

**Quality Attributes of Breads Made from Wheat - Millet Composite Flours Fortified with Vital  
Wheat Gluten**

by

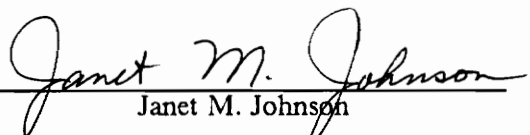
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QUALITY ATTRIBUTES OF BREAD MADE FROM  
WHEAT-MILLET COMPOSITE FLOURS  
FORTIFIED WITH VITAL WHEAT GLUTEN

BY

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Human Nutrition and Foods

(ABSTRACT)

The effects of incorporating pearl millet (Pennisetum americanum (L.) Leeke) flour into wheat (Triticum aestivum L.) flour along with vital wheat gluten were evaluated. Bread was made from wheat Flour (control) and composite flours of 30%, 40%, and 50% pearl millet Flour replacement with (5%) and without vital wheat gluten. The quality attributes of the loaves were assessed by dough rheology tests, differential scanning calorimetry (DSC), and both objective and sensory evaluation.

Farinograph results indicated that millet flour decreased absorption (water uptake) when compared to the control, decreased peak time for dough development and dough stability. Vital wheat gluten increased dough stability of the composite flours.

A stepwise decrease in loaf volume was observed with each increase in millet content of the composite flours. Addition of vital wheat gluten did not significantly

increase the loaf volume of the breads. Bread made from higher percentages of pearl millet flour also had a higher moisture content, firmer texture and darker crumb color.

Differential scanning calorimetry (DSC) results indicated that the control breads staled faster and that loaves of bread containing 50% millet flour with gluten exhibited the least amount of staling by day 7.

Results of sensory evaluation indicated that millet flour replacement resulted in bread with darker crumb and crust color, and a more bitter and intense after taste. Vital wheat gluten was judged by panelists to darken crust color, increase cell uniformity and improve chewiness. Consumer panelists preferred bread made from 30% millet without wheat gluten over the breads made from the other composite flours.

In conclusion, pearl millet flour can be used to replace part of wheat flour in the bread making process and the addition of vital wheat gluten is not necessary.

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## TABLE OF CONTENTS

ABSTRACT.....	ii
ACKNOWLEDGEMENTS.....	iv
TABLE OF CONTENTS.....	v
LIST OF TABLES.....	vii
LIST OF FIGURES.....	viii
INTRODUCTION .....	1
RATIONALE FOR STUDY.....	3
REVIEW OF LITERATURE.....	5
Pearl Millet Flour.....	6
Wheat Flour.....	7
Composite Flour.....	10
Vital Wheat Gluten.....	12
Functions of Bread Ingredients.....	13
OBJECTIVES.....	17
MATERIALS AND METHODS.....	18
Experimental Design.....	18
Ingredients.....	20
Milling of Millet.....	20
Bread Baking Procedure.....	20
Proximate Composition of Flour.....	21
Dough Rheology.....	22
BAKING CHARACTERISTICS OF COMPOSITE FLOUR	
Volume of Bread.....	22
Crust and Crumb Color of Bread.....	22

Moisture Content of Bread.....	22
Tenderness.....	23
Staling of Bread.....	23
SENSORY EVALUATION Q.D.A.....	24
Consumer Acceptance Test.....	24
STATISTICAL ANALYSIS.....	25
RESULTS AND DISCUSSION	
Proximate Composition.....	28
Dough Rheology.....	32
Volume.....	39
Moisture Content.....	45
Tenderness.....	47
Crumb and Crust Color.....	47
DSC OF Wheat and Millet Flour.....	52
Bread Crumb Staling.....	54
Sensory Evaluation (Q D A).....	60
Consumer Preference.....	65
CONCLUSIONS.....	72
FURTHER RESEARCH NEEDED.....	74
LITERATURE CITED.....	75
APPENDIX A .....	82
APPENDIX B.....	84
APPENDIX C.....	86
VITA.....	92

