Rheological Properties and Food Applications of Proso Millet Flours

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ABSTRACT

Rheological properties and possible food applications of flours milled from proso millets (*Panicum miliaceum*) are discussed. Farinograph absorptions, arrival times, and peak times decreased and the mixing tolerance index increased as the amount of millet flour in the wheat-millet flour blend increased. Amylograph curves indicated a very low α-amylase activity in each of the proso millet flours. Specific volumes of breads decreased as the level of millet flour in the formulation increased. Up to a replacement level of 15%, the breads were considered quite acceptable compared with a white bread control. Cookie spread factors increased and cookie top grain scores improved with increasing amounts of millet flour in the formulation, presumably because of the high fat content of the proso millet flours. The millet flours imparted a slight grittiness, however, which was objectionable. Noodles of very acceptable quality were prepared with 20% proso millet flour in the blend. High levels of millet flour (40% or higher) in the formulation caused the noodles to be gritty, because of the high ash content of the proso millet flours.

In the United States, millets are used as emergency hay or catch crops. The grain is incorporated to a limited extent into feeds and birdseeds. Very little presently is used directly as human food (Hinze 1972, Schery 1963).

Millet is consumed mostly in northern China, India, Africa, and southern Russia, where about 85% of the crop is consumed directly as human food. A porridge of millet is made in eastern Europe, and a gruel in countries of Asia and Africa (Schery 1963). The rather strong taste, however, is not generally preferred by persons with access to blander grains. Millets have been used in the malt industry in India, and in fermented beverages in eastern Europe and Africa.

Leavened bread cannot be made from 100% millet flours because millets do not have gluten-forming proteins. Flours of 100% millet produce rather compact breads with a dense texture, so they must be baked into flat breads, as is done in eastern Europe and Africa (Schery 1963). Awadalla (1974) baked leavened breads from blends of wheat flour and millet flour (*Pennisetum typhoideum*), using a very lean formulation that included only flour, salt, yeast, and enough water to make a dough of proper consistency. Replacement of 20% of the wheat flour with millet flour caused a decrease in bread volume, darker crumb color, a more open grain, and a slightly coarse texture. Adding 3% fat or 0.5% calcium stearoyl-2-lactylate to the dough improved bread quality significantly. Badi et al (1976) and Crabtree and Dendy (1979) produced breads of optimum quality with 10% millet flour. Thiam and Ndoye (1977) successfully replaced up to 30% wheat flour with millet flour (*Setaria italica*).

Biscuits formulated with millet flours and a small percentage of wheat flour (10%) had acceptable consumer responses in Niger (DeRuiter 1972).

Cookies have been prepared from flours of *Eleusine coracana* in India. Millet flours (*P. typhoideum*) alone, however, do not produce acceptable cookies by U.S. standards. The cookies do not spread; they have poor top grain characteristics and are tough, hard, gritty, and mealy in texture and taste (Badi and Hoseney 1976). Soybean lecithin added at 0.6% to millet flours greatly improved top grain and cookie spread, but these cookies still did not show the quality of cookies made with wheat flour. Cookies made from blends of wheat flour and pearl millet flour were more fragile than were wheat flour cookies. No baking conditions were found to improve the fragility.

Most previous reports have discussed the use of *P. typhoideum*, *S. italica*, and *E. coracana* in food products, but very little work has been done with proso millets (*Panicum miliaceum*). In this study, the rheological properties and possible food applications of proso millet flours are discussed.

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MATERIALS AND METHODS

Sample Identification

Two varieties of proso millets (*P. miliaceum*), Cope and Turghai, and a wheat sample, Chris, were used for bread baking in this study. Turghai is a standard red proso variety and Cope a new white-seeded proso millet. The grains were milled individually in a Quadrumat Jr. mill. The wheat sample was tempered to 12% moisture; the millet samples were milled without prior conditioning. Wheat flour was extracted to 73.4%, millet (Cope) to 87.3%, and millet (Turghai) to 78.4%. Milling characteristics of the grains and proximate compositions of the flours were reported previously (Lorenz et al 1980). A sample of the millet cultivar Cope, without dehulling, was also heated for 1 hr at 80°C before being milled in an attempt to improve the baking performance of the flour. For cookie baking and noodle preparation, a medium-spread cookie flour and a durum flour were obtained from a local flour mill.

