Milling Process to Produce Low-Fat Grits from Pearl Millet[1]

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ABSTRACT

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A simple milling system using roller mills was developed for producing low-fat grits from pearl millet. Average yield of grits was 61% with a fat content of 1.20%. The system involved decorticating the grain, tempering to 22% moisture, and single-pass milling on finely corrugated rolls. The germ was more easily separated from the grain when the tempering moisture was increased. Short tempering time gave better separation of germ from endosperm and, thus, better yield of low-fat grits. Tempering was not beneficial in producing grits or flours of fine particle size.

Pearl millet (*Pennisetum americanum* (L.) Leeke) is the staple food for millions of people in Africa and Asia. It is a nutritious grain with a protein efficiency ratio higher than that reported for wheat and sorghum (Oke 1977, Pushpamma et al 1972, Rao et al 1964). It has a higher protein content than do other cereals grown under similar conditions (Hoseney et al 1981), and a fat content up to 8% (Lai and Varriano-Marston 1980b, Rooney 1978).

Despite those facts, the use of pearl millet is limited to traditional foods (Deyoe and Robinson 1979, Vogel and Graham 1979). Traditional milling is time consuming and often affects the end-use performance of the meal (Hoseney and Varriano-Marston 1980). A milling process is needed that will produce more uniform products and flours that can be stored. The quality of pearl millet quickly deteriorates after it has been ground into meal; hydrolytic and oxidative changes occur in lipids during storage (Carnovale and Quaglia 1973, Lai and Varriano-Marston 1980a). As with flours of other cereals, low-grade pearl millet flours give more rapid and pronounced changes than do refined flours.

Very little has been reported on the dry milling of pearl millet (Badi and Hoseney 1976, Crabtree and Dendy 1979, DeMan et al 1973, Reichert and Youngs 1977). Hoseney et al (1981) and Hulse et al (1980) thoroughly reviewed the methods commonly used. The purpose of milling is to make the most complete separation possible of endosperm, bran, and germ, and to reduce the particle size of the endosperm to produce flour. In wheat milling, both the separation and reduction of the endosperm can be done simultaneously. Tempering the grain toughens the bran, causes the germ to swell and pull away, and increases the friability of the endosperm (Bradbury et al 1960). Pearl millet has a small kernel with a firmly embedded germ and a very hard endosperm, which makes the grain difficult to mill.

We studied the response of pearl millet to various tempering conditions and milling processes and describe a milling process for producing low-fat grits from pearl millet.

MATERIALS AND METHODS

Pearl millet (HMP550), grown in Kansas in 1979, was used. The grain was scoured lightly with an experimental scourer to remove dust on the grain surface without affecting the pericarp. The light debris was removed with a model FC9 Kice aspirator (Kice, Metal Products Co., Wichita, KS), and samples were decorticated with a SATAKE decorticator.

Tempering Conditions

The effects of tempering conditions were studied by using whole grain (undecorticated) pearl millet samples. Samples with initial moisture contents of 9.55% were tempered to different moisture levels (16, 18, 20%) and held for 6, 12, and 18 hr. The nine samples were passed through the milling system shown in Fig. 1. The effects of high moisture content (22%) and short tempering time (1 and 3 hr) were also studied, using the same flow. The fractions obtained were analyzed for moisture and fat (AOAC 1975).

Decortication

Decorticated (12% removed) and whole grain were used to study the effect of decortication on the milling characteristics of pearl millet. Samples were milled by two different systems, with each sample tempered to 20% moisture content and held for 6 hr before milling.

In one system, milling was done by passing the sample only once through a pair of corrugated rolls (22 corrugation; 0.015-in. roll gap). The milled product was then sifted for 3 min into three fractions (+16 w, +20 w, and −20 w), using a Ro-Tap sifter (+ = overs, − = throughs, w = wire).

In the other system, milling was done according to the flow shown in Fig. 1. That milling system was longer than the previous one and included three breaks. Fractions obtained from all samples were analyzed for moisture and fat (AOAC 1975).