## LIST OF TABLES

TABLE	PAGE
1. Experimental design for evaluation of pearl millet and vital wheat gluten in breadmaking.....	19
2. Mean proximate composition of whole millet, millet flour and wheat flour.....	31
3. Mean farinogram data for composite flours and Trump flour (control).....	33
4. Mean results for crumb color of control and breads from various composite flours.....	50
5. Mean results for crust color of control and breads from various composite flours.....	51
6. Mean scores for sensory attributes of baked breads (1).....	61
7. Mean scores for sensory attributes of baked breads (II).....	6 2

## LIST OF FIGURES

Figure	PAGE
1. Sensory score card for Q.D.A.....	26
2. Sensory score card for consumer evaluation.....	27
3. Farinograms of control flour and 30% millet flour variations.....	34
4. Farinograms of control flour and 40% millet flour variations.....	35
5. Farinograms of control flour and 50% millet flour variations.....	36
6. Mean loaf volume of control and breads baked from various composite flours.....	40
7. Photograph showing breads baked from 30% millet flour variations and control.....	41
8. Photograph showing breads baked from 40% millet flour variation and control.....	42
9. Photograph showing breads baked from 50% millet flour variation and control.....	43
10. Photograph showing all bread variations.....	44
11. Mean moisture content of control breads and breads baked from various composite flours.....	46
12. Mean tenderness of control breads and breads baked from various composite flours.....	48
13. DSC thermograms of wheat and millet flour.....	53
14. Extent and rate of bread staling of bread	

measured by the DSC.....	56
15. Extent and rate of bread staling of bread measured by the DSC.....	57
16. Extent and rate of bread staling of bread measured by the DSC.....	58
17. Mean results from consumer testing.....	66
18. Circular graph showing composite flour with millet flour replacement.....	68
19. Circular graph showing composite flour with millet flour replacement.....	69
20. Circular graph showing composite flour with millet flour replacement.....	70
21. Circular graph showing all bread variations.....	71

## CHAPTER 1

### INTRODUCTION

Milletts are small seeded, annual cereal grasses that are adapted to hot climates (Hulse et al., 1980). At least four varieties of millet are grown in different parts of the world. These are pearl millet (Pennisetum americanum (L.) Leeke), proso millet (Panicum miliaceum L.), finger millet (Eleusine coracana (L.) Gaertn.), and foxtail millet (Setaria italica (L.) Beauv.) Pearl millet is the most widely grown of all millets. It is drought resistant and is grown primarily in the Sahel zone across Africa and in the semi arid areas of India (Hoseny et al, 1981). Pearl millet kernels are usually tear shaped and have a relatively small size in comparison with other cereals. Millet like other cereal grains , contains three morphological parts : pericarp, embryo and endosperm. The grain endosperm is composed of both hard and soft parts. The hard endosperm contains starch granules embedded in a protein matrix containing protein bodies ranging in size from 0.3 to 0.4um (Badi et al, 1976, Sullins and Rooney, 1977). The soft endosperm has loosely packed, spherical starch granules covered with a thin sheet of protein.

In most developed countries, millets are used mainly as animal feed, whereas in Africa and India, millet is a dietary staple supplying a large portion of the human

requirements for protein, energy, and micronutrients.

Advancing national propensity and urbanization coupled with increasing population in recent years have led to an increase in the consumption of wheat - based products such as bread in subsaharan Africa.

Bread is one of man's oldest foods and is an almost universal article of the diet. Wheat is the most widely cultivated of all the cereal grains and is preferred for cereal milling into flour (Demus, 1969). Wheat flour is the only flour that will produce good quality bread, cakes, cookies, and pasta (Hosseney and Seib, 1978). However, wheat production is not evenly distributed all over the world. In many of the less developed countries where bread consumption is increasing, the climate and soil conditions are not ideal for the production of wheat varieties. As a result of this, these countries spend foreign currency to import wheat or flour. The world wide inflation in commodity prices has resulted in considerable loss in foreign currency, which most African countries cannot sustain. Therefore use of a composite flour with a reduced amount of wheat is one approach to help solve this problem.

PROBLEM STATEMENT AND RATIONALE FOR THE PROPOSED  
INVESTIGATION

Pearl millet by virtue of its remarkable sturdiness and adaptability to conditions of moisture and stress and its short growing period is a main source of calories and proteins in the driest and poorest regions of the world (Awadella, 1974).