Rheological Properties

Farinograph curves of blends of wheat flour and millet flours provided information about changes in absorption, mixing time, and mixing tolerance due to replacement of the wheat flour with 5, 10, 15, and 20% millet flours.

Amylograph viscosities in Brabender Units (BU) of blends of wheat flour and millet flours were determined. Reference viscosities recorded were: peak viscosity, viscosities at 92°C and after 30 min at 92°C, viscosities when cooled to 35°C and after 60 min at 35°C.

Baking Experiments

Breads. Pup loaves were baked by the straight dough procedure from the four blends of wheat and millet flours. The bread formulation was: 100% wheat flour or blend of wheat flour and millet flours, 4% sugar, 3% shortening, 2.5% yeast, 2% salt, 0.5% yeast food, 0.3% calcium propionate, and 10 ppm potassium bromate. Another series was baked with the addition of 0.5% sodium stearoyl-2-lactylate (SSL). Fermentation time was 1.5 hr at 30°C and 85% RH. The loaves were scaled at 200 g each. They were mechanically molded, proofed to height at 35°C and 95% RH, and baked at 208°C for 18 min. Specific loaf volume was measured by rapeseed displacement. To score the breads, a maximum number of points was given to each bread characteristic: crust color, 7: symmetry, 7: break and shred, 6; crumb color, 10; volume, 15; flavor, 15; grain, 20; and texture, 20.

Bread crumb color was also measured with a Hunter color difference meter. The standard was L = 94.65, a = −0.6, and b = 0.1.

Cookies. Cookies were baked from four blends of cookie flour and millet flours with and without addition of 2% soy lecithin, using the AACC (1969) cookie spread factor test (method 10-50D). Millet flours replaced 5, 10, 20, and 30% of the cookie flour. Top grain characteristics of the cookies were scored and crust color was measured using the Hunter color difference meter. Cookie spread factors were determined. The quality of the cookies was evaluated by a panel, as described by Badi and Hoseney (1976).

TABLE I
Farinograph Data of Wheat Flour-Millet Flour Blends (Chris Wheat and Cope Millet)

Millet Flour in Blend (%)	Absorption (%)	Peak Time (min)	Stability (min)	Tolerance Index (BU)
0	67.0	5.7	5.25	45
5	65.4	2.0	6.50	48
10	63.2	1.8	6.50	60
15	62.0	1.7	5.70	65
20	61.5	1.8	5.25	65

TABLE II
Amylograph Peak Viscosities of Blends of Wheat and Millet Flours (Chris Wheat and Cope Millet)

Blend Composition		Peak Viscosity (BU)	Temperature of Initial Gelatinization at 20 BU (°C)
Wheat Flour (%)	Millet Flour (%)		
100	0	740	58.5
95	5	710	59.25
90	10	800	60.0
85	15	1360	60.0
80	20	1450	60.75
0	100	2500+	72.75

