THE IMPORTANCE OF FLOUR PARTICLE SIZE IN COMPOSITE FLOUR BREAD

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Summary
Maize and pearl millet grains were milled into flour, semolina and grits. Particle-Size Analysis were carried out for the various fractions. The various granulations and wheat flour were blended with 10% to 40% levels of replacement. Bread was baked from the different blends and the changes in freshness evaluated up to 7 days. It was established that the coarser the granulation of maize and pearl millet, the higher the volume of the bread baked from them. Freshness and shelf-life properties were also better for coarser granulations.

Introduction

The idea of the composite flour bread has been the subject of scientific investigation for a long time. The original aim of the composite flour programme initiated by the Food and Agricultural Organisation (FAO) in 1964 was to determine, through intensive research, whether it is possible to produce a wide range of acceptable, high quality, nutritious bakery, confectionary and pasta goods, from flours and starches other than wheat, that can be, or are being produced in major wheat-importing countries (FAO, 1969).

The FAO (1969) noted that since many of the non-wheat producing countries produce other cereals, such as maize, sorghum and millet in substantial quantities, it appears logical for such countries to replace, at least, in part, imported wheat flour by other flours, which are locally available and relatively less expensive.

With the current Economic Recovery Programme (ERP) underway in Ghana and the projected increase in the yields of local cereals through the introduction of better varieties and farming techniques, the FAO (1969) statement cannot be over-emphasized.

Olatunji *et al.* (1982), as well as many other authors, including the FAO (1969), maintained that with the conventional bread-making methods, only 10% of total flour was the maximum substitution possible, if significant deterioration in the resultant bread quality is to be avoided. However, with the recent assertion by Brümmer *et al.* (1988) that, in the substitution of other cereal flours in bread, the coarser the non-wheat fraction the better, this hitherto conventional belief is called into serious question. Another very important factor in the production of composite flour bread is how well the quality keeps after baking. A knowledge of how the shelf-life of bread is affected by the introduction of other cereals is therefore necessary.

With regard to the particle size of composite flours, the tendency, up till now, has been to aim for very fine flour. In its "Technical Compendium on Composite Flours" the UNECA (1985) stated that, "The first important characteristic of the flour is the particle size, which should be almost the same as that of wheat flour and should preferably be smaller than 130 μm . . ." Casier *et al.* (1977), Dendy (1988), Subramanian and Jambunathan (1988) also recommend the small size particle of the non-wheat component. Perten (1977), however, reported a higher specific volume for composite flour bread compared to that with finer flour. Brümmer *et al.* (1988) stated that for other cereals, apart from wheat and rye, coarser flours are to be preferred in bread making.

This work tries to ascertain the veracity of the statement of Brümmer *et al.* (1988) and to establish how the bread quality changes with different levels of substitution of maize and pearl millet in wheat bread. A greater attention is paid to the particle size of the maize and pearl millet additions.

Materials and Methods

Maize and Pearl Millet Grains

Maize *(Zea mays L.)* grains, yellow in colour and grown locally (in Germany) were obtained from the Lippische Hauptgenossenschaft (Detmold, Germany). The pearl millet *(Pennisetum americanum L. Leeke)* grains of tan colour were obtained from C. Hahne Mühlenwerke (Bad Oeynhausen, Germany) in the Summer of 1991. The grains were kept in paper bags and stored in a cold room at 8°C until needed.

Maize and Pearl Millet Milled Products

The milled products, namely grits, semolina and flour, used in the study here were obtained by milling the above grains to varying degrees.

Wheat Flour

The wheat flour used was obtained from the Bundesanstalt für Getreider-, Kartoffel- und Fettforschung in Detmold, Germany. It had been milled from locally grown hard summer wheat with a 78% extraction rate.

Particle Size (Sieve) Analysis

Wheat Flour

100g sample was aspirated for 5 min. through a USA Standard Testing ASTM EII - sieve with a mesh size of 75 μm on an Alpine A.G. (Augsburg, Germany) air suction sieve and the percentage retained on the sieve recorded.

Maize and Pearl Millet Fractions

100g sample was agitated for 5 min through a set of sieves of mesh openings 150μm, 250μm, 450μm, 500μm, 750μm and 1000μm fitted on a J. Engelmann portable sieve shaker and the percentages retained on different mesh sizes recorded.

Various percentages by weight of wheat flour and maize flour, as well as wheat flour and pearl millet flour were blended for 3 min. in a Gebr.-Lödige (Paderborn, Germany) laboratory flour mixer. The samples were then stored in a cold room at 8°C until needed.