The nutritional advantages of pearl millet are well known and, include a protein content which is generally higher than other grains (Burton et al, 1972). Some disadvantages of using millets in foods intended for human consumption include difficulties in milling due to the small kernel size (DeFrancisco et al, 1982), rapid off flavor development in the milled grain due to its high oil content (Shasi and Kapor, 1983) and the fact that pearl millet is low in gluten proteins (Shawney and Naki, 1969) which are needed to produce a dough that will entrap gas during yeast fermentation and yield a well aerated loaf of bread with good volume, a unique quality found in wheat flour alone (Matz, 1972 ; Pyler, 1973).

The increasing price of wheat and its shortage in many less developed countries prompted this study to replace part of wheat flour used in bread making with flour of locally grown grains. Millet flour seems an obvious choice because

it is drought resistant, has a short growing period, and a high protein content.

The effects of incorporating pearl millet flour into wheat flour along with vital wheat gluten have not been studied. This proposed investigation will prepare a composite flour from wheat flour and millet flour for bread baking and study the effects of vital wheat gluten on the baking qualities.

## CHAPTER 11

### REVIEW OF LITERATURE

#### PEARL MILLET

Pearl millet may be divided into two broad classes; (1) varieties harvested within 60-90 days and (2) late season varieties which mature within 130-150 days (Hulse et al, 1980) The many cultivars vary in several readily apparent characteristics, including height which ranges from 0.5-4 m, and size, shape and colour of the grain which may be near white, pale yellow, brown, grey, slate-blue or purple.

There are several references to the chemical composition and nutritive value of pearl millet. Pennisetum grain is among the most nutritious of the major cereal grains. It's protein content is not only high but of good nutritional quality (Rachie and Majmudar, 1980). Animal tests show that lysine is the limiting amino acid in pearl millet protein. Rats fed ground whole millet gained an average of 24 g in 35 days, whereas, similar rats gained an average of 132g when 0.3% lysine hydrochloride was added to the diet (Howe and Gilfillan, 1970). Both diets contained adequate levels of all nutrients except for protein of the millet. Lysine is thus, the limiting amino acid in millet.

Shawhney and Naki (1969), studied protein fractions distributed in several pearl millet varieties. The storage proteins (prolamin and glutenin) predominated and comprised

over 60% of the total proteins. The albumin fraction averaged 15% and globulin 9% respectively. The prolamin and glutelin fractions ranged from 21% to 38%. The prolamin fraction was deficient in lysine, and sulfur containing amino acids but strikingly rich in tryptophan in contrast to maize and sorghum.

Sawaya and Khalil (1983) conducted a study on the nutritional quality of pearl millet flour and bread. Pearl millet flour was found to contain 17.4% protein, 6.3% fat, 2.8% fiber and 2.2% ash. Lysine was the limiting amino acid. Linoleic acid (44.8%), oleic acid (63.3%) and palmitic acid (22.3%) were reported to be the dominant fatty acids in the millet. In vitro digestibility of millet flour was 75.6% and the protein efficiency ratio was 1.38 in comparison to casein values of 90% and 2.50 respectively.

Khalil and Swaya (1984) studied the mineral content of Saudi Arabian pearl millet flour and bread and concluded that pearl millet is superior to many cereals in its profile of essential mineral elements and water soluble B vitamins. They reported that millet bread contributed approximately the following percentages of the United States Recommended Dietary Allowances (U.S.R.D.A) requirement, 3% of Ca, 6% of Zn, 11 - 12% of Mg, 31% of P, 17-31% of Fe, 2% vitamin B12, 5% folic acid, 5-6% niacin, 6-8% riboflavin, and 11-15 % of thiamine.

Pearl millet contains about 67% - 72% carbohydrate, of which starch is the major constituent (Rachie and Majmudar 1980). Badi et al., (1976) characterized the composition of pearl millet starch and found the starch fraction to contain 17% amylose and 83% amylopectin.

## WHEAT FLOUR COMPONENTS IN BREAD MAKING

### PROTEIN CONTENT

The bread making potential of wheat flour is largely associated with the quantity and quality of its' proteins (Pomeranz, 1980). The proteins in wheat include water soluble proteins (albumin), salt soluble proteins (globulins), alcohol soluble proteins (prolamins or gliadins) and acid/alkali soluble proteins (glutelins).