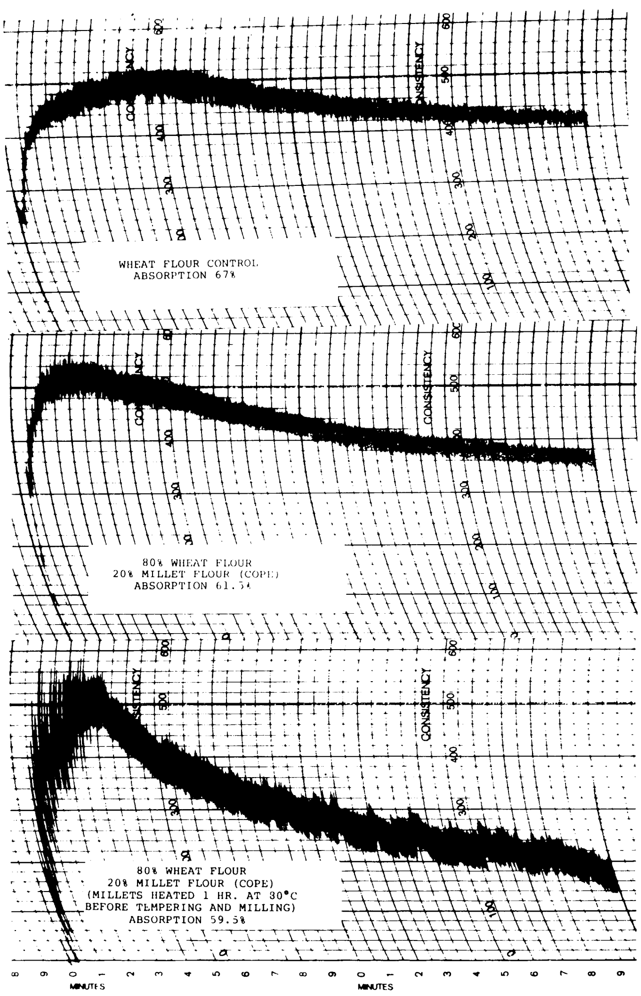

Fig. 1. Farinograph curves of wheat flour and wheat flour/millet flour (80:20) blends.

Preparation and Evaluation of Noodles

Noodles were prepared with a Biondi (Italy) pasta press. A durum flour (12.9% protein, 0.65% ash) was used as a control. The millet flours replaced 20, 40, and 60% of the durum flour in subsequent batches. The noodle formulation consisted of 500 g of flour or flour blend, 10 g of salt, and enough water to make a firm dough (approximately 55% absorption). The doughs were mixed for 2 min and then formed into noodles with the pasta press. The noodles were placed on racks, allowed to dry at room temperature, and stored in plastic bags until quality tests were performed. The flavor and firmness of the noodles were evaluated by a panel after cooking times of 10, 20, and 30 min. Each sample was coded randomly and identified to the panel by marking the code on the section of the plate containing the sample.

The cooked weight and cooking loss were determined after cooking times of 10, 15, 25, and 30 min. Forty grams of noodles were cooked in 600 ml of water. The noodles were then drained for 2 min and the drained weight of the noodles recorded. Cooking loss was determined by centrifuging the cooking water at 3,000 RPM for 20 min, pouring off the supernatant, and weighing the residue

The color of the uncooked ground noodles was also measured with the Hunter color difference meter as described above. Grinding of the dry noodles into a flour was necessary to obtain a correct color measurement with the Hunter color difference meter. The L value of the millet flour was 78.8 and that of the durum flour 68.4.

RESULTS AND DISCUSSION

Rheological Properties of Wheat-Millet Flour Blends

Farinograph data of blends of wheat flour and millet flour (Cope) are presented in Table I. Absorption decreased as the amount of millet flour in the blend increased. Arrival times and peak times decreased significantly with only 5% millet flour in the blend. The mixing tolerance index increased with increasing levels of millet flour. These changes in farinograph characteristics were also observed with millet flour milled from the cultivar Turghai. The trends indicate that dough mixing becomes quite critical at higher substitution levels.

The effects on farinograph characteristics of heating the millets before milling is illustrated in Fig. 1. Comparison of the 80:20 wheat/millet flour blends shows that dough stability, departure time, and mixing tolerance are greatly reduced by heating the millets before milling. The absorption was also lower. The dough had greater initial mobility, indicated by the width of the band. Overall, mixing became very critical.

