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PRODUCTION, BAKING AND OTHER PROPERTIES OF MAIZE AND PEARL MILLET COMPOSITE FLOURS

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Zusammenfassung

Mais- und Hirsekörner wurden zu Mehl, Grieß und Grits verarbeitet.

Diese Verarbeitungsstufen wurden in Anteilen von 10 bis 40 % mit Weizenmehl vermischt, rheologisch untersucht und anschließend verbacken. Die Brote wurden über 7 Tage auf Frischhaltung geprüft.
Außerdem wurden Mischungen aus Mais- und Hirsegrieß mit Weizenmehl hergestellt.

Mit abnehmender Feinheit der Granulationen von Mais und Hirse stellte sich ein erhöhtes Backvolumen ein. Ebenso verbesserten sich Frischhaltung und Haltbarkeit der Brote.

Eine 1%-ige Zugabe von DAWE-Backmittel führte zu einem größeren Volumen und einer besseren Frischhaltung als die Zugabe von Lecithin-Backmittel. Günstiger als die Backmittelzugabe wirkte sich eine 2%-ige Zugabe von Fett auf das Brotvolumen aus.

Es trat ein additiver Effekt unter dem Einsatz von mehr als 2 Getreidearten auf.

SUMMARY

Maize and pearl millet grains were milled into flour, semolina and grits.

The various granulations and wheat flour were blended with 10% to 40% levels of replacement. The rheological properties of these composite flours were determined.

Bread was baked from the different blends and the changes in freshness evaluated up to 7 days. Trails were also made blends of wheat, maize and pearl millet.

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.

A 1% (w/w) addition of DATEM bread improver increased volume and freshness over malt-lecithin bread improver. However, volume increase was even more with a 2% addition of bakery fat.

The effect of blending more than 2 cereals in bread was found to be additive.

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1. 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).

Incidentally, the FAO concluded in that a scientific breakthrough can only be achieved by producing a truly synthetic or substitute for gluten (FAO, 1970). It also went on to say that production of a synthetic gluten would not be possible because of the high cost of the amino acids present in gluten and the lack of knowledge concerning the synthetic pathways of gluten. Finally, the FAO said that the use of composite flours should not be promoted in competition to the present use of wheat flour and that products from composite flours should find their place on the commercial market on their own merit. The FAO (1969) also noted 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 breads is how well the quality keeps after baking. In many developing countries and for that matter Ghana, bread is kept for a few days before being completely consumed. A knowledge of how the shelf-life of bread is affected by the introduction of other cereals is therefore necessary.

This work tries 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. Two and three different granulations were used for pearl millet and maize respectively. An investigation was also carried out to determine whether any advantages could be gained from the combination of wheat, maize and pearl millet. How the freshness changes over a period of 7 days was also determined.

2. LITERATURE REVIEW

Maize (Zea mays L.) and Pearl Millet (Pennisetum americanum L. Leeke) are among the major cereals grown in the warmer and drier parts of the world (Kent, 1984).

2.1 Physical Characteristics

2.1.1 Maize

Maize grains are the largest cereal seeds with a 1000-seed weight of between 2000 and 3000g. The largest fraction of the grain is the endosperm, which is largely composed of starch. Other anatomically important parts of the maize grain are the tip cap, the bran layer and the germ. Maize may be white yellow or reddish in colour (Kent, 1984). Maize may also be classified based on its hardness. Flour corn is very soft and characterized by soft endosperm throughout the grain. Flint corn has a thick, hard, vitreous endosperm layer surrounding a small soft centre. Dent corn is commercially the most important. It has a corneous horny endosperm at the sides and back of the grain while the centre is soft (Johnson, 1991).

2.1.2 Pearl Millet

Pearl millet on the other hand belongs to a broad group of millets with very small seed sizes. Grain colours range from white, yellow and tan to grey, green, purple and black. The grains of pearl millet have an average 1000-seed weight of about 8,90g (Serna-Saldivar et al 1991). Hoseney and Varriano-Marston (1980) reported that (a) the germ of pearl millet is large in proportion to the rest of the kernel and (b) in any given sample , the ratio of hard to soft endosperm varies considerably. After examing 5 pearl millet samples, Sullins and Rooney (1977) found that the testa layer was absent in all of them.

2.2 Chemical Composition

2.2.1 Maize

The chemical composition of maize varies considerably as a result of the numerous types of the crop being grown (Johnson, 1991). Dent corn has an average protein content of about 10,0%, fat content of about 4,5% and approximately 3,5% crude fibre. The mineral matter content is about 2,0% with a carbohydrate percentage of 80,0 on the average (Kent, 1984). Howling (1980) reported 74:26 as the amylopectin:amylose ratio of maize starch.

2.2.2 Pearl Millet

The chemical composition of pearl millet is also widely variable. Protein and fat percentages of up to 13,6 and 5,4 respectively have been reported (Kent, 1984). The same author also published a mineral matter content of 1,3%, 1,8% crude fibre and carbohydrates of up to 77,9% for pearl millet grains.

2.3 Milling Characteristics

2.3.1 Maize

The maize grain is difficult to mill. It is large, hard, flat and in addition, contains a larger germ than other cereals. This germ which is 34% fat must be removed if the product is to be stored without becoming rancid (Hoseney, 1986). The milling of maize may or maynot include the removal of the germ. Non-de-germing dry milling is carried out traditionally in small grist mills or in modern roller mills with sifters and purifiers. The maize is ground to make coarse whole meal of 85 to 95% extraction rate (Kent, 1984). The objective of the de-germing is to remove the bran and germ and to recover the endosperm in the form of grits, semolina and flour (Pomeranz, 1987). The maize is cleaned and water is added to increase the moisture content to about 20%. The moistened grains are tempered for up to 18 hours and this toughens the germ and bran making their separation easier (Johnson, 1991). Once the germ and bran are removed, the endosperm is reduced in size by roller mills in the fashion of wheat milling. Sometimes, the milled maize products are dried to reduce the moisture content and to improve the shelf life (Hoseney, 1986).

2.3.2 Pearl Millet

According to Helweg (1977), the milling of pearl millet may be classified in 2 ways: (a) The milling for starch extraction or wet milling and (b) dry milling for flour production. In many developing countries, millets are still decorticated and ground with a mortar and pestle or with grinding stones followed by winnowing or washing at various stages to remove the bran. These milling techniques are labour intensive. For example, in Senegal (West Africa), one person spends up to six hours per day milling whole millet grains into flour required to feed one family in one day (Serna-Saldivar et al 1991). The analysis for a flour produced by these traditional methods was 10,3% protein, 3,55% cellulose and 2,7(g/100g protein) lysine (Goussault and Adrain, 1977).

A number of industrial milling processes have been devised for the production of pearl millet flour. The SOTRAMIL and SEPIAL processes were described by Goussault and Adrain, (1977). The SOTRAMIL process which was developed in Niger (West Africa), involves the washing of the grains and grading to remove large impurities and small malformed grains. The washed grains are then dehusked in a "Bavaria" dehusking machine with a horizontal millstone. The dehusked grains are grinded by attrition and the flour separated by sifting. Here, the extraction rate is 65 to 75% and the average particle size is 40 µm.

In the SEPIAL process, superficially dampened grains are dehusked in two operations. The grains are placed in an apparatus where the rotation of a vertical arm equipped with paddles results in the removal of the pericap by friction of the grains against each other. The husks are then mechanically separated from the grains. In the second decortication, the aleurone, parts of the germ and scutellum are removed. Finally, after grinding, 80% of the grain is yeilded as meal. Reichert and Youngs (1976, 1977) concluded that in the of milling of millets and sorghum, abrasive mills are more suitable than attrition mills. Also, mechanically dehulled grains lost more oil, ash and protein than did traditionally dehulled grains at the same extraction rate.

In the wet milling of pearl millet, starch yeilds were lower than those obtained for maize and sorghum (Serna-Saldivar et al 1991).

2.4 Composite Flours

Composite flours may be considered as a combination of wheat and non-wheat flours for the production of leavened breads, other baked products and pastas (Dendy, 1988). The degree of substitution of wheat flours and the types of substitutes may vary from year to year according to the availability of the non-wheat substitutes and the type of products desired (UNECA/FAO, 1985). Many authors including FAO (1969), Olatunji et al (1982), Subramanian and Jambunathan (1988) have suggested an upper limit of non-wheat flour substitution of 10%. Higher levels of up to 25% were however suggested by UNECA (1985). Although a lot of literature on composite flours in general is available, very little is found on the direct comparison of the various composite flour breads. Dendy (1988) noted that most of the composite flour research was on cassava, not very much on sorghum and very little on the millets. In instances where more than one non-wheat flour has been added to wheat flour in baking, the emphasis has been on the addition of a cereal and a legume to improve the protein content. Very little literature is found on the addition of two or more coarse cereals to wheat in any particular product.

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 recommened the small particle size of the non-wheat component. Perten (1977) however reported a higher specific volume for composite flour bread with a millet fraction of particle size greater than 125 µm as compared to that with finer flour. Koleoso et al (1988) reported that in the use of 100% non-wheat flour in bread baking, the suitable particle size range was between 152 µm and 306 µm. Brümmer et al (1988) stated that for other cereals apart from wheat and rye, coarser flours are to be prefered in bread making.

2.4.1 Rheological Properties of Doughs

Most of the published works on the rheological properties of doughs from composite flours have been on legumes and root crops mixtures. This may apparently be due to the relative ease with which legumes and root crops could be milled to wheat flour particle size for which most rheological instruments are designed. Using different legumes, Sathe et al (1981), Deshpande et al (1983), Kailasapathy and MacNeil (1985) reported increasing levels of water absorption as the legume component increased. Youssef and Bushuk (1986) however found a decrease in water absorption as wheat flour was mixed with a legume concentrate. According to Olatunji et al (1982) and Bamidele et al (1990), water absorption also increased with the substitution of sorghum and plantain flours respectively. All the above mentioned authors also reported to various degrees, a decrease in dough resistance and dough elasticity as well as increases in dough development times. The rather complicated nature of the rheological properties of composite flours was summed up by Howling (1980) that , "that the structure of a molecule should affect its rheological properties is obvious to all; precisely how is what makes life interesting".

2.4.2 Composite Flour Breads

Generally, there is a drop in loaf volume as higher percentages of wheat are replaced in bread products (Hoseney and Varriano-Marston, 1980). As the concentration of the substitute flour increases, the crust colour darkens progressively (Sathe et al 1981). Bread containing millet flours have been reported to have excellent flavour (Badi et al 1976, Casier et al 1977 and Basse, 1978).

The improving action of millet flour added to wheat flour indicated that the millet flour contained a highly active α-amylase system (Badi et al 1976). However, there is no evidence that all millet varieties contain such an active amylase system.

