Table I) of similar extraction (yield).

This inefficiency is explained, in part, by the crease bran (20 to 30% of total) which is not accessible to the abrasive action. Additionally, most of the starting wheat kernels tended to have a triangular cross-section (Fig. 4) with the result that the points of the triangle were heavily abraded (dorsal ridge and two cheeks), but the areas between the points were relatively lightly abraded. The brush ends of the kernels were, in general, heavily abraded and the germ ends moderately abraded. Examination of the pearled wheats showed that a portion of the germ (embryo and scutellum) remains. A progressive loss of thiamine with increased pearling (Table I) indicates a gradual loss of germ (scutellum contains 62% of all thiamine in the wheat kernel (20)).

The epidermis and hypodermis (beeswing) were the only tissues essentially completely removed (except in the crease). Addition of water at the 2% level, 5 min before pearling, aided substantially in removing the beeswing. The beeswing has been determined to be about 4% of the kernel weight; its crude fiber content is 24% (20). If whole wheat contains 2 to 3% crude fiber, then one-third to one-half of the crude fiber is located in the beeswing and, thus, its removal contributes substantially to fiber reduction in pearled wheats.

Ash reduction in pearled wheat was considerably less than for roller mill flours of similar extraction. Since some 60% of the total ash of the wheat kernel resides in the aleurone (20), this is evidence of substantial retention of aleurone tissue in the pearled wheats.

Reduction in lysine content from whole wheat to 75% extraction flour (roller mill) averages about 29% (2.60 g down to 1.94 g lysine per 16 g N) (21). At comparable yield, lysine reduction in pearled wheat was only about 10%. Again, this reflects retention of germ and bran tissue at certain locations in the pearled wheat.

The compositions of abraded brans (Table II) indicate that they have substantial nutritional value. Whereas the protein of the bran from roller milling is only partially digestible by monogastric animals (Table III) (13), the protein of brans produced by abrasive action in the CeCoCo mill showed higher *in vitro* protein digestibilities; these are high even after taking into account the higher starchy endosperm content of abraded brans. Saunders *et al.* (22) showed that low protein digestibility in roller-milled brans is, in part, owing to a physical

barrier, the intact aleurone cell wall which prevents access to the aleurone cell contents by the digestive enzymes. Microscopic examination of pearled wheat showed that from the cross cells inward, the abrasive action was progressive, cutting-up and, generally, disrupting the cellular structure of successive layers. This, then, probably explains the high *in vitro* protein digestibilities of the abraded brans.

The presence of considerable starchy endosperm in the abraded brans, the high protein digestibilities, the substantial content of nutrients, and the floury (small particle size) nature of the brans suggest usefulness in food formulations. The quality of the brans might be enhanced if the beeswing were removed before pearling. This can be accomplished, in large part, in mills such as the McGill or Engelberg (9).

To demonstrate this, 1000 g of Gaines wheat was dampened with 70 ml water, allowed to temper 10 min, and peeled 30 sec in a McGill No. 3 mill with minimum pressure. Beeswing was separated and the wheat remilled an additional 30 sec in the McGill. The beeswing was removed, mostly as large splinter-like pieces. The beeswing was moist, but not wet, and it could be separated from the wheat with gentle aspiration. Examination of the peeled wheat under magnification showed that the rootlet of the embryo was generally broken off, and that the crease was filled with debris from the rubbing action in the McGill. The debris in the crease could not be removed by passing the peeled wheat through a Carter dockage tester. About 88% of the kernels had, essentially, 90+% of beeswing removed (except in the crease). The quantity of beeswing recovered from the two millings was 25.5 g (dry basis), or a yield of 2.9%. Crude fiber concentrations (dry basis) were: original wheat, 3.0%; McGill peeled wheat, 2.0%; and beeswing, 24.3%. Possibly, the crude fiber might be reduced slightly more if the debris in the crease were removed.

In conclusion, pearled wheats were produced with a cooking tenderness (Fig. 2) which approached that of rice. Cooking with an excess of water was preferred because it minimized grain stickiness. However, this had the disadvantage of a 4 to 5% loss of solids in the cooking water.

In general, before wheat can be consumed, it must be processed and cooked. Many of the available processes and cooking methods are quite complex and do not readily lend themselves to small village operations. Abrasive pearling can be carried out easily on a small scale and the pearled wheat product lends itself to the easiest of cooking methods, boiling in water. In addition, the bran products obtained in the pearling process may have direct application as food material, for example, in a whole wheat-type chapatti. Such a total food-use system for wheat would require appropriate wheat cleaning equipment. Additionally, the palatability of the bran fractions would probably be substantially enhanced if a pre-pearling or scouring operation to remove beeswing were incorporated in the overall process.

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