Amylograph peak viscosities of the wheat and millet (Cope) flours and of blends of the two are given in Table II. The amylograph peak viscosity of 100% millet flour was extremely high. As the percentage of millet flour in the blend increased, peak viscosity and viscosity at each reference point increased. The initial temperature of gelatinization, determined at 20 BU, also increased slightly with replacement of wheat flours by millet flours. Millet flour milled from the proso cultivar Turghai showed very similar results, which indicates that the proso millet varieties in this study have very low α-amylase activity. Badi et al (1976) reported very high α-amylase activity in flour from pearl millet.

The relatively low peak viscosity of the wheat flour (740 BU) indicates that the wheat (Chris) from which it was milled had sprouted, although no signs of sprouting were visible.

Bread-Baking Results

Bread-baking data of wheat and millet flour blends are presented in Table III. Baking absorption and optimum mixing times decreased with increasing amounts of millet flour in the formulation, as indicated by the farinograph curves. The specific volumes of the breads decreased due to the replacement of millet flour for wheat flour. The breads are shown in Fig.2.

Cookie-Baking Results

Cookies baked with a medium-spread cookie flour and various levels of millet flours, with and without soy lecithin, are shown in Fig. 3. Cookie spread factors, top grain scores, color differences,

TABLE III
Bread Baking Data of Blends of Wheat Flour and Millet Flour (Cope)

Blend Composition		Baking	Mixing	Proof	Bread	Total	Bread[b]	Hunter
Wheat (%)	Millet (%)	Absorption (%)	Time (min)	Time (min)	Spec. Volume (cc/g)	Score[a] (100 pts. of max.)	Crumb	Crumb Color (L)
100	0	73.0	5.5	46	4.60	86	S	77.8
95	5	72.7	5.25	47	4.41	87	S	77.1
90	10	72.4	5.25	47	4.20	84	S	75.9
85	15	71.2	5.0	48	4.20	81	S	73.8
80	20	70.0	5.0	48	4.16	79	S-Q	72.7
100	0 + 0.5% SSL[c]	73.0	5.5	50	4.73	91	S	78.8
95	5 + 0.5% SSL	72.7	5.25	48	4.59	90	S	77.9
90	10 + 0.5% SSL	72.4	5.25	51	4.40	86	S	75.0
85	15 + 0.5% SSL	71.2	5.0	51	4.27	81	S	74.9
80	20 + 0.5% SSL	70.0	5.0	52	4.21	80	S-Q	72.8

[a]Scored on crust color, symmetry, break and shred, crumb color, volume, flavor, grain, and texture.
[b]S = satisfacotry, Q = questionable.
[c]SSL = sodium stearoyl-2-lactylate.

TABLE IV
Millet Flour (Cope) in Cookies

	Percent in Blend				
	0	5	10	20	30
Without Lecithin					
Cookie spread (W/T)[a]	5.11	5.27	6.44	6.50	6.61
Grain score (9 pts. max.)	3	4	8	9	9
Top color (L)[b]	75.5	75.9	72.4	68.7	69.3
(ΔE)[c]	25.2	25.3	28.2	30.8	30.3
Appearance[d]	3.0	3.25	3.5	3.5	3.0
Taste[d]	3.75	3.75	4.0	4.25	3.5
Texture[d]	4.25	3.75	3.75	4.0	3.0
Grittiness[e]	1.25	2.25	2.0	2.25	2.5
With 2% lecithin					
Cookie spread (W/T)[a]	6.88	7.07	7.31	7.49	7.67
Grain score (9 pts. max.)	6	8	9	9	9
Top color (L)[b]	69.6	69.0	70.8	68.6	66.0
(ΔE)[c]	30.1	30.6	30.4	30.6	32.3
Appearance[d]	4.0	3.75	3.75	3.75	3.5
Taste[d]	3.5	3.0	3.25	3.0	3.25
Texture[d]	3.75	3.25	3.5	3.25	3.0
Grittiness[e]	1.25	2.5	2.5	2.5	2.75

[a]W/T = width/thickness ratio.
[b]L = value from Hunter color difference meter.
[c]ΔE = total color difference = $\sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$
[d]Scale for judging appearance, taste, texture: 1 = poor, 5 = excellent.
[e]Scale for grittiness: 1 = not gritty, 5 = very gritty.

and sensory evaluation data are presented in Table IV.