Cooling and Measurements

The bread was allowed to cool at room temperature for 2 hours, bagged in polythene bags and stored in a warm cupboard at 28°C and 60-65% RH. After 24 hours, the following measurements were carried out as adopted by the Federal Centre for Cereal Research in Detmold, Germany:

(i) Loaf weight (g)

(ii) Loaf volume (cc) by seed displacement.

(iii) Loaf volume yield (LVY)

$$= \frac{\text{Loaf volume} \times 100}{\text{Flour weight}}$$

(iv) Baking value $= \frac{\text{Loaf volume} \times \text{Pore factor}}{100}$

(v) Evaluation score = Baking value +/- Crumb value.

The loaf volume factor (LVF) is related to the loaf volume yield as shown below:

LVY	300	356	389	400	430	472	520
LVF	0	56	89	100	115	136	160

i.e., for volume yields between 300 and 400. (LVY) 300 has (LVF) 0 and (LVY) 400 has (LVF) 100. Whatever that is over 400 is divided by 2 and added to 100.

The Pore Values (PV) are on a scale of 1 = very coarse pores to 8 = very fine pores and is related to the pore factor (PF) as shown below:

PV	1	2	3	4	5	6	7	8
PF	30	40	50	60	70	80	90	100

The crumb values were computed taking into account the loaf form, crumb texture, pore distribution and elasticity.

(a) Loaf Form

Description	Value
Good	0
Satisfactory	(- 5)
Somewhat flat	(-10)
Flat	(-20)

(b) Crumb Texture

Description	Value
Coarse	0
Somewhat coarse	(+10)
Somewhat soft	(+15)
Soft	(+20)
Soft Silky	(+30)
Silky	(+40)

(c) Crumb Elasticity

Description	Value
Good	0
Somewhat good	(- 5)
Satisfactory	(-30)
Questionable	(-75)
Unquestionable	(-100)

(d) Pore Distribution

Description	Value
Uniform	(+5)
Somewhat uniform	0
Not Uniform	(- 5)

(vi) Crumb and crust characteristics

These were determined by sensory evaluation on a scale of 1 = very good to 6 = very bad and repeated every other day up to 7 days.

Storage Conditions

The loaves, wrapped in polythene bags, were stored in a warm cupboard at 28°C and 60 to 65% RH for up to 7 days.

Freshness Measurements

The softness of bread was measured by means of two instruments, namely, the Panimeter and Penetrometer.

Panimeter Measurements

An I.C.F.B.; TNO (Wageningen, Netherlands) panimeter was used. Here, the behaviour of a defined part of the bread crumb during compression and relaxation was measured.

A bread slice, 3cm thick with parallel surfaces was cut. A section of the crumb, 5cm in diameter in the centre of the slice was removed with a metallic cylinder. The compressibility and relaxation were read from the curve and the elasticity number calculated according to the relation:

$$\text{Elasticity Number (EN)} = \frac{\text{Relaxation} \times 100}{\text{Compressibility}}$$

Penetrometer Measurements

A (SUR Berlin, Germany) penetrometer was used to measure the penetrability in 1/10mm of a bread crumb by a prescribed weight. A 5cm thick bread slice was cut. A stencil in which 5 equally-spaced holes has been punched was placed on the cut surface and the 5 points marked out. Care was taken so as to have all points at least 1 cm from the crust in order to reduce differences in measurements to within 30 units from each other. The measurements were made at the marked points on both sides. A prescribed weight of 223g was applied at the points for 5s and the depression (1/10mm) measured. The average of 10 readings per sample was reported.

Results and Discussions

Physical Characteristics

Maize and Pearl Millet Milled Products

As a result of the large size and relative hardness of the maize grains, it was possible to produce 3 different granulations (grits, semolina and flour) as against 2 granulations (semolina and flour) from pearl millet.

Particle Size (Sieve) Analysis

42.5% of wheat flour was retained on a 75μm mesh after being aspirated for 5min on an Alpine A.G. (Ausberg, Germany) air suction sieve (Table 1a).

Table 1b and c show the percentages of maize and pearl millet granulations retained on the different sieve mesh openings. Almost 90% of the maize grits was retained on the 1000μm sieve. While over 50% of maize flour was passed through the 250μm sieve, less than 25% of maize semolina passed through the same sieve (Table 1b).

While over 90% of the pearl millet flour passed through the 150μm sieve, the amounts of pearl millet semolina passing through the 150μm sieve, as well as being retained on the 150μm and 250μm sieves were approximately equal (Table 1c).