Roll Differential and Corrugation

Decorticated pearl millet samples (12% removed) with initial

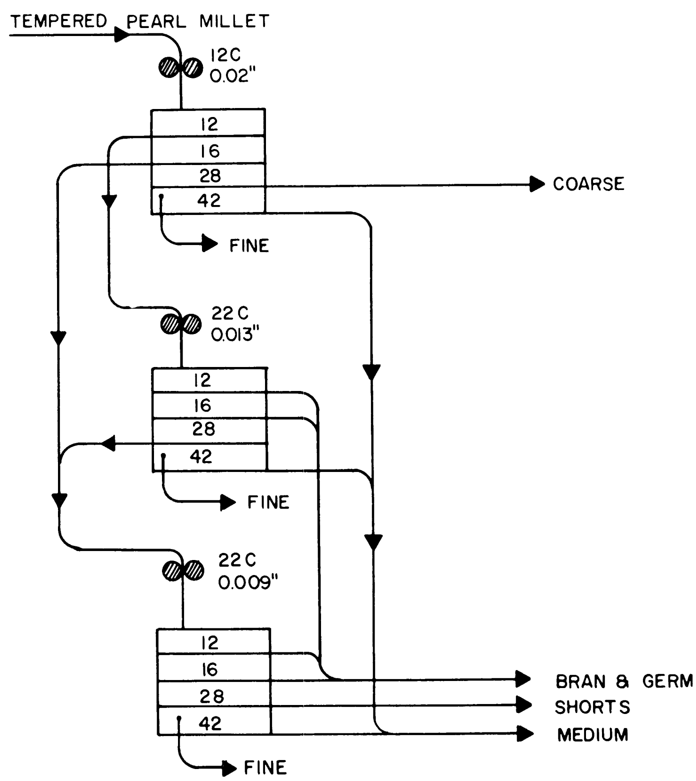

Fig. 1. Milling flow for pearl millet.

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moisture content of 13.8% were tempered to 22% and held for 6 hr. The samples were passed through corrugated rolls (12 corrugation; 6×6 in.), with roll speeds adjusted to give three differentials: 1:1.30, 1:2.62, and 1:4.24. The products were sifted (Ro-Tap) into six fractions.

Decorticated pearl millet samples (12% removed) with initial moisture content of 9.60% were tempered to 22% moisture. The samples were passed through three types of rolls: smooth, 12 corrugation, and 22 corrugation. The milled products were sifted into three fractions that were analyzed for moisture and fat (AOAC 1975).

RESULTS AND DISCUSSION

Effect of Tempering

The effect of different tempering conditions on the behavior of pearl millet during milling was studied by comparing the total yield and fat content of each fraction produced by each set of tempering conditions (Table I). Increasing the moisture content of the grain or the tempering time did not affect the yield of fine and medium grits (Table I). The germ and coarse grits were the only two fractions affected by moisture and tempering time. Increasing the moisture content of the grain increased the amount of germ recovered and consequently increased the amount of fat separated in that germ for all three tempering times used. The increase in germ produced was balanced by a decrease in coarse grits. As the moisture increased, grits with lower fat were produced. Therefore, the increase in tempering moisture helped to separate the germ from the endosperm.

At a constant moisture level, and as the tempering time increased, the amount of germ produced decreased (Table I). Under the same conditions, the yield and fat content of the coarse grits increased. Those results suggest that water penetrates the endosperm during long tempering times, and leaves the pericarp and germ relatively dry. Thus, during milling, the germ and pericarp break into small pieces that contaminate the grits.

Those results showed that tempering to high moisture for a short time produced grits with low fat and encouraged us to study shorter tempering times and higher moisture levels. Tempering the grain to 22% moisture gave no significant differences in yield or fat content for tempering times of 1, 3, and 6 hr.

The results reported in Table I also indicated that tempering conditions up to 20% moisture did not affect the softness of the endosperm (soft endosperm would be expected to give finer particle size). The amount of medium and fine grits produced under the different tempering conditions did not change significantly.

TABLE I
Effect of Tempering Conditions on Milling of Pearl Millet

Mill Fraction	Temper Time 6 hr Moisture (%) 16	18	20	12 hr Moisture (%) 16	18	20	18 hr Moisture (%) 16	18	20
					Yield (%)				
Germ	11.07	15.93	20.68	8.47	10.95	19.24	5.10	10.88	17.87
Bran	12.08	12.20	11.86	12.20	12.72	12.37	11.56	12.93	12.37
Coarse grits	32.22	28.47	25.76	34.58	30.39	26.21	39.46	32.31	27.49
Medium grits	28.19	27.80	26.78	27.80	28.98	26.81	27.55	27.55	26.80
Fine grits	16.44	15.60	14.92	16.95	16.96	15.46	16.33	16.33	15.47
					Fat[a]				
Germ	31.62	42.16	50.73	26.22	···	47.35	15.76	32.95	47.53
Bran	21.40	19.32	17.41	22.43	···	17.62	25.16	23.19	17.63
Coarse grits	19.02	15.41	13.47	20.74	···	14.88	23.78	17.38	14.62
Medium grits	18.25	15.61	12.39	20.44	···	14.18	23.56	18.67	13.75
Fine grits	9.71	7.50	6.00	10.17	···	5.97	11.74	7.81	6.47

[a]Expressed as percent of total fat.