Cookie spread factors increased and top grain scores improved with increasing amounts of millet flour in the formulation, presumably due to the high fat content of the proso millet flours (Lorenz et al 1980). This is contrary to the findings of Badi and Hoseney (1976), who reported decreased cookie spreads with increasing levels of millet flour but who did not provide a proximate analysis of the millet flour for comparison. At a 10% or greater wheat flour substitution level, the top grain characteristics of the cookies were very satisfactory. The color of the cookies became darker, however, with increasing levels of millet flour, as indicated by lower Hunter L values and higher total color difference values.

Cookie spread values and top grain scores were even higher for formulations with soy lecithin, which, however, also caused a slightly darker cookie color.

The sensory panel rated the appearance, taste, and texture of the cookies as very satisfactory. The sensory characteristics improved with higher levels of the millet flours in the formulation. Differences in these characteristics due to lecithin were insignificant. The grittiness of the cookies, even at only 5% millet flour in the formulation, was objectionable, however. This is because the ash content of the millet flours is high and was also mentioned by Badi and Hoseney (1976).

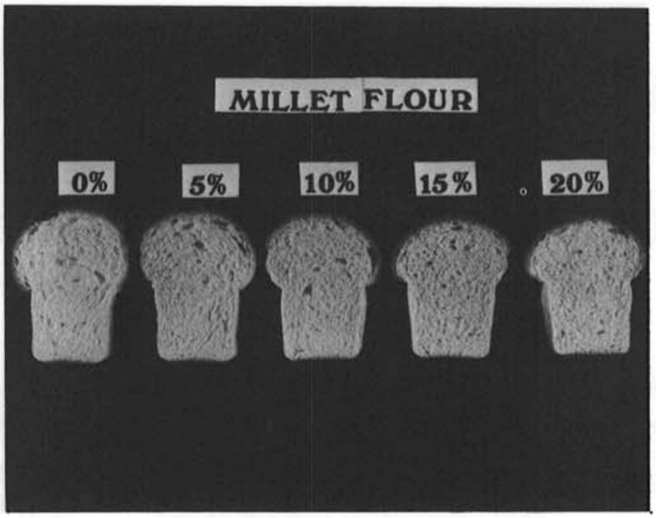

Fig. 2. Breads containing various levels of millet flour (Cope).

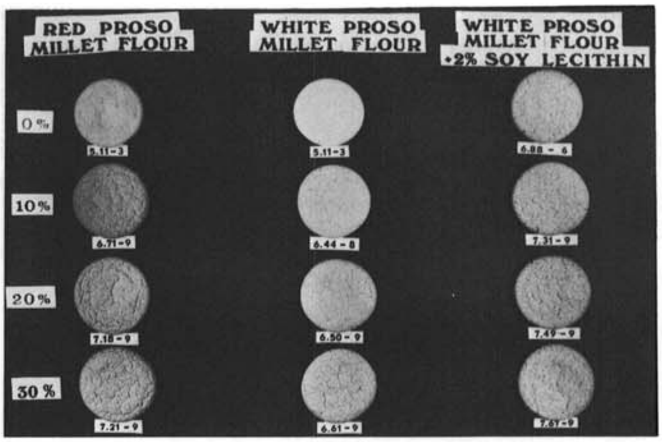

Fig. 3. Cookies containing various percentages of red proso (Turghai) and white proso (Cope) millet flours, with and without 2% soy lecithin. Cookie spread factor and top grain score are shown under each cookie.