Wheat is unique among cereals in that it contains water insoluble gluten proteins which enable a wheat flour dough to entrap gas during yeast fermentation. The glutenin fraction makes up approximately 40% of the proteins in wheat flour and is responsible for the viscoelastic properties of the dough. However, an over abundance of glutenin proteins would likely produce resistance to the expansion of gas cells in wheat flour dough resulting in reduced bread volume (Pylar, 1973). When water is added gliadin and glutenins combine to form a three dimensional viscoelastic complex called gluten which is largely

responsible for the variation in baking quality. MacRitchie (1980), demonstrated that gluten proteins manifest its variation from one flour to another by interacting with the lipid content. The question of whether loaf volume can be attributed to a specific protein fraction remains unanswered.

Wheat gluten imparts to dough physical properties that differ from those of doughs made from other cereal grains. It is gluten formation rather than any distinctive nutritional property, that gives wheat its prominence in the diet.

Early work demonstrated there was a simple correlation between some bread-making quality parameters and the proportions of each protein fraction or combination of fractions in wheat. Orth and Bushuk, 1972, showed that the proportions of both glutenin and residue protein had a direct effect on baking performance. The gliadin proteins are responsible for loaf volume and their quantity varies in flour that differ in bread making potential (Hoseney et al., 1978). However the presence of excessive gliadin proteins in wheat flour would result in poor carbon dioxide retention and possible dough collapse (Cheftel et al., 1985). Wheat flour also contains starch granules, pentosans, polar and non - polar lipids, and soluble proteins, all of which contribute to the formation of a dough network and

final texture of bread.

#### LIPIDS IN BREAD MAKING

Flour lipids make an important contribution to the dough properties, baking behavior and bread staling (MacRitchie, 1981). MacRitchie (1977) demonstrated the role of lipids in bread making and reported that loaf volumes were higher in breads baked with lipid containing flour than from defatted flour. Studies with defatted flour have shown that nonpolar lipids are deleterious and that polar lipids are beneficial in bread making (Pomeranz 1980). Daftary, (1968) reported that the deleterious effect of non polar lipids can be counteracted by polar lipid, and the effect on loaf volume has been shown to depend on the level of nonpolar lipids as well as the non polar lipid ratio. Although lipids are minor flour components, they have major importance in bread making.

#### INTERACTION OF LIPIDS, PROTEINS AND STARCH IN BREAD BAKING

During dough development, lipids interact mainly with gluten rather than with soluble wheat flour proteins thus promoting gas retention in doughs (Pomeranz, 1980). During baking, lipids interact mainly with starch.

The significance of starch-protein interactions in bread systems was demonstrated by Hosney et al.,(1978).

Fractionation studies have shown that starch although contributing to water absorption, is not essential for optimum loaf volume.

Wehrli and Pomeranz (1970) studied interactions that take place between starch and gluten proteins in dough and bread using galactolipids. In the dough, the galactolipids were distributed in the gluten and to a limited extent, in the starch. In bread, most of the galactolipids were associated with the gelatinized starch granules and formed a complex, which seemed to be responsible for the improved retention of freshness in bread baked with glycolipids. Wehrli (1969) proposed that glycolipids improved gas retention and, hence, loaf volume, by sealing the gas, presumably by complexing with the swelling starch granules and the coagulating proteins.

#### COMPOSITE FLOURS

A composite flour refers to a dry mixture of milled cereals. Wheat is usually combined with other starch and protein sources including those derived from other cereals, nuts, food legumes and oil seeds. Several researchers have reported the use of composite flour in bread making, snack food and pasta products. The bread making properties of wheat flour blends have often been rejected (Tsen, 1974). However slight modifications in the bread making process

complimented by functional additives have improved the quality of such breads (Fleming and Sosulski, 1974).

Pearl millet flour has been used to replace part of wheat flour with reasonable success. Badi et al (1976) incorporated 5%, 10% and 20% millet flour into the straight dough baking procedure. However a reduction in loaf volume was observed when millet flour was used beyond ten percent.