TABLE II
Effect of High-Moisture Tempering on the Softness[a] of Pearl Millet Endosperm

Mesh	Moisture (%) 22	35
+28	8.04	9.55
+42	66.33	54.27
+60	13.57	18.59
+100	9.55	12.06
−100	2.51	5.53

[a]Expressed as finer particle size when ground under standard conditions.

High-Moisture Tempering

In wet milling, soaking the grain in water makes it soft and easy to grind (Watson 1967). In dry milling, tempering to high moisture is usually impractical. Because tempering up to 22% moisture had no effect on softness of the endosperm, high-moisture tempering was studied. Pearl millet grits (−20 +28 mesh) were tempered to 35% moisture and milled on corrugated rolls (22 corrugation; 0.08 in. roll gap). The product was air-dried at room temperature and sifted (Ro-Tap) into five fractions. The results (Table II) showed that a shift toward fine material with 35% moisture temper. This indicates that very high moisture levels are required for softening the endosperm. Grits tempered above 35% moisture stick together and do not flow through the feed rolls.

Effect of Decortication

Although high moisture and short tempering time helped to separate the bran and germ from the endosperm, the grits produced were still relatively high in fat content. Decortication was studied in an attempt to reduce the fat content of grits.

When pearl millet samples were milled with a three-break system (Fig. 1), no differences in yield of total grits and their fat contents were observed between decorticated and whole grain samples (Table III). However, when milling was with a single pass through corrugated rolls, high yields of low-fat grits were produced from decorticated grain (Table III). Small fractions with high fat content (germ) were separated over a 16-wire sieve, indicating that removal of the pericarp by decortication prevents contamination of grits with pieces of the pericarp and helps to separate the germ.

With the three-break system, the low-fat grits obtained from the first break from decorticated grain became contaminated with pieces of germ from the second and third breaks. Therefore, when the milling system included regrinding, decorticated grain had no advantage over whole grain in producing low-fat grits.

Effect of Roll Differential

In an effort to increase the yield of low-fat grits obtained with one-step grinding, we studied the effect of changing roll differential. No significant differences in particle size distribution were observed between the three differentials used (Table IV), except for the coarse material (+12 w) from the 1:1.3 differential. Rolls with the 1:1.3 differential did not grind the grain but merely broke open the kernel, producing more coarse material.

Effect of Roll Corrugation

Rolls with fine (22) corrugation produced a higher yield of grits (−20 w) than did rolls with a coarse (12) corrugation (Table V). The fat content of the grits from both rolls was similar. Smooth rolls produced a smaller amount of grits with lower fat content. They had a flaking action on the grain, which resulted in a low production of grits. Smooth rolls may be useful when high-quality (low-fat) grits are required, and when yield is not important.

TABLE III
Effect of Decortication on Yield and Fat Content of Grits

Mill Fraction	Whole Grain Yield (%)	Whole Grain Fat (%)	Decorticated Grain Yield (%)	Decorticated Grain Fat (%)
Three-Break Milling System				
Germ	20.84	11.30	13.66	17.51
Bran	7.18	9.38	14.12[a]	···
Coarse grits	31.25	2.36	46.29	1.75
Medium grits	22.91	2.66	15.75	2.60
Fine grits	17.82	2.04	10.18	2.21
Total grits	71.98	2.38	72.22	2.00
One-Break Milling System				
Bran (decorticated)	···	···	12.00[a]	···
+16 w[b] (germ)	28.94	10.6	19.13	15.63
+20 w[b]	22.86	3.8	7.92	5.30
−20 w[b] (grits)	48.2	2.2	60.95	1.20

[a] Removed during decortication.
[b] w = Wire.

TABLE IV
Effect of Roll Differential on Particle-Size Distribution During Milling of Pearl Millet

Mesh	Differential 1:1.3	1:2.62	1:4.24
12	30.30	21.11	20.20
28	53.02	58.79	59.60
42	7.58	9.55	10.10
60	3.03	4.02	3.54
100	4.54	4.02	4.04
Pan	2.53	2.51	2.52

SUMMARY AND CONCLUSIONS

A simple milling system using roller mills was developed for producing low-fat grits from pearl millet. The system involved three steps: decorticating, tempering, and milling the grain through finely corrugated rolls. An average yield of 61% grits (from whole grain) with 1.2% fat content was obtained using this system (Table III).

The results of the study showed that the tempering conditions had an effect on the quality (fat content) of grits produced. Tempering the decorticated grain to a high moisture content (22%) for a short time gave optimal yields of low-fat grits. Tempering had no effect on the softness of the endosperm. Using rolls with fine corrugations increased the yield of grits. Roll differentials of more than 1:2.5 did not affect the particle size distribution. A system including regrinding of the grain produced grits with higher fat content. Decortication was not advantageous when a multiple-pass system was used.