Noodles

The quality characteristics of noodles prepared with increasing

TABLE V
Millet Flour in Noodles (DurumWheat and Cope Millet Flours)

Blend Composition		Color of Dry Noodles					Panel Evaluation	
Durum (%)	Millet (%)	L[a]	ΔE[b]	Cooking Time (min)	Cooked Weight (% weight grain)	Cooking Loss (% of cooked weight)	Texture[c]	Flavor[d]
100	0	79.0	22.3	10	112.2	12.1	5.4	1.9
		···	···	15	134.2	12.6	5.4	1.9
		···	···	25	156.8	11.9	4.8	2.0
		···	···	30	166.8	12.3	4.6	1.5
80	20	79.9	20.7	10	118.8	12.0	6.1	3.1
		···	···	15	136.8	12.1	4.7	2.9
		···	···	25	160.1	11.6	4.5	2.8
		···	···	30	169.4	12.3	4.1	2.5
60	40	79.9	20.6	10	121.7	14.6	5.0	3.7
		···	···	15	133.7	16.3	4.6	3.3
		···	···	25	156.7	18.1	4.4	3.3
		···	···	30	169.7	18.9	4.4	3.9
40	60	79.8	19.8	10	126.1	20.6	3.7	4.7
		···	···	15	137.9	24.5	3.9	4.3
		···	···	25	161.4	25.8	3.9	4.3
		···	···	30	168.2	25.1	3.9	4.6

[a]L = value from Hunter color difference meter.
[b]ΔE = total color difference.
[c]Texture (firmness) key: 1 = mushy, 2-3 = soft, 4 = slightly soft, 5 = preferred firmness, 6-7 = slightly firm, 8-9 = too firm, 10 = tough.
[d]Flavor key: 1 = like, 2 = like slightly, 3 = undecided, 4 = dislike slightly, 5 = dislike.

amounts of proso millet flour in the formulation are given in Table V. The maximum possible replacement level appeared to be 60% proso millet flour. At higher levels, proper extrusion of noodles with the pasta press became rather difficult.

The proso millet flour caused only a slight change in the color of the noodles. Noodles made with 20% millet flour had slightly higher cooked weights than the control noodles at comparable cooking times; the weights did not change at the 40 and 60% wheat flour substitution levels. Cooking losses for the control noodles and for those prepared with 20% millet flour were approximately the same. Cooking losses increased, however, with 40 or 60% millet flour in the formulation and with longer cooking time.

Texture and flavor scores of the control noodles and of noodles with 20% millet flour improved with longer cooking times. At a substitution level of 40% or higher, the flavor of the noodles was considered less desirable and the noodles were gritty. A 10-min cooking time was even too long for optimum firmness with 60% millet flour in the formulation.

The sensory evaluations indicated that the noodles made with up to 20% proso millet flour are quite acceptable.

Volume reductions in bread made with proso millet flours have been reported by Crabtree and Dendy (1979), Awadalla (1974), and Badi et al (1976) when 20% millet flour (*P. typhoideum*) was used in the flour blend. At substitution levels of up to 10% in a lean formulation, bread volume improved slightly due to the high α-amylase activity in the millet flour (Badi et al 1976).

The grain of the breads in this study was satisfactory up to a 15% substitution level. Crumb color became darker with increasing amounts of millet flour in the formulation, as indicated by lower Hunter L values. Proof times increased very slightly with the use of millet flour.

The addition of 0.5% SSL to the formulation produced a very slight volume increase, which is mainly responsible for the slightly higher total scores of these breads. The relatively high fat content of millet flour probably also improved bread volume. Badi et al (1976) reported no volume increases in their baking studies with pearl millet flour.

The aroma of the breads baked with millet flour was very pleasant. The taste was described as nutty. At the 20% substitution level, a slight objectionable grittiness was detected. The high ash content of millet flour causes the grittiness (Lorenz et al 1980).

Flour milled from the red proso variety Turghai performed in the same manner as did flour from the white-seeded variety Cope.

Heating the millets before milling had absolutely no advantageous effect on the baking performance of the flour, a result expected from the farinograph curve shown in Fig. 1. Overall, bread volumes were lower, the grain of the breads more open, and the texture slightly harsher than that of breads baked with untreated millet flours.

The change in performance of the millet flours is possibly due to a change in protein configuration as the result of heating.

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