2.5 Bread Freshness

The quality of baked products deteriorates after baking for differnt reasons and at different rates (Spicher and Pomeranz, 1985). Seibel et al (1968) defined staling of bread broadly as all changes that take place after baking. The changes that occur during the storage of bread may involve any, or all the following: loss of crust crispness (or shortness), flavour changes, microbiological attack and crumb firming (Marston and Short, 1969). According to Pomeranz (1987), crust staling is caused almost entirely by moisture absorption from the atmosphere and the interior of the loaf. As the moisture redistributes, the crust becomes tough and leathery. Crumb staling is however more complicated. Firmness or freshness is usually measured by determining the force required to compress a slice of bread and by sensory evaluation. Crumb staling is often confused with drying out of bread but Pomeranz (1987) cited Boussingault as having shown as early as 1852 that bread crumb may stale without loss of moisture. The significance of starch in general and amylopectin in particular in staling is implied in many indirect findings (Lineback, 1984). Since the early work of Katz (1928), it has been believed that staling was caused by the retrogradation of starch. However, using the Differential Scanning Calorimetry (DSC), Hoseney (1987) showed that retrogradation and bread crumb firming are two separate events which only happen to occur at the same time during storage. Staling basically however continues to be a matter of consumer judgement, involving several sensory perceptions. These include the firmness of the crumb, the feel of the surface of a cut slice, odour, flavour and mouth feel (Pomeranz 1987).

3. MATERIALS AND METHODS

3.1 Materials

3.1.1 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.

3.1.2 Maize and Pearl Millet Milled Products

The milled products namely grits, semolina and flour used in the study were obtained by milling the above grains to varying degrees. The milling processes are described under sections 3.2.1 and 3.2.2.

3.1.3 Wheat Flour

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

3.1.4 Other Ingredients

Sugar (sucrose), salt, groundnut fat, fresh baking yeast, ascorbic acid solution (0,1% w/w), sorbic acid as well as malt-lecithin and diacetyltartaric acid ester (DATEM) bread improvers were used. These were also obtained from the Bundesforschungsanstalt in Detmold.

3.2 Methods

3.2.1 Maize Milling

Dry milling of maize was mechanically carried out as follows:

(i) Cleaning
The maize grains were cleaned in a Granotest (DGM) 71 cereal cleaner (Kalker Trieurfabrik, Köln, Germany) to remove dust and impurities.

(ii) Tempering
A computed amount of water was added to the grains to raise the moisture content to 20%. The water and the grains were mixed in a J. Engelmann A.G.(Ludwigshafen a.Rh., Germany) mixer for 90 min. The wet grains were then conditioned overnight for 18 hrs.

(iii) Degerming
The tempered grains were crushed in a roller mill with 3,5 grooves/cm. The crushed grains were then passed twice through a bran polisher with 3300 µm mesh openings to remove the bran and germs.

(iv) Grits Production.

The products from (iii) above was then milled in a Bühler Automatic (MLU 202) laboratory mill fitted with sieves of 1450 µm, 1250 µm and 1000 µm mesh sizes. The different granulations produced from this milling were mixed in a (Engelmann) mixer for 90s. The resulting product was designated as grits.

(v) Semolina Production

A portion of the grits from (iv) was passed twice through a MIAG (Braunschweig, Germany) semolina polisher to produce a finer and a coarser fraction. The two fractions were thoroughly mixed and designated as semolina.

(vi) Flour Production

A part of the semolina produced in (v) was milled at a rate of 1,6kg/h to produce maize flour.

3.2.2 Pearl Millet Milling

Dry milling of pearl millet grains was carried out mechanically as described below.

(a) Dehulling

The pearl millet grains were dehulled in 500g batches in a F.H. Schule GmbH (Hamburg, Germany) Barley Pearler for 7,5min and cleaned by aspiration.

(b) Semolina Production

The dehulled grains were milled in a Bühler laboratory (MLU 202D) durum mill, polished in a MIAG semolina polisher and designated as pearl millet semolina.

(c) Flour Production

A part of the semolina produced in (b) above was milled at a rate of 2,8kg/h to produce pearl millet flour.

3.2.3 Particle Size (Sieve) Analysis

3.2.3.1 Wheat Flour

100g sample was aspirated for 5min through a 75 µm mesh sieve on an Alpine A.G.(Augsburg, Germany) air suction sieve and the percentage retained on the sieve recorded.

3.2.3.2 Maize and Pearl Millet Fractions

100g sample was agitated on a (J. Engelmann) sieve shaker for 5min and the percentages retained on different mesh sizes recorded.

3.2.4 Flour Blending

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

3.2.5 Proximate Analysis

Ash and crude fat contents were determined according to the ICC (1986) Standard methods of analysis (ICC No. 104) and AGF (1978) - Standard Methoden für Getreide Mehl und Brot (No. 87) respectively.

The automatic Kjel-Foss apparatus (16210 N. Foss Electric, Denmark) was used to determine the total nitrogen content according to the principle of the micro-Kjeldahl procedure. The conversion factor of 5,7 for wheat was used for all the composite flours as well.

3.2.6 Other Determinations

The Falling Number, wet gluten percentage and Sedimentation Values were determined according to ICC Standard Nos. 107,137 and 116 (1986) respectively.

3.2.7 Rheological Characteristics of Doughs

3.2.7.1 Amylograph Characteristics

The peak viscosities as well as the initial and peak gelatinisation temperatures of the wheat and composite flours were determined according to ICC Standard No. 126 (1986).

3.2.7.2 Farinograph Characteristics

The Brabender Farinograph was used to study the dough characteristics during the mixing of wheat and the various composite flours with water. This was carried according to ICC Standard No. 115 (1986). From the farinograph, the dough development time (min), dough stability (min), dough resistance (min) and the degree of softening (FU) were computed.

3.2.7.3 Extensigraph Characteristics

The dough resistance to extension (Rm), dough extensibility (E), the proportional number (Rm/E) and the dough strength (S) of the doughs from wheat and the composite flours were determined according to ICC Standard No. 114 (1986).

3.2.7.4 Alveograph Characteristics

Using the Chopin alveograph, the maximal overpressure, (P), which is in relation with the resistance of the dough to deformation, the swelling index (G), the curve configuration ratio (P/L) and the work required to deform 1g. of dough (W) were calculated according to the ICC No. 121 (1986).

3.2.8 Baking Procedures

Bread was processed from 100% wheat flour as well as from 10%, 20%, 30% and 40% wheat flour replacements. The substitutes were maize flour, maize semolina, maize grits, pearl millet semolina and pearl millet flour. The most desirable granulation of maize and pearl millet were selected and bread from mixtures of wheat, maize and pearl millet with these granulations processed.

3.2.8.1 Ingredients

Wheat flour/ plus replacements (14% m.b.)	100	parts
Fresh yeast (Saccharomyces cervisia) Uni. DHW	4	parts
Salt	1,8	parts
Sugar (sucrose)	1	part
Groundnut fat	1	part
Bread improver (see 3.1.4)	1	part
Ascorbic acid	0,002	parts
Sorbic acid	0,2	parts
Water according to farinograph absorption	(Table 4)	

3.2.8.2 Dough Preparation

3.2.8.2.1 Maize Grits Replacements.

Due to the hardness of the grits, equal quantities by weight of grits and boiling water were left to stand for 4 to 5 hours before being incoporated into the other ingredients for dough preparation.

3.2.8.3 Moulding and Proofing

The dough from 3.2.8.2. was shaped by a Frilado (F. Laureck Bäckereimaschinen, Dortmund, Germany) mechanical moulder, panned in a pre-greased aluminium pans and proofed at 32°C and 80% RH for 60min. (100% wheat dough was proofed for 70min).

3.2.8.4 Baking

The proofed doughs were baked in a Matador (Werner & Pfleiderer) oven at 230°C for 40 min.

3.2.9 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.

(i) Loaf weight (g).

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

(iii) Loaf volume yeild (LVY) = $\frac{\text{Loaf volume X 100}}{\text{Flour weight}}$

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

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

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

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

ie. for volume yeilds 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 crumb 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)
Unsatisfactory	(-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.

3.2.10 Storage Conditions

The loaves were rapped in polythene bags as described under 3.2.9 and stored in a warm cupboard at 28°C and 60 to 65% RH for up to 7 days.

3.2.11 Freshness Measurements

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

3.2.11.1 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 metllic cylinder. The compressibility and relaxation were read from the curve and the elasticity number calculated according to the relation:

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

3.2.11.2 Penetrometer Measurements

A (SUR Berlin, Germany) penetrometer was used to measure the penetrability in (1/10mm) of a bread crumb by a prescibed weight. A 5cm thick bread slice was cut. A stencil in which 5 equally spaced holes had 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 1cm 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.

4. RESULTS AND DISCUSSIONS

4.1 Physical Characteristics

4.1.1 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.

4.1.2 Particle Size (Sieve) Analysis

42,5% of wheat flour was retained on a 75 µm mesh after being aspirated for 5min on an Alpine A.G. (Ausburg, Germany) air suction sieve (Table 1a).

Table 1b & 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 1000 µm sieve, While over 50% of maize flour was passed through the 250 µm 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 150 µm sieve, the amounts of pearl millet semolina passing through the 150 µm sieve as well as being retained on the 150 µm and 250 µm sieves were approximately equal (Table 1c).

4.2 Proximate Composition

The wheat flour had a wet gluten content of 31,3%.

Table 2 shows the proximate composition of straight and composite flours on dry matter basis. The data reveals that:

(a) There were wide differences in ash content with 0.92% for pearl millet flour and 0.49% for maize flour. Wheat flour had an ash content of 0.64%. Hence, ash content of composite flours increased with pearl millet additions and decreased with maize additions.

(b) Pearl millet flour had a high crude fat content of 2,53%. The crude fat content of wheat flour and maize flour were 1,30% and 1,26% respectively giving their composite flours a relatively constant fat content of about 1,28%. On the other hand, crude fat content increased as more pearl millet was added to wheat flour up to a level of 1,74% for 60% wheat/40% pearl millet flour.

(c) The wheat flour had a protein content of 13,40%. Protein contents for maize and pearl millet flours were 10,60% and 11,60% respectively. As a result, protein content decreased as maize and pearl millet flours were added to wheat flour.

(d) Sedimentation value for wheat flour was 32. This decreased as maize and pearl millet flours were added. The rate of decrease was higher with the addition of pearl millet flour.