Dough and Bread Characteristics

Tables 2 to 4 show the dough and bread characteristics of wheat and the various composite flours. As a result of the high water absorption of maize flour, the dough yield increased

TABLE 1

Particle Size (Sieve) Analysis

(a) 42, 50% of the wheat flour was retained on a 75μm sieve after aspiration for 5 min.					
(b)	% Retained on sieve openings				
Sample	1000μm	750μm	500μm	250μm	Pass through 250 μm sieve
Maize flour	0,20	0,60	13,14	32,60	52,46
Maize semolina	0,20	6,55	23,59	47,18	22,48
Maize grits	89,11	6,25	3,02	1,01	0,61
(c)	% Retained on sieve openings				
Sample	500μm	450μm	250μm	150μm	Pass through 150 μm sieve
Pearl millet flour	0,00	0,00	0,20	8,03	91,77
Pearl millet semolina	0,00	3,40	32,83	28,83	34,94

TABLE 2

Dough and Bread Characteristics at 20% level of replacement

Characteristics	100% wheat	20% millet flour	20% millet semolina	20% maize flour	20% maize semolina	20% maize grits
Dough yield	163	162	159	166	161	161
Dough characteristics - surface	normal	normal	normal	normal	normal	normal
- elasticity	normal	somewhat short	somewhat short	somewhat short	somewhat short	normal-somewhat short
Volume yield	666	536	580	543	547	583
Grain characteristics	Soft silky	almost soft	soft	almost soft	almost soft	soft
Crumb elasticity	good	good	good	good	good	somewhat good
Taste/flavour	good/ typical	still good	still good	slightly tart	slightly tart	slightly tart

with the substitution with maize flour. Dough yields decreased as wheat was replaced with pearl millet flour. Dough elasticity changed towards "very short" at 40% replacement of wheat flour.

Bread volume decreased as the level of substitution of wheat flour increased (Table 5). Also, for both maize and pearl millet, bread volume increased as the particle size of the substitute fraction increased. This confirms the suggestion of Brümmer *et al.* (1988). The nature of the bread slice grain changed gently from "soft silky" towards "coarse" as more wheat

TABLE 3

Dough and Bread Characteristics at 30% level of replacement

Characteristics	100% wheat	30% millet flour	30% millet semolina	30% maize flour	30% maize semolina	30% maize grits
Dough yield	163	161	156	167	159	159
Dough characteristics - surface - elasticity	normal normal	normal short	normal short	somewhat dry short	normal short	somewhat moist somewhat short
Volume yield	666	512	538	470	490	521
Grain characteristics	Soft silky	somewhat coarse	almost soft	somewhat coarse	somewhat coarse	almost soft
Crumb elasticity	good	good	good	good	good	satisfactory
Taste/flavour	good/ typical	somewhat tart	somewhat tart	tart	tart	somewhat tart

TABLE 4

Dough and Bread Characteristics at 40% level of replacement

Characteristics	100% wheat	40% millet flour	40% millet semolina	40% maize flour	40% maize semolina	40% maize grits
Dough yield	163	160	154	168	158	158
Dough characteristics - surface - elasticity	normal normal	normal very short	normal very short	somewhat dry very short	normal very short	somewhat moist short
Volume yield	666	450	466	388	414	442
Grain characteristics	Soft silky	coarse	somewhat coarse	coarse	coarse	somewhat coarse
Crumb elasticity	good	good	good	good	good	satisfactory
Taste/flavour	good/ typical	tart	tart	tart/slightly bitter	tart/slightly bitter	tart

flour was replaced. Using the taste of 100% wheat flour bread as standard, tastes of the composite flour breads were judged as changing gently towards "tart" and "slightly bitter" at 40% levels of replacement.

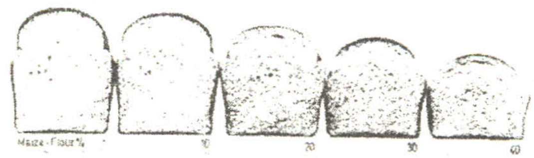
Bread Evaluation Scores

The bread evaluation scores, which takes into account volume, the nature and distribution of pores, the loaf form, crumb texture and elasticity are reported in Table 6. From these scores, bread from all blends with up to 20% levels of substitution, as well as with 30% pearl millet semolina, were judges as "very good." Based on

TABLE 5

Percentage Relative Volume to 100% Wheat Flour (670ml/100g Flour)

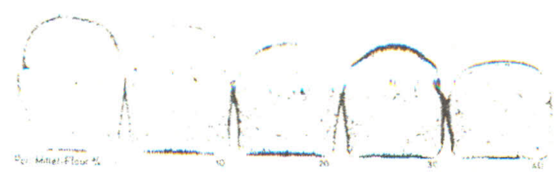
% Non-Bread Cereal	10	20	30	40
Maize Flour	88	82	71	58
Maize Semolina	90	82	74	62
Maize Grits	94	88	80	67
Pearl Millet Flour	92	81	77	68
Pearl Millet Semolina	95	87	80	70