Awadella (1974) reported that replacing wheat flour with Pearl millet flour decreases the baking quality of the flour and this decrease was compensated to a great extent by the addition of dough improvers or dough conditioners such as seeds high in fat and by chemical additives such as S-S-L (sodium stearyl-2-lactylate), diactyl tartaric acid and esters of mono and diglycerides. Badi and Hosenev (1976) evaluated the use of millet and sorghum flour (Sorghum bicolor L.) in the production of cookies. They observed that cookies made from pearl millet did not spread during baking, had a poor top grain texture and were compact and dense.

It is sometimes desirable to fortify bakery products with proteins for nutritional enrichment or dough improvement. This is done either by the miller or the baker. Isolated gluten can be added to wheat flour to reinforce the dough network.

## VITAL WHEAT GLUTEN

Vital wheat gluten is concentrated natural wheat protein in the form of a light tan powder. It is produced from hard wheat flour by kneading wheat flour with about an equal amount of water, to produce a soft dough which is then washed gently. The starch and the water soluble proteins separate from the gluten. The wet gluten, which contains about 30% gluten and 70% water is then dried rapidly at low temperature to prevent denaturation of the protein. The end product is about 75% gluten.

Rather than using high - protein flours for production of specialty breads, bakers can fortify their basic flours with gluten to obtain desired performance. Since gluten is natural wheat protein, its addition to a white bread dough increases the protein (gluten) content, and the added gluten functions in a manner similar to the gluten in flour (Dubios, 1974).

Gluten is normally added to to a flour to improve dough strength, processing tolerance, and also to improve gas retention (Stenvert et al., 1981). Other applications include; (1) increasing the protein content of a flour which is inherrently low in protein; (2) improving the "carrying" capacity of a dough which may contain a high proportion of material (e.g fiber) which can dilute or disrupt the available protein.

Vital wheat gluten's unique viscoelastic properties, improve dough strength, mixing tolerance, and dough handling properties. It's film forming ability provides gas retention and controlled expansion for improved loaf volume, cell uniformity, and texture. It's water absorption capacity improves baked product yield, softness and shelf life. Vital gluten is used in hard rolls, multigrain, high fiber and other specialty breads at levels ranging from 2% to 10% (Magnuson, 1985).

## THE FUNCTION OF INGREDIENTS IN THE BREAD BAKING FORMULA

### FLOUR

Flour is the single most important and basic ingredient in bread making (Bennion, 1985). This is because the flour provides the proteins that, when hydrated and mixed, produce gluten. Gluten is responsible for extensibility and elasticity of the dough.

### WATER

Water and flour provide the foundation for bread making (Jenkins, 1975). Water performs many functions. First, in order to make gluten, water must be present to hydrate the proteins. Starch granules also become hydrated during gluten formation. During baking, water is absorbed by the starch and becomes gelatinized. The degree of gelatinization

depends largely on the percentage of moisture present. Secondly, water encourages the activity of flour enzymes and also provides part of the moisture requirement for yeast cells to flourish (Jenkins, 1975). Water also acts as a solvent to dissolve other ingredients used in bread making.

### SALT

Salt is added for taste and for dough handling. Salt helps swelling of flour proteins, shorten the gluten, reduces dough extensibility, improve gas retention, bread crumb grain, and slicing properties (Jenkins, 1975). Salt has a firming effect on gluten structure. Breads made without salt are often crumbly in texture.(Bennion 1985).

### Yeast

Yeast is used in bread-making for three basic reasons; (1) leavening action due to the carbon dioxide that is produced; (2) flavor development, as a consequence of the alcohols, esters and flavour precursors that are formed ; and (3) dough development.

## FATS

Fats in a dough system generally lubricates the ingredients, improve moistness, tenderness, extend shelf life and provide nutritional benefits (Pyler, 1973). The use of fats in dough was reviewed by Bell et al (1977), who visualised two mechanisms of shortening effect: chemical and physical. The chemical effect involves lipid oxidation. This mechanism was considered insignificant in bread-making process. Bell et al., (1977) showed that the rate of carbon dioxide released was faster in doughs baked with shortening than without. Fat incorporation in dough increased gas retention in the initial stage of rapid expansion.