Table 1: Particle Size (Sieve) Analysis

(a) 42,50% of the wheat flour was retained on a 75 μm sieve after aspriation for 5 min

(b)

Sample	% Retained on sieve openings				
	1000 μm	750 μm	500 μm	250 μm	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)

Sample	% Retained on sieve openings				
	500 μm	450 μm	250 μm	150 μm	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: Proximate composition of straight and composite flours on dry matter basis

Sample	Sedimentation Values	Ash %	Fat %	Protein %
100 % wheat flour	32	0,64	1,30	13,40
100 % maize flour	-	0,49	1,26	10,60
100 % pearl millet flour	-	0,92	2,53	11,60
90 % wheat/10 % maize	29	0,62	1,28	13,00
80 % wheat/20 % maize	27	0,61	1,28	12,70
70 % wheat/30 % maize	24	0,59	1,29	12,30
60 % wheat/40 % maize	22	0,57	1,28	11,90
90 % wheat/10 % pearl millet	28	0,67	1,40	13,10
80 % wheat/20 % pearl millet	24	0,70	1,55	12,80
70 % wheat/30 % pearl millet	19	0,73	1,61	12,60
60 % wheat/40 % pearl millet	15	0,75	1,74	12,30

4.3 Rheological Characteristics of Doughs

The wheat flour had a Falling number of 401. This decreased as maize and pearl millet flours were added. (Table 3). Here the rate of decrease was higher with the addition of maize flour. 90% wheat/10% maize flour had a Falling number of 352 as against 388 for 90% wheat/10% millet flour. Falling numbers for 60% wheat/40% maize flour and 60% wheat/40% millet flour were 284 and 360 respectively.

4.3.1 Amylograph

The amylogram characteristics of the flours are shown in Table 3. The wheat flour had initial and peak gelatinisation temperatures of 62,5°C and 88,0°C respectively. The maximum viscosity of wheat flour was 840AU. As maize flour was substituted for wheat flour, the maximum viscosity and peak temperatures dropped. 100% maize flour had a maximum viscosity of 410AU and a peak gelatinisation temperature of 80,0°C. The reverse was the case for pearl millet composite flours. Maximum viscosities and peak temperatures increased with pearl millet flour substitution. 100% pearl millet had a maximum viscosity of 1610AU and a peak temperature of 90,0°C.

Table 3 also shows pearl millet as having a very high α-amylase activity and despite that, high maximum viscosity values. This may be due to the very high initial and peak gelatinisation temperatures of 74,0°C and 90,0°C respectively for pearl millet flour. As a result, the α-amylase system was probably inactivated before the gelatinisation process of millet starch was completed.

4.3.2 Farinograph

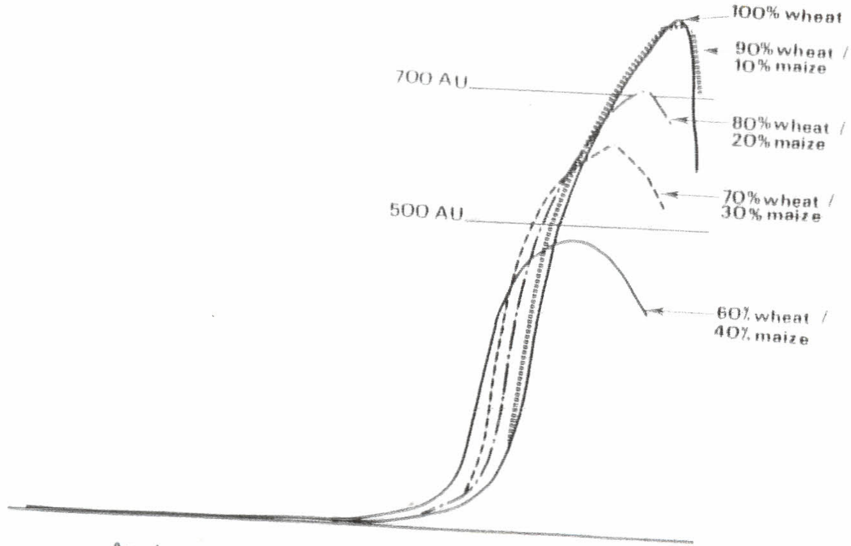
The farinogram behaviour of doughs made from wheat and the various composite flours blends are presented in Table 4. Water absorption for wheat flour was 64,0%. This increased by an average of 1,1% for every 10% substitution with maize flour.

The water absorption for 60% wheat/40% maize flour was 68,5%. On the other hand, water absorption decreased by an average of 0,9% for every 10% substitution with pearl millet flour. 60% wheat/40% pearl millet flour had a water absorption of 60,5%.

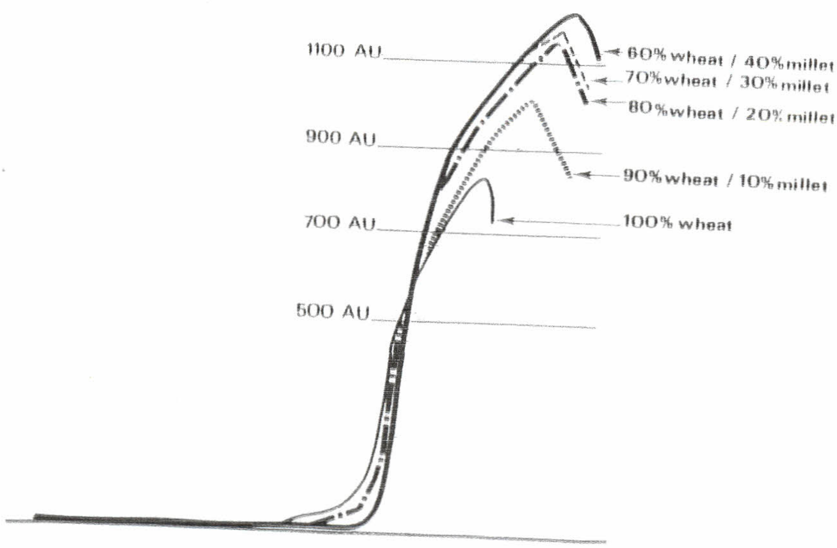
Dough development times for pearl millet composite flours ranged from 2,5min to 3,0min. This compared well with that of wheat flour of 2,5min. However, dough development times for maize composite flours increased steadily to 7,0min for 60% wheat/40% maize flour. This followed the general trend reported by Sathe et al (1981), Olatunji et al (1982), Youssef and Bushuk (1986) among others.

Table 3: Amylograph characteristics of wheat and composite flour doughs

Sample	Falling Number	Peak Viscosity (AU)	Initial Gel.temp. °C	Peak Gel.temp. °C	α-Amylase (ICC-Units)
100 % wheat flour	401	840	62,5	88,0	0,24
100 % maize flour	-	410	63,0	80,0	3,54
100 % millet flour	-	1610	74,0	90,0	4,28
90 % wheat/10 % maize	352	830	64,0	87,5	-
80 % wheat/20 % maize	328	710	63,5	86,5	-
70 % wheat/30 % maize	297	620	64,0	84,5	-
60 % wheat/40 % maize	284	480	63,0	81,5	-
90 % wheat/10 % millet	388	1030	65,5	88,5	-
80 % wheat/20 % millet	373	1190	68,5	89,0	-
70 % wheat/30 % millet	369	1200	70,0	89,0	-
60 % wheat/40 % millet	360	1280	72,0	89,5	-



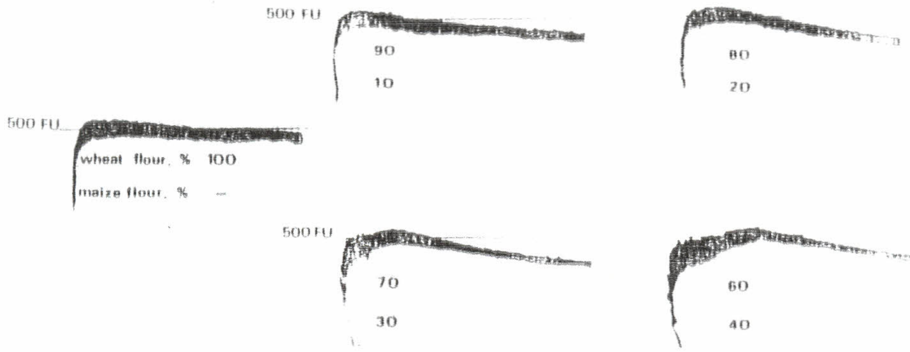
Amylographs For Wheat and Maize Composite Flours



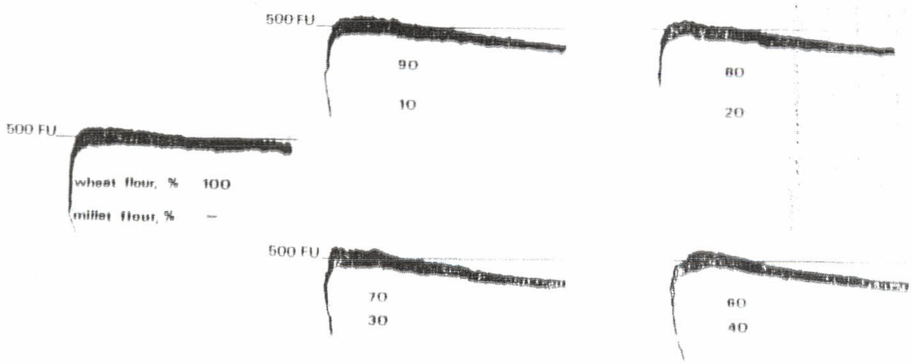
Amylographs For Wheat and Millet Composite Flours

Table 4: Farinograph characteristics of wheat and composite flour doughs

Sample	Water absorption (%)	Dough devpt.time (min)	Dough stability (min)	Dough resistance (min)	Degree of softening (FU)
100 % wheat flour	64,0	2,5	2,5	5,0	20
90 % wheat/10 % maize	65,1	3,0	1,5	4,5	85
80 % wheat/20 % maize	66,2	3,5	1,5	5,0	105
70 % wheat/30 % maize	67,3	4,0	1,5	5,5	110
60 % wheat/40 % maize	68,5	7,0	1,0	8,0	110
90 % wheat/10 % millet	63,1	2,5	2,0	4,5	70
80 % wheat/20 % millet	62,2	3,0	0,5	3,5	75
70 % wheat/30 % millet	61,3	2,5	0,5	3,0	85
60 % wheat/40 % millet	60,5	3,0	1,0	4,0	100



Farinographs For Wheat and Maize Composite Flours



Farinographs For Wheat and Millet Composite Flours

The dough stability of 2,5min for wheat flour tended to decrease with the substitution with other flours. The degree of softening increased sharply from 20FU for wheat flour to 110FU and 100FU for 60% wheat/40% maize flour and 60% wheat/40% millet flour respectively, (Table 4).

Dough resistance for wheat flour was 5,0min. This increased with the substitution with maize flour to 8,0min for 60% wheat/40% maize flour. On the other hand, dough resistance decreased as pearl millet flour was substituted for wheat flour (Table 4).