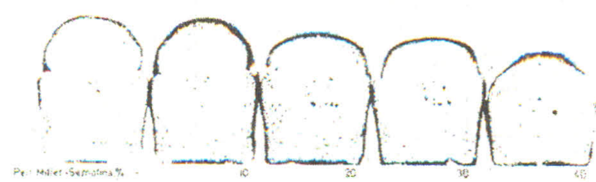
Maize - Flour, %

Maize - Semolina, %

Maize - Grits, %



Pearl Millet - Flour, %



Pearl Millet - Semolina, %

these scores, maize semolina was chosen as the best granulation for maize composite flours, while pearl millet semolina was preferred to pearl millet flour.

Freshness Evaluation - Sensory Evaluation

Using the softness as a measure of freshness, the crust and crumb characteristics were evaluated on a scale of 1 to 6. The results are reported in Tables 7 and 8. Freshness deteriorated with age as well as with replacement of wheat flour. The freshness also followed the pattern of volume depression, namely, deteriorating as the particle size of the substitute became finer. Maize composite flour breads had a particularly softer crust and this was very probably due to the higher water absorption of maize flour.

TABLE 6

Bread Evaluation Scores

Sample	Pearl Millet Flour	Pearl Millet Semolina	Maize Flour	Maize Semolina	Maize grits
% Replacement					
0%	216	216	216	216	216
10%	185	204	174	179	188
20%	141	163	143	144	143
30%	127	142	110	117	96
40%	94	110	66	79	63

Over 140 = very good; 110-140 = good; 90-109 = satisfactory; below 90 = not satisfactory.

TABLE 7
Sensory evaluation of crust and crumb characteristics of pearl millet semolina

		% Replacement				
Num. Of days old		0%	10%	20 %	30%	40%
1	Crust Crumb	1 1	1 1	1-2 1-2	2 2	2-3 2-3
3	Crust Crumb	1-2 1-2	2-3 2-3	3 3	3-4 3-4	4 4
5	Crust Crumb	2 2	3-4 3-4	4 4	4-5 4-5	5 5
7	Crust Crumb	2-3 2-3	4 4	4-5 4-5	5 5	5-6 5-6

1 = very good; 6 = very bad.

TABLE 8
Sensory evaluation of crust and crumb characteristics of maize semolina

		% Replacement				
Num. Of days old		0%	10%	20%	30%	40%
1	Crust Crumb	1 1	1 1	1-2 1-2	2-3 2-3	3 3
3	Crust Crumb	1-2 1-2	2 2	2 2-3	3 3	3-4 3-4
5	Crust Crumb	2 2	2-3 2-3	3 3	3-4 3-4	4 4
7	Crust Crumb	2-3 2-3	3-4 3	4 3-4	4-5 4	5-6 5

1 = very good; 6 = very bad.

Penetrometer Evaluation

The penetrometer readings decreased with the age of the bread and with the replacement of wheat flour. These corresponded broadly with the sensory evaluation and the loaf volume, namely, the larger the volume, the higher the penetrometer readings, implying a softer crumb.

Panimeter Evaluation

The determination of the freshness of the bread samples, using the panimeter was in some cases, very difficult. As Seibel *et al.* (1968) observed, due to the differences in softness of the bread crumbs, measurements had to be done, using different weights in order to obtain readable curves. As a result of this, the evaluation of the results was made considerably difficult.

Conclusion

In the use of cereals other than wheat and rye in bread making, the coarser fractions are to be preferred (Brümmer *et al.*, 1988). This study confirmed the above statement. In this respect, future scientific work on the use of composite flours would have to be on coarser, rather than finer granulations. The case of the segregation of the various fractions during transport (UNECA, 1985) is one which needs to be looked at again. The segregation could be taken care of during kneading, which should ensure a homogenous dough.

Pearl millet composite flours produce breads of good volume. The freshness (shelf-life) qualities were also good. Scientifically, it would be of interest to investigate the factors responsible for the good baking properties of pearl millet.

Although maize semolina was preferred to maize grits in this study, the case for the grits may not be totally closed. Maize grits produced a higher volume than maize semolina (Table 2). The grits could be flaked to reduce or eliminate the wet-heat treatment time. This would, in turn, reduce the strong browning and the hard bite.

Bread volume was found to be a major freshness determining factor with most other parameters dependent on it. The first three days were the most important in bread freshness evaluation. Freshness on subsequent days followed the same pattern.

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