The use of fat in dough brings about a variety of changes in the dough which ultimately affects the finished product. During mixing the fat is dispersed into the dough and a thin film of fat is deposited throughout the dough which lubricates the strands of gluten proteins. The effect of lubrication allows the gluten to become more extendable in a very short period of time, which promotes the retention of gases (Bennion, 1985).

## SUGAR

Apart from providing sweetness, sugar enhances fermentation and browning, improves dough stability, elasticity, and makes the bread crumb tender (Bennion 1985).

Bennion also reported that bread flavour, texture, and browning are affected by the use of sugar although the browning of bread is primarily the result of the Maillard reaction. Campbell (1972) stated that due to the ability of sugar to increase the coagulation temperature of proteins and the gelatinization temperature of starch, the tenderness and elasticity of the crumb is further enhanced. In addition, sugars have a tendency to retain moisture which helps to retard staling.

#### **MILK**

Milk and other liquids help to dissolve sugar and other solutes, hydrate proteins, and partially gelatinize starch (Campbell 1972). Milk contains a reducing sugar, lactose, which is involved in the browning reaction and accentuates the crust colour (Matz, 1972). Whole milk was reported to have a tenderizing effect due to the presence of milk fat, while skim milk has a toughening effect.

SPECIFIC OBJECTIVES OF THIS STUDY ARE (1) to produce an acceptable loaf of bread with satisfactory quality attributes from a composite flour of wheat and pearl millet, (2) to test the effects of vital wheat gluten on the baking qualities of these composite flours.

The overall goal of this study was to utilize Pearl millet as a replacement for wheat, to reduce dependence on wheat.

**MATERIALS AND METHODS**

The statistical design of this study was an incomplete block design. The two factors or independent variables tested in this study were: 1. the level of millet flour (30%, 40%, and 50%) and 2. the use of gluten (present or absent). Bread was made from composite flours containing various levels of millet flour as a replacement for wheat flour either with or without vital wheat gluten as shown in Table 1.

Breads were baked from the composite flours in a pilot study to determine which flours might be useful in bread baking. Farinograph and rapeseed displacement (loaf volume) tests were used to determine which variations of composite flours to use in the study.

Three replications of each treatment were prepared using a balanced incomplete block design. All bread samples were baked twice during the first week on Sunday and Thursday. Sensory and objective tests were performed on Monday and Friday. During the second week, all samples were baked three times; Sunday, Tuesday, and Thursday. Sensory and objective test were performed on Monday, Wednesday and Friday. (See Appendix A). Each bread sample was assigned a single digit number. The combinations used for objective test and sensory evaluation were randomly chosen. (See Appendix B)

**TABLE 1**  
**Experimental Design for Evaluation of Pearl Millet**  
**and Vital Wheat Gluten in Bread making.**

WHEAT FLOUR (%)	MILLET FLOUR (%)	GLUTEN (5%)
65%	30%	WG
70%		WOG
55%	40%	WG
60%		WOG
45%	50%	WG
50%		WOG

**WG = WITH GLUTEN**

**WOG = WITH OUT GLUTEN**

## INGREDIENTS

Pearl millet was purchased from Conlee Seed, Plain View, Texas. "Trumps", high gluten, enriched brominated, bread flour and "saf" instant dry yeast were purchased from a bakery in Blacksburg, Virginia. Vital wheat gluten was purchased from Watson foods, Boston MA. The vital wheat gluten had a moisture content of 6.15 and protein content of 74%.

All the other ingredients were purchased from Radford Brothers Blacksburg, Virginia. Crisco shortening, Carnation instant nonfat dry milk, Morton iodized salt, and Richfood granulated sugar were used for this study.

## MILLING OF MILLET

Milling was done according to an adapted AACC Method 26-20 (AACC, 1983) for milling wheat. The Quadromat junior experimental mill model No.279 with fixed break roll settings was used. The millet was first tempered to a moisture content of 16% for 18hr, then milled and sifted through a No.60 mesh screen.

## BREAD BAKING PROCEDURE

An adapted Straight dough method (AACC 10-11, 1983) was used to produce bread from the composite flours. The bread

formulations are given in Appendix C. The bread ingredients were weighed to the nearest 0.1g on a Mettler top loading balance (model P100) Heighstown, NJ. A Hobart Kitchen Aid mixer (model K5-A) Troy Ohio, with a Galab experimental timer (