4.3.3 Extensigraph

Table 5 shows the extensigram behaviour (after 135min) of wheat and the various composite flours (with and without ascorbic acid). Dough resistance to extension, the energy of the dough (dough strength) and the dough extensibility decreased with increasing replacement of wheat flour. This is in general agreement with the findings of Sathe et al (1981), Kailasapathy and MacNeil (1985), Bamidele et al (1990) among others. In all these parameters, the rate of decrease was lower with the substitution of pearl millet flour as against maize flour.

4.3.4 Alveograph

Alveogram characteristics of wheat and the composite flours are shown in Table 6. The alveogram behaviour of 60% wheat/40% millet flour dough as well as doughs of flours with more than 10% maize could not be measured. Weipert (1981) found a strong relationship between the maximal overpressure (P) and the farinogram water absorption of flours. The high maximal overpressure for 90% wheat/10% maize flour dough as well as the lower values for pearl millet composite flour doughs confirmed this relationship when compared with the farinogram water absorptions of Table 4.

The higher swelling index (G) of 90% wheat/10% millet flour dough as compared to that of 90% wheat/10% maize flour dough and the general tendency for G to decrease with the substitution of wheat flour also confirms the finding by Weipert (1981) of a strong correlation between G and loaf volume (Tables 6 and 11).
The sharp drop in deformation energy (Work) with the substitution of wheat flour and the higher energy for 90% wheat/10% millet flour dough as compared to that for 90% wheat/10% maize flour follows the AACC (1987) report that, in comparing bread evaluation scores with alveogram values, deformation energy (W) was the best differentiator of quality (Tables 6 and 12).

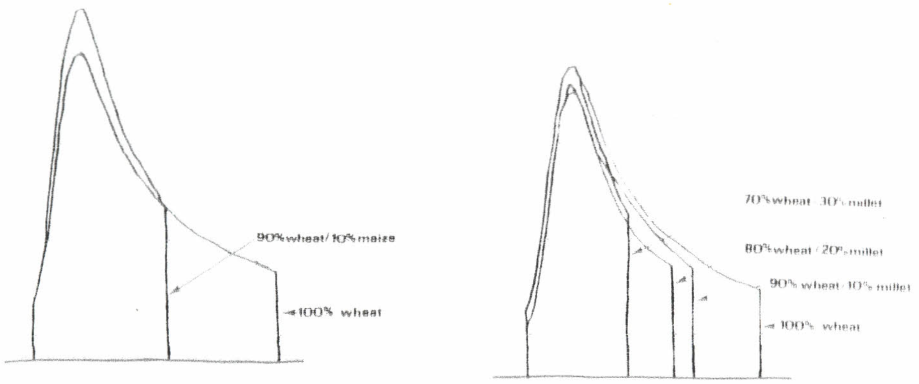
Table 5: Extensigraph characteristics (after 135 min) of wheat and composite flour doughs

Sample	Normal				with Ascorbic acid			
	Rm(EU)	E(mm)	Rm/E	S(cm2)	Rm(EU)	E(mm)	Rm/E	S(cm2)
100 % wheat flour	240	170	1,40	51	510	145	3,50	96
90 % wheat/10 % maize	180	133	1,40	30	535	119	4.50	80
80 % wheat/20 % maize	185	123	1,50	28	420	103	4,10	53
70 % wheat/30 % maize	150	104	1,40	20	425	78	5,50	40
60 % wheat/40 % maize	not measurable				not measurable			
90 % wheat/10 % millet	225	146	1,50	39	575	120	4,80	86
80 % wheat/20 % millet	210	126	1,70	32	480	106	4,50	64
70 % wheat/30 % millet	170	105	1,60	22	470	91	5,20	51
60 % wheat/40 % millet	95	88	1,10	12	225	74	3,00	20

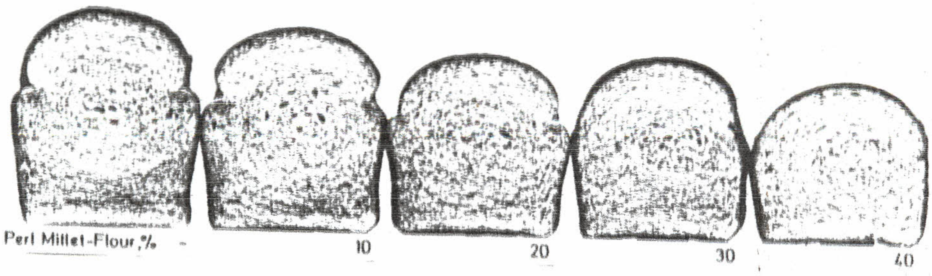
Rm = Dough resistance
E = Dough extensibility
Rm/E = Proportional number
S = Dough strength (area under curve)

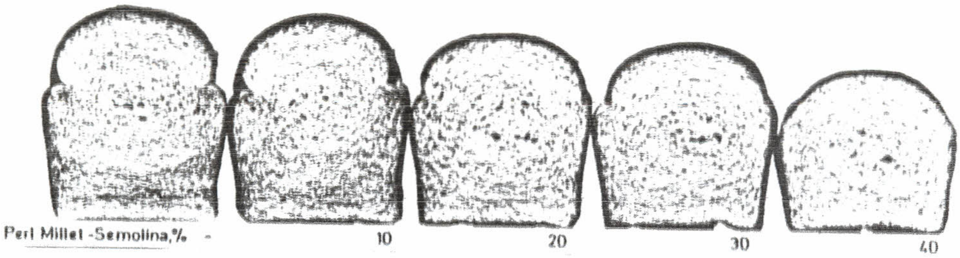
Table 6: Alveograph characteristics of wheat and composite flour doughs

Sample	Maximal Overpressure (P m/m)	Swelling Index (G)	Curve Configuration Ratio (P/L)	Work (WX10-4joules)
100 % wheat flour	98,7	18,0	1,48	214
90 % wheat/10 % maize	111,2	13,3	3,09	162
80 % wheat/20 % maize			not measurable	
70 % wheat/30 % maize			not measurable	
60 % wheat/40 % maize			not measurable	
90 % wheat/10 % millet	97,7	15,3	2,04	164
80 % wheat/20 % millet	89,1	14,1	2,17	141
70 % wheat/30 % millet	90,8	11,8	3,13	109
60 % wheat/40 % millet			not measurable	



Alveographs For Wheat and Composite Flours





4.4 Dough and Bread Characteristics

Tables 7 to 10 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 yeild increased with the substitution with maize flour. Dough yeilds 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 11). 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 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.

4.4.1 Bread Evaluation Scores

The bread evaluation scores which takes into account the volume, the nature and distribution of pores, the loaf form, crumb texture and elasticity are reported in Table 12. From these scores, breads from all blends with up to 20% levels of substitution as well as with 30% pearl millet semolina were judged as "very good". Based on these scores, maize semolina was chosen as the best granulation for maize composite flours while pearl millet semolina was prefered to pearl millet flour.

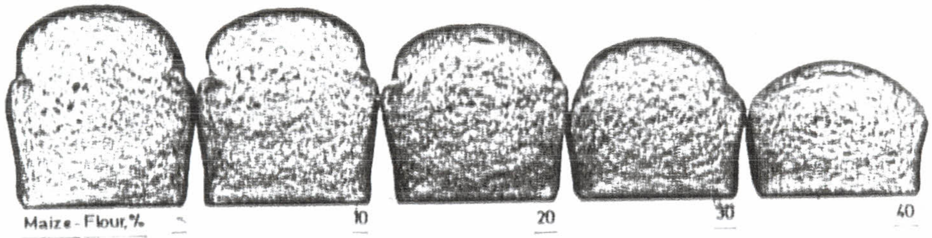
4.5 Freshness Evaluation

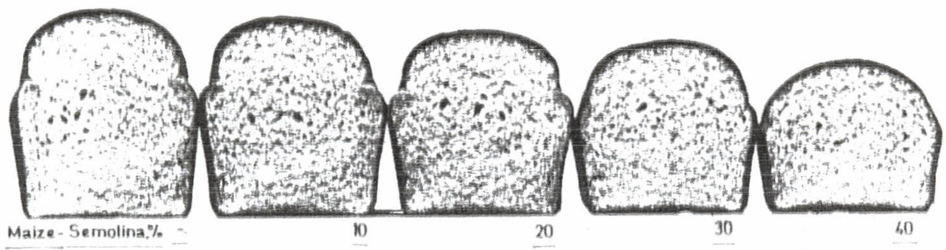
4.5.1 Sensory Evaluation

Using 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 13 to 17. 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.

4.5.2 Penetrometer Evaluation

Appendices 1 to 9 show the penetrometer readings over 7 days for wheat and the various composite flour breads. 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.


Maize-Flour,%
-
10
20
30
40


Maize-Semolina,%
-
10
20
30
40

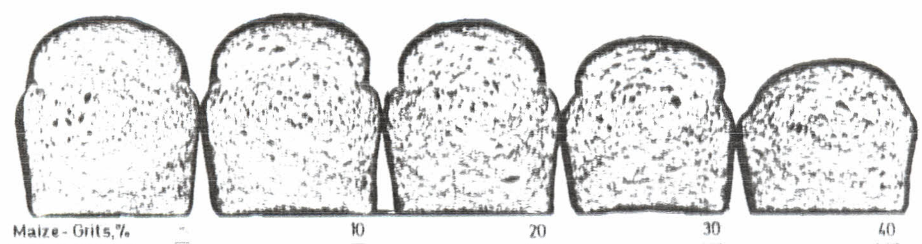

Maize-Grits,%
-
10
20
30
40

Table 7: Dough and bread characteristics at 10% level of replacement

Characteristics	100% wheat	10% millet flour	10% millet semolina	10% maize flour	10% maize semolina	10% maize grits
Dough yield	163	163	161	165	162	162
Dough characteristics						
- surface	normal	normal	normal	normal	normal	normal
- elasticity	normal	normal-somewhat short	almost normal	almost normal	almost normal	almost normal
Volume yield	666	612	634	587	599	624
Grain characteristic	soft silky	soft	soft silky	soft	soft	soft silky
Crumb elasticity	good	good	good	good	good	good
Taste/flavour	good/ typical	good/ typical	good/ typical	good/ typical	good/ typical	good/ typical

Table 8: 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 characteristic	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

Table 9: 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	normal	normal	normal	somewhat dry	normal	somewhat moist
- elasticity	normal	short	short	short	short	somewhat short
Volume yield	666	512	538	470	490	521
Grain characteristic	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