The system described would not be practical in small villages, where the cost of equipment would be too high. In some countries, notably Senegal and Sudan, people are moving to the cities. Traditional millet eaters are turning to other foods because they no longer have the time required to manually pound millet. At the same time, excess millet is produced that is never consumed. These conditions indicate a need for relatively large mechanical production of a stable millet grit or flour. We hope that the work described here may provide useful information for designing such a system.

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TABLE V
Effect of Roll Corrugation on Milling of Pearl Millet

Sieve Fraction	Smooth Yield[a] (%)	Smooth Fat (%)	12 Corrugation Yield[a] (%)	12 Corrugation Fat (%)	22 Corrugation Yield[a] (%)	22 Corrugation Fat (%)
+16 (germ)	37.85	10.2	31.60	10.09	21.74	15.63
+20	18.24	2.8	19.59	1.86	9.00	5.30
−20 (grits)	43.91	0.82	48.81	1.23	69.26	1.20

[a] Based on decorticated grain.

LITERATURE CITED

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1975. Official Methods of Analysis, 12th ed. The Association, Washington, DC.

BADI, S. M., and HOSENEY, R. C. 1976. Use of sorghum and pearl millet flours in cookies. Cereal Chem. 53:733.

BRADBURY, D., HUBBARD, J. E., MACMASTERS, M. M., and SENTI, F. R. 1960. Conditioning wheat for milling. A survey of the literature. Miscellaneous publication 824. USDA, Washington, DC.

CARNOVALE, E., and QUAGLIA, G. B. 1973. Influence of temperature and humidity controlled preservation on the chemical composition of milling products from millet. Ann. Technol. Agric. 22:371.

CRABTREE, J., and DENDY, D. A. V. 1979. Co-milling of four species of millet with wheat to produce composite flours. Cereal Foods World 24:103.

deMAN, J. M., BANIGO, E. O. I., RASPER, V., and GADE, H. 1973. Dehulling of sorghum and millet with the palyi compact milling systems. Can. Inst. Food Sci. Technol. J. 6:188.

DEYOE, C. W., and ROBINSON, R. J. 1979. Sorghum and pearl millet foods. Page 217 in: Tropical Foods, Vol. I. G. Inglett, ed. Academic Press, New York.

HOSENEY, R. C., and VARRIANO-MARSTON, E. 1980. Pearl millet: Its chemistry and utilization. Page 461 in: Cereals for Food Beverages. G. Inglett and L. Munch, eds. Academic Press, New York.

HOSENEY, R. C., VARRIANO-MARSTON, E., and DENDY, D. A. V. 1981. Sorghum and millets. Page 71 in: Advances in Cereal Science and Technology, Vol. IV. Y. Pomeranz, ed. Am. Assoc. Cereal Chem., St. Paul, MN.

HULSE, J. H., LAING, E. M., and PEARSON, D. E. 1980. Sorghum and Millets: Their Composition and Nutritive Value. Academic Press, New York.

LAI, C. C., and VARRIANO-MARSTON, E. 1980a. Changes in pearl millet during storage. Cereal Chem. 57:275.

LAI, C. C., and VARRIANO-MARSTON, E. 1980b. Lipid content and fatty acid composition of free and bound lipids in pearl millets. Cereal Chem. 57:271.

OKE, O. L. 1977. The potential of millet and sorghum as food in Nigeria. Page 121 in: Proc. Symp. Sorghum and Millets for Human Food. D. A. V. Dendy, ed. Tropical Products Institute, London.

PUSHPAMMA, S., PARRISH, D. B., and DEYOE, C. W. 1972. Improving protein quality of millet, sorghum, and maize diets by supplementation. Nutr. Rep. Int. 5:93.

RAO, S. V., SWAMINATHAN, M., and PARPIA, H. A. B. 1964. Mutual supplementation of dietary proteins for meeting protein needs and overcoming protein shortages in developing countries. J. Nutr. Diet. 1:128.

REICHERT, R. D., and YOUNGS, C. G. 1977. Dehulling cereal grains and grain legumes for developing countries. II. Chemical composition of mechanically and traditionally dehulled sorghum and millet. Cereal Chem. 54:174.

ROONEY, L. W. 1978. Sorghum and pearl millet lipids. Cereal Chem. 55:584.

VOGEL, S., and GRAHAM, M. 1979. Sorghum and millets: Food production and use. International Development Research Center, Ottawa, Canada.

WATSON, S. A. 1967. Manufacture of corn and milo starches. Page 22 in: Starch Chemistry and Technology. R. L. Whistler and E. F. Paschall, eds. Academic Press, New York.

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