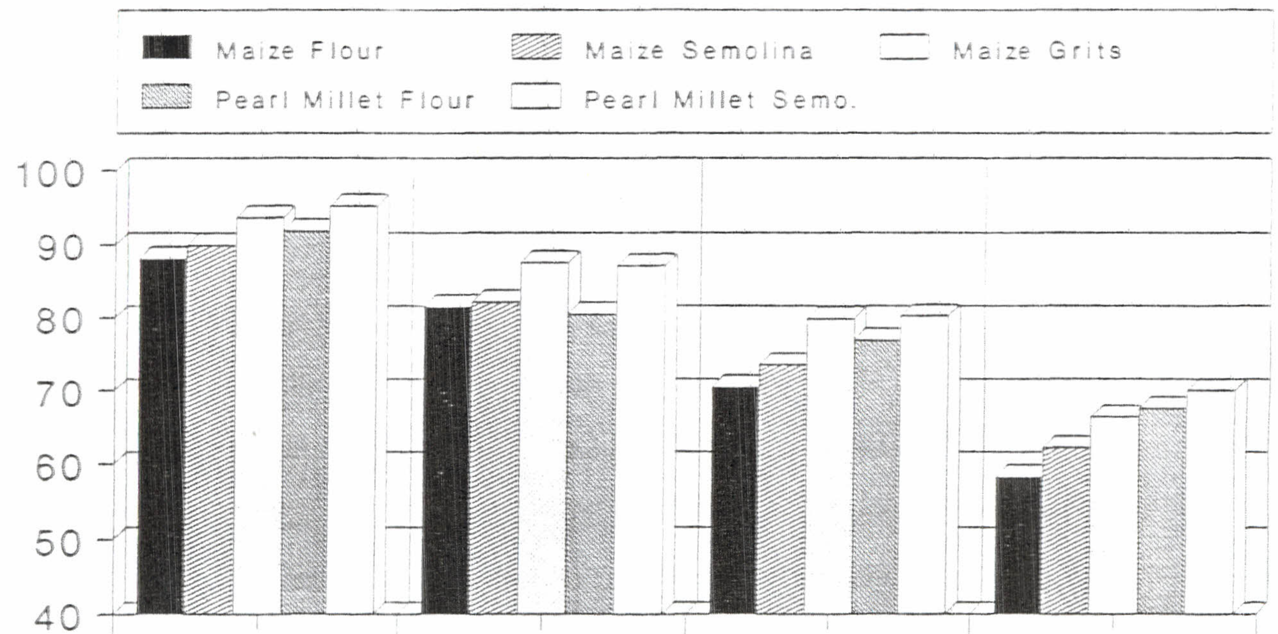
Table 10: Dough and bread characteristics at 40% level of replacement

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	normal	normal	normal	somewhat dry	normal	somewhat moist
- elasticity	normal	very short	very short	very short	very short	short
Volume yield	666	450	466	388	414	442
Grain characteristic	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

Table 11

% Relative Volume

Wheat Flour Bread = 100 % (670 ml/100 g 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 Semo.	95	87	80	70

Table 12: 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

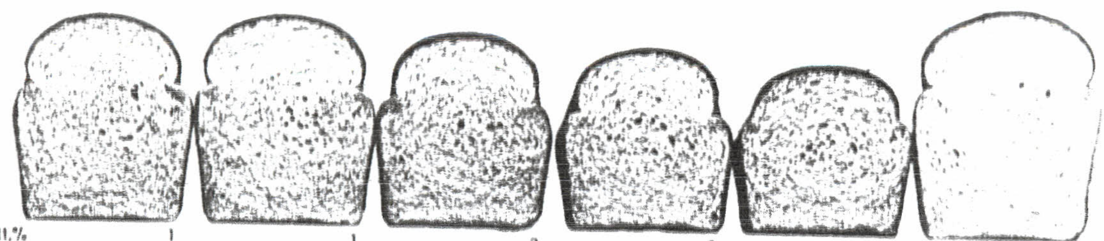
over 140 = very good
110 - 140 = good
90 - 109 = satisfactory
below 90 = not satisfactory

4.5.3 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.

4.6 Three (3)-Cereal Breads

Based on the bread evaluation scores (Table 12), bread was baked from blends of wheat flour, maize semolina and pearl millet semolina. The results of these trials are reported in Tables 18 to 20. The amounts of lipid added was varied and diacetyltartaric acid ester (DATEM) was substituted for malt-lecithin as bread improver in the composite flour breads to enhance freshness.



Fell,%	1	1	2	2	2	2
Lecithin-Backmittel,%	1	–	–	–	–	–
DAWE-Backmittel,%	–	1	1	1	1	1
Maisgrieß %	–	–	10	15	20	–
Hirsegrieß %	–	–	10	15	20	–

Fett = Bakery Fat
Lecithin-Backmittel = Lecithin Bread Improver
DAWE-Backmittel = DATEM Bread Improver
Maisgrieß = Maize Semolina
Hirsegrieß = Pearl Millet Semolina

There were no significance changes in the dough yeilds of the 3-cereal breads when compared to the 2-cereal breads. Dough yeilds of the 3-cereal breads were always between that of wheat flour/millet semolina and wheat flour/maize semolina doughs. Dough elasticity changed towards "very short" at 40% replacement of wheat flour just as in the 2-cereal doughs. This means that, at the stage of kneading, the bakery fat and bread improvers made no significant difference. There were however large changes in volume as bakery fat was increased from 1% to 2% and 1% DATEM bread improver was added. Relative volume increased to 94%, 85% and 78% for 20%, 30% and 40% levels of replacement respectively. There was no noticeable change in taste with the addition of DATEM bread improver. Improvement in the bread evaluation scores were high and this was also reflected in the freshness evaluation (Tables 19 and 20).

4.7 General

Preliminary trials (results not shown) indicated that, for every recipe, volume and other characteristics of the 3-cereal breads were approximately the average of wheat flour/millet semolina composite bread and wheat flour/maize semolina composite bread. This means that the effect of blending various cereal flours was simply additive. In all the trials, bread from millet blends was better than those from maize blends. Although DATEM bread improver produced breads of higher volumes than malt-lecithin bread improver, an increase of bakery fat content from 1% to 2% produced even more volume. This agreed with the findings of Pomeranz et al (1965, 1966a and 1966b). However, Hoseney et al (1976), Rogers and Hoseney (1983) and Schuster and Adams (1984) found DATEM as being most effective in combination with mono- and diglycerides (MDG)

It is worth noting that although pearl millet fractions (flour and semolina) had a finer particle size (Table 1), higher ash content (Table 2) and a lower water absoption capacity (Table 4) as compared to the maize fractions, they always produced larger volumes. Probably, the more active α-amylase system played a role in the improving action of pearl millet flours (Badi et. al., 1976).

Table 13: Sensory evaluation of crust and crumb characteristics of pearl millet flour

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

1 = very good
6 = very bad

Table 14: Sensory evaluation of crust and crumb characteristics of pearl millet semolina

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

1 = very good
6 = very bad

Table 15: Sensory evaluation of crust and crumb characteristics of maize flour

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

1 = very good
6 = very bad

Table 16: Sensory evaluation of crust and crumb characteristics of maize semolina

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

1 = very good
6 = very bad

Table 17: Sensory evaluation of crust and crumb characteristics of maize grits

Nr.of days old		% Replacement				
		0%	10%	20%	30%	40%
1	Crust	1	1	1-2	2	2-3
	Crumb	1	1	1-2	2	2-3
3	Crust	1-2	1-2	2	2-3	3
	Crumb	1-2	1-2	2	2-3	3
5	Crust	2	2	2-3	3	3-4
	Crumb	2	2	2-3	3	3-4
7	Crust	2-3	3	3-4	4	5
	Crumb	2-3	2-3	3	3-4	4-5

1 = very good
6 = very bad

Table 18: Dough and bread characteristics of 3-cereal breads

Characteristic	Nr. 1	Nr. 2	Nr. 3	Nr. 4	Nr. 5	Nr. 6
Dough yield	163	163	159	157	156	163
Dough characteristics						
- surface	normal	normal	normal	normal	normal	normal
- elasticity	normal	normal	somewhat short	short	very short	somewhat supple
Volume yield	666	684	623	564	521	719
Grain characteristic	soft silky	soft silky	soft	almost soft	somewhat coarse	silky
Crumb elasticity	good	good	good	good	good	good
Taste/flour	good/typical	good/typical	still good	somewhat tart	tart	good/typic
<u>Recipe</u>						
Bakery fat, %	1	1	2	2	2	2
Bread improver, %						
- Lecithin	1	-	-	-	-	-
- DATEM	-	1	1	1	1	1
Maize semolina, %	-	-	10	15	20	-
Millet semolina, %	-	-	10	15	20	-

Table 19: Bread evaluation scores of 3-cereal breads*

* over 140 = very good
* 110 - 140 = good
* 90 - 109 = satisfactory
* below 90 = not satisfactory

	Nr. 1	Nr. 2	Nr. 3	Nr. 4	Nr. 5	Nr. 6
	216	236	188	150	121	274
Recipe						
Bakery fat, %	1	1	2	2	2	2
Bread improver, %						
- Lecithin	1	-	-	-	-	-
- DATEM	-	1	1	1	1	1
Maize semolina, %	-	-	10	15	20	-
Millet semolina, %	-	-	10	15	20	-

Table 20: Sensory evaluation of crust and crumb characteristics of 3-cereal breads*

*1 = very good
*6 = very bad

Nr. of days old		Nr. 1	Nr. 2	Nr. 3	Nr. 4	Nr. 5	Nr. 6
1	Crust	1	1	1-2	2	2-3	1+
	Crumb	1	1	1-2	2	2-3	1+
3	Crust	2	2	2-3	3	3-4	1-2
	Crumb	2	2	2-3	3	3-4	1-2
Recipe							
Bakery fat, %		1	1	2	2	2	2
Bread improver, %							
- Lecithin		1	-	-	-	-	-
- DATEM		-	1	1	1	1	1
Maize semolina, %		-	-	10	15	20	-
Millet semolina, %		-	-	10	15	20	-

CONCLUSION AND RECOMMENDATIONS

e use of cereals other than wheat and rye in breadmaking, the coarser ons are to be prefered (Brümmer et al, 1988). This study confirmed the statement. In this respect, future scientific work on the use of osite flours would have to be on coarser rather than finer granulations. case of the segregation of the various fractions during transport CA, 1985) is found to be of little consequence. This is taken care of g kneading which should ensure a homogenous dough.

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

ugh maize semolina was prefered to maize grits in this study, the case ne grits may not be totally closed. Maize grits produced a higher volume maize semolina (Table 11). The grits could be flaked to reduce or ate the wet-heat treatment time. This would in turn reduce the strong ning and the hard bite.

significant improving effect of bakery fat on composite flour breads d be an encouragement to traditional bakers without advanced ologies. With the appropriate amounts of bakery fat, higher levels of vheat flours can always be used.

effect of blending more than two cereals was found to be additive. Hence us cereals could be blended to satisfy consumer tastes and preferences.

d volume was found to be a major freshness determining factor with most parameters dependent on it. The first three (3) days were the most tant in bread freshness evaluation. Freshness on subsequent days ved the same pattern.

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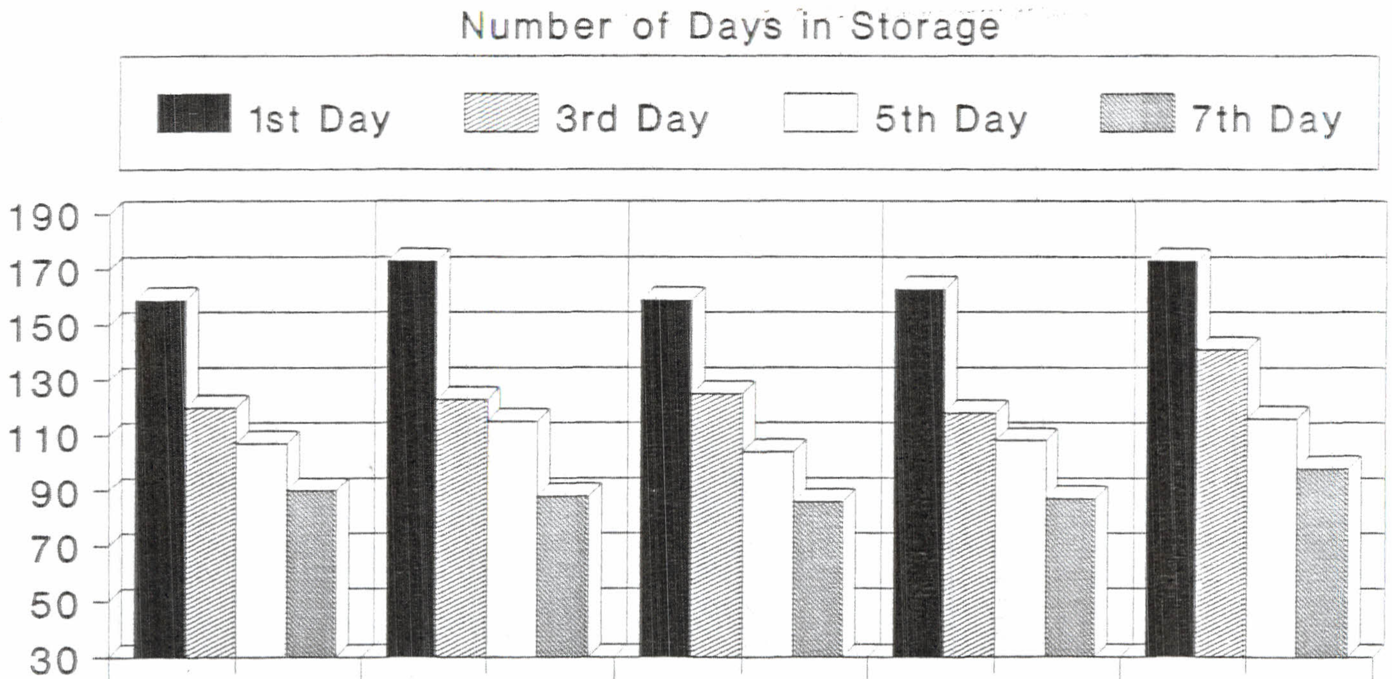
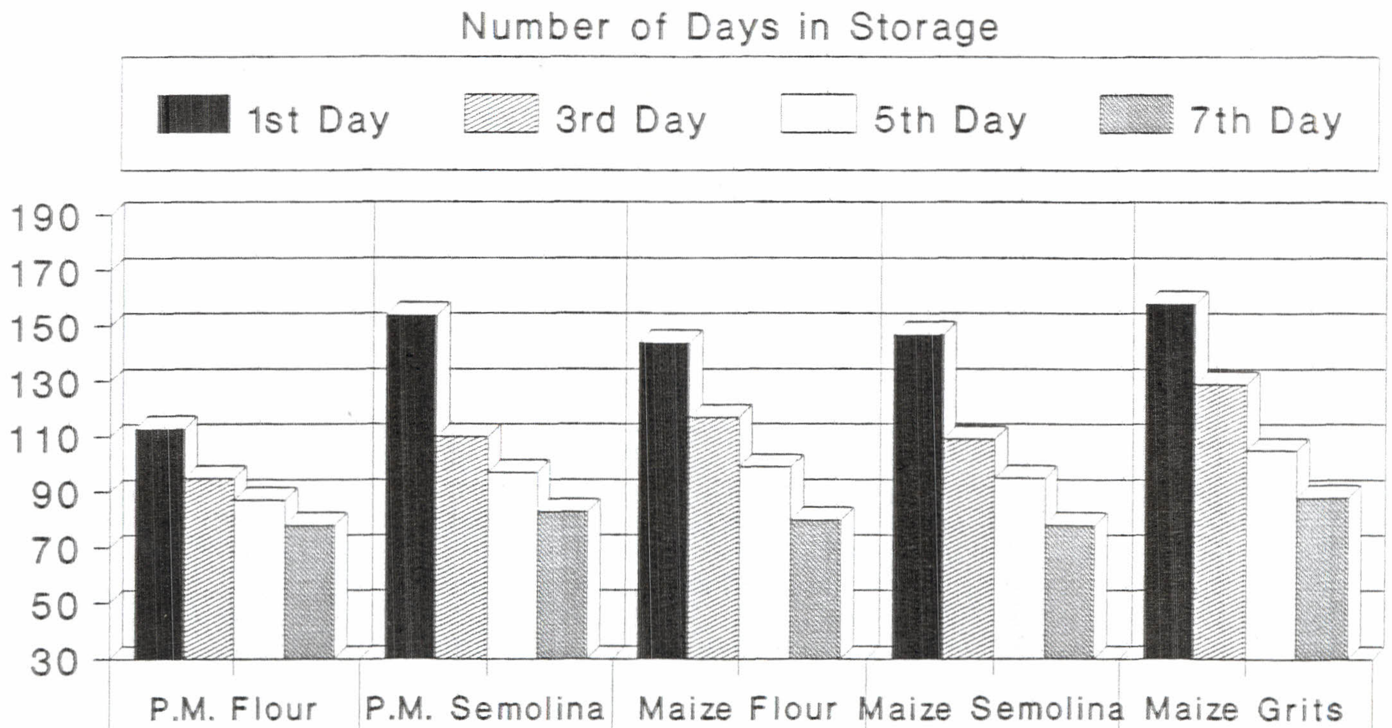
Appendix 1. **Penetrometer Readings (1/10 mm)**
10 % Non-Bread-Cereal



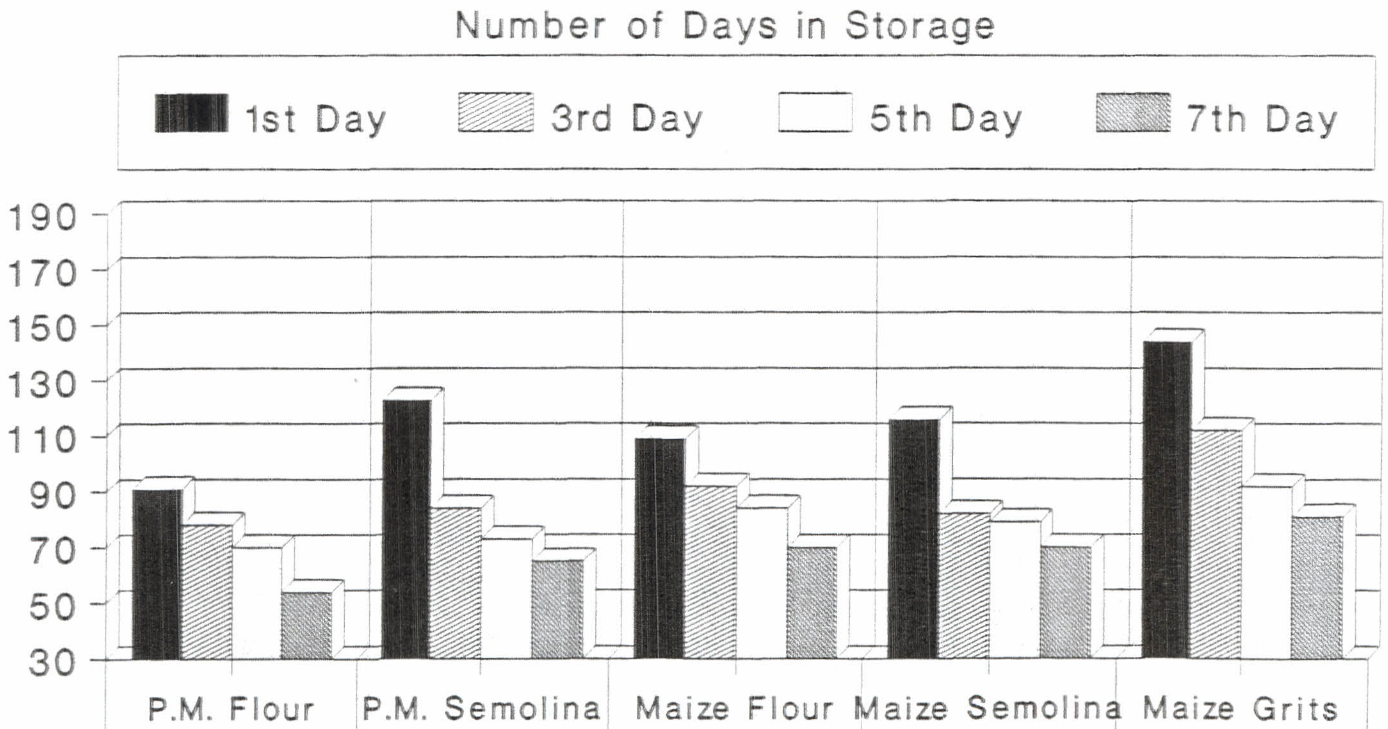
	P.M. Flour	P.M. Semolina	Maize Flour	Maize Semolina	Maize Grits
1st Day	159	173	159	163	173
3rd Day	120	123	125	118	141
5th Day	107	115	104	108	116
7th Day	90	88	86	87	98

Appendix 2. Penetrometer Readings (1/10 mm)
20 % Non-Bread-Cereal



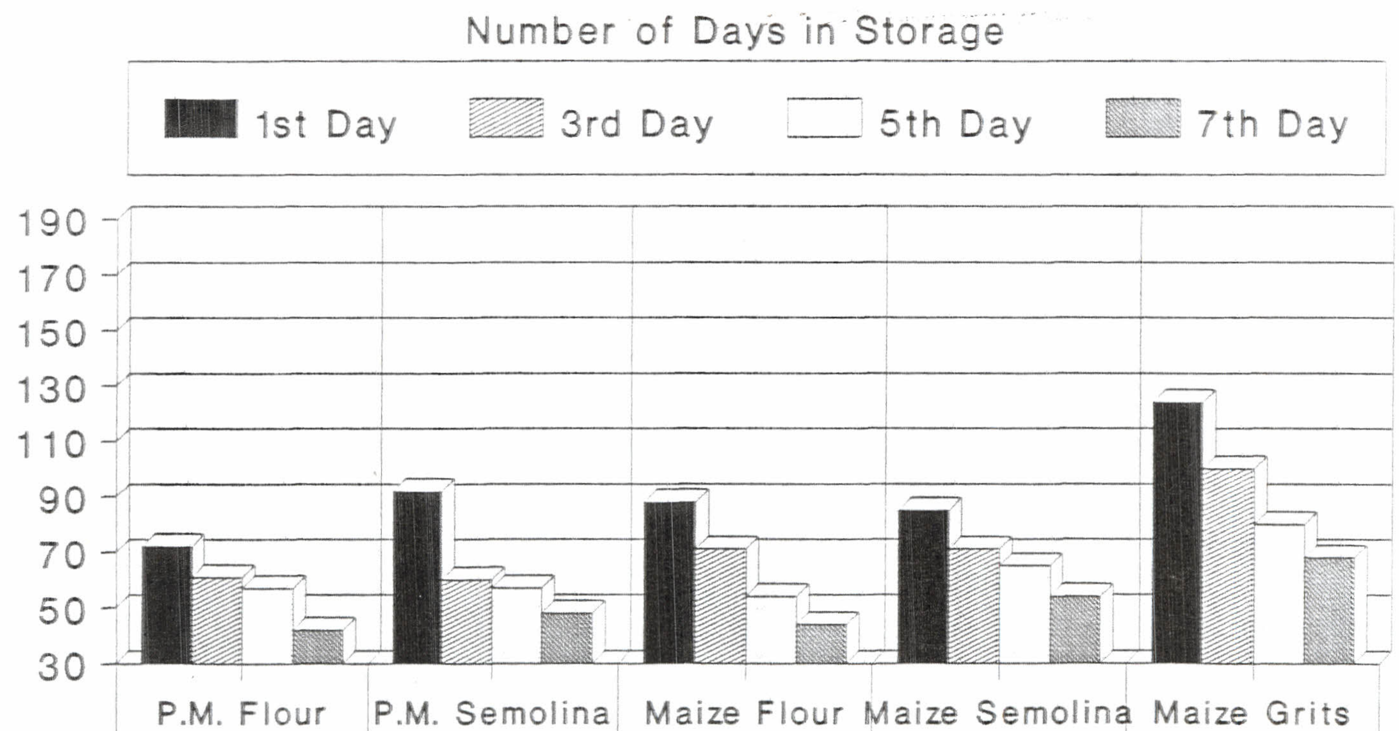
	P.M. Flour	P.M. Semolina	Maize Flour	Maize Semolina	Maize Grits
1st Day	113	154	144	147	158
3rd Day	95	110	117	109	129
5th Day	87	97	99	95	105
7th Day	78	83	80	78	88

Appendix 3. **Penetrometer Readings (1/10 mm)**
30 % Non-Bread-Cereal



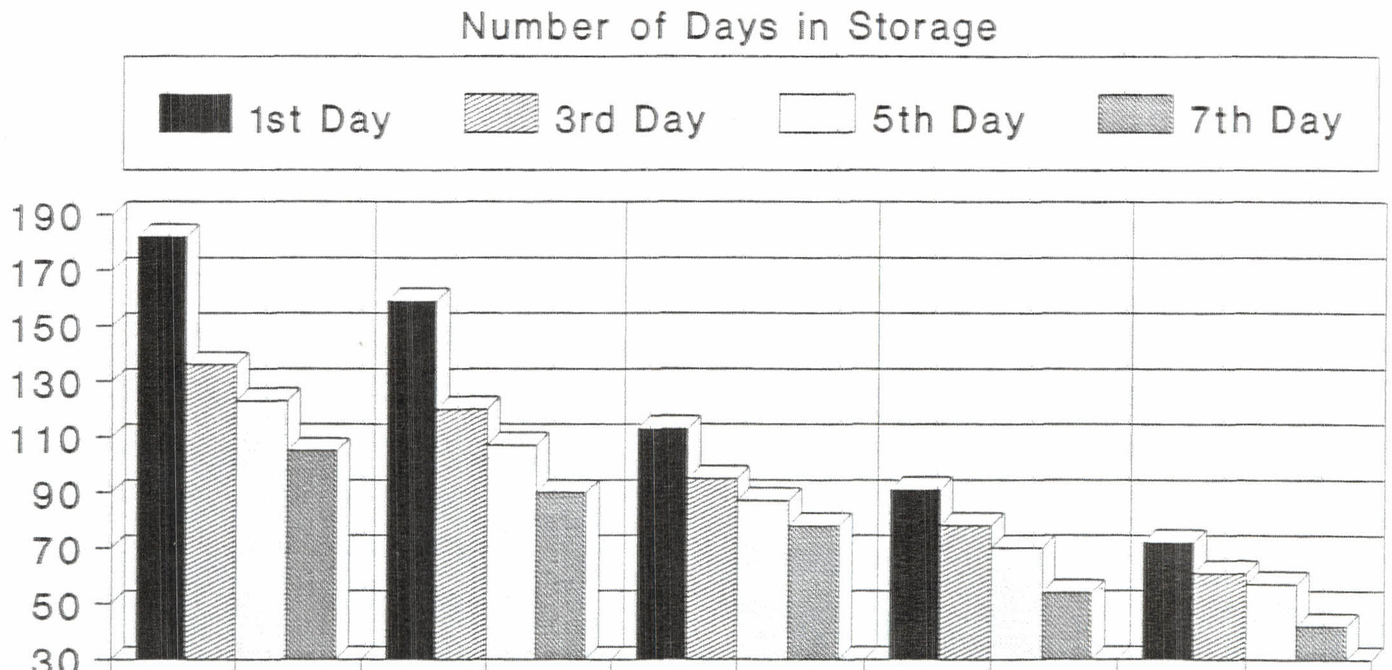
	P.M. Flour	P.M. Semolina	Maize Flour	Maize Semolina	Maize Grits
1st Day	91	123	109	116	144
3rd Day	78	84	92	82	112
5th Day	70	73	84	79	92
7th Day	54	65	70	70	81

Appendix 4. **Penetrometer Readings (1/10 mm) 40 % Non-Bread-Cereal**



	P.M. Flour	P.M. Semolina	Maize Flour	Maize Semolina	Maize Grits
1st Day	72	92	88	85	124
3rd Day	61	60	71	71	100
5th Day	57	57	54	65	80
7th Day	42	48	44	54	68

Appendix 5. Penetrometer Readings (1/10 mm)
Pearl Millet Flour

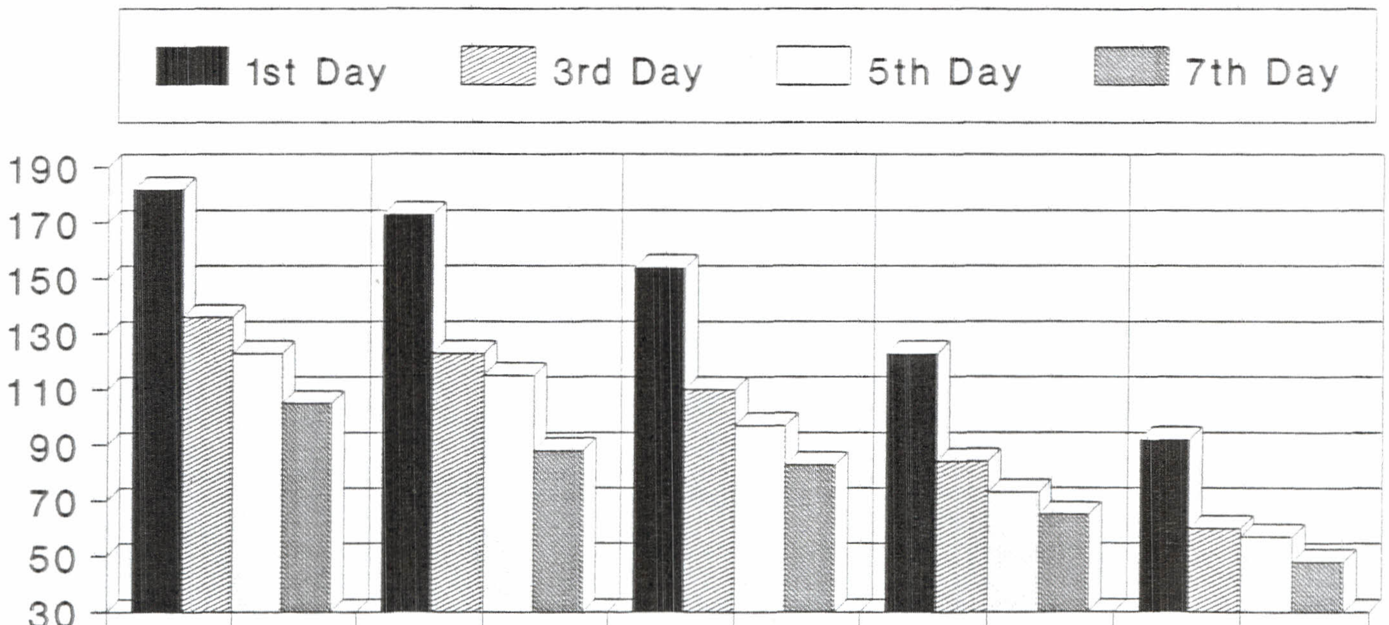


% Replacement	0	10	20	30	40
1st Day	182	159	113	91	72
3rd Day	136	120	95	78	61
5th Day	123	107	87	70	57
7th Day	105	90	78	54	42

Appendix 6. **Penetrometer Readings (1/10 mm)**

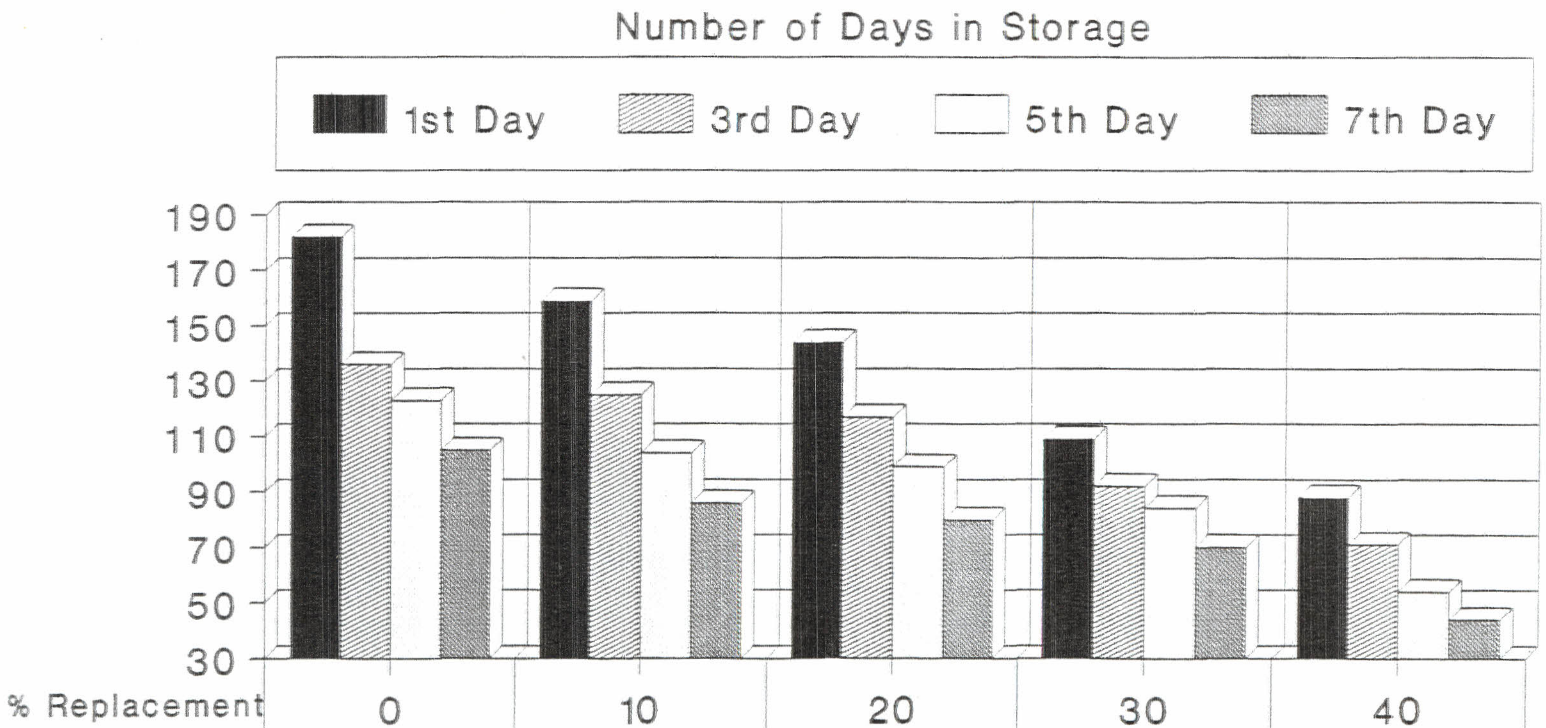
Pearl Millet Semolina

Number of Days in Storage



% Replacement	0	10	20	30	40
1st Day	182	173	154	123	92
3rd Day	136	123	110	84	60
5th Day	123	115	97	73	57
7th Day	105	88	83	65	48

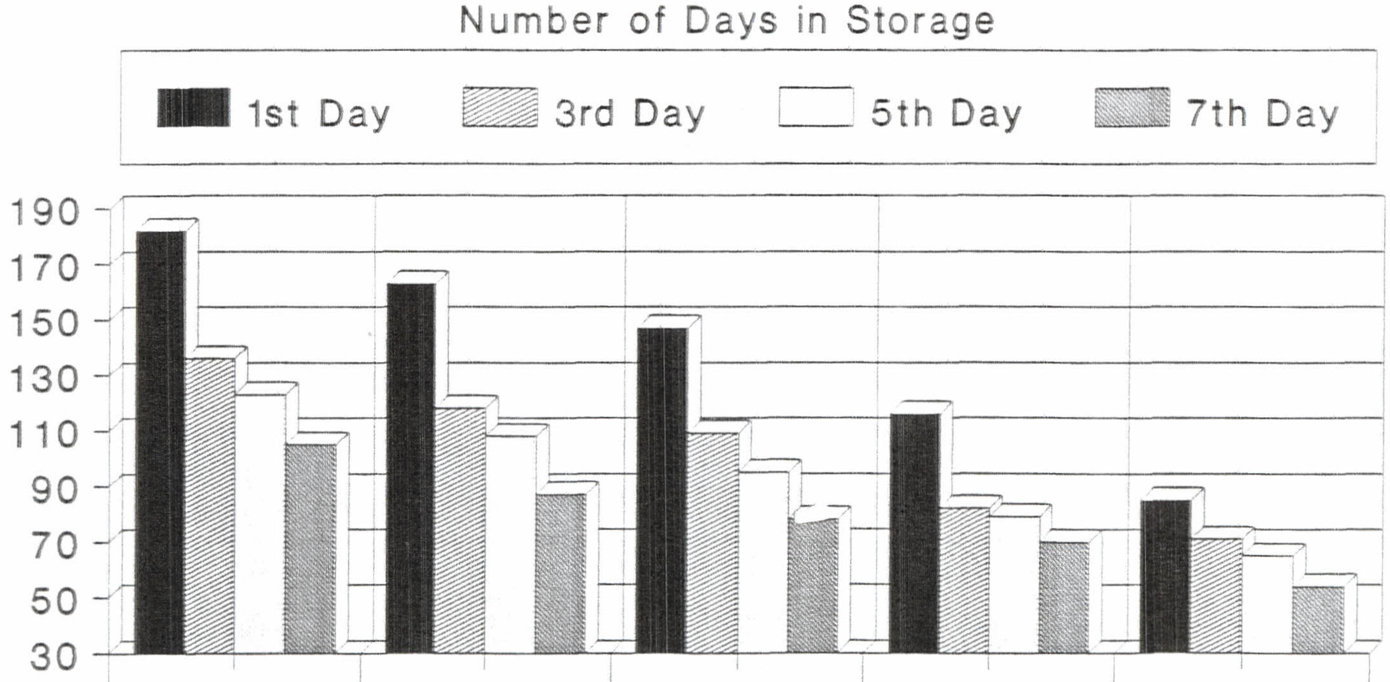
Appendix 7. Penetrometer Readings (1/10 mm) Maize Flour



% Replacement	0	10	20	30	40
1st Day	182	159	144	109	88
3rd Day	136	125	117	92	71
5th Day	123	104	99	84	54
7th Day	105	86	80	70	44

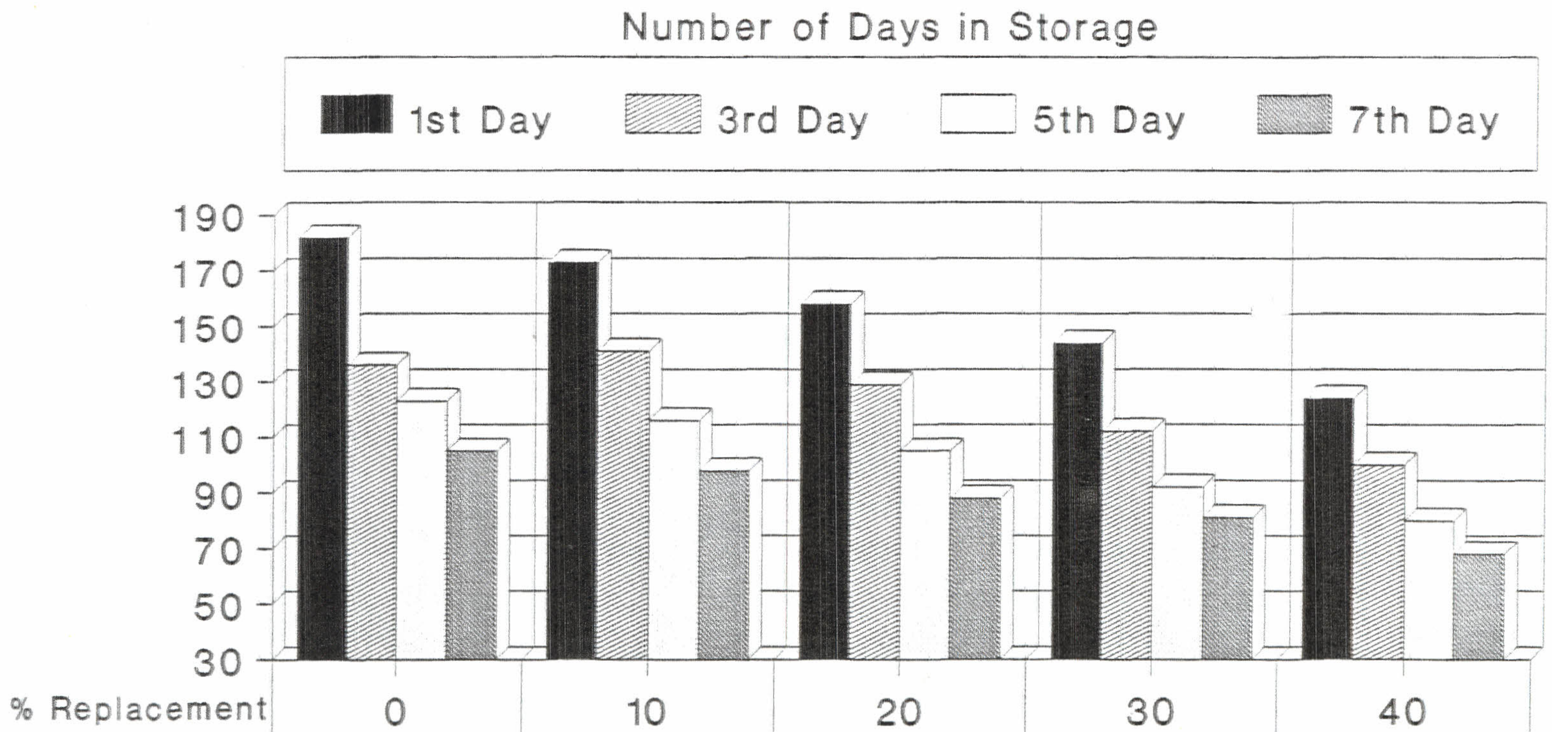
Appendix 8. **Penetrometer Readings (1/10 mm)**

Maize Semolina



% Replacement	0	10	20	30	40
1st Day	182	163	147	116	85
3rd Day	136	118	109	82	71
5th Day	123	108	95	79	65
7th Day	105	87	78	70	54

Appendix 9. Penetrometer Readings (1/10 mm) Maize Grits



% Replacement	0	10	20	30	40
1st Day	182	173	158	144	124
3rd Day	136	141	129	112	100
5th Day	123	116	105	92	80
7th Day	105	9[illegible]	88	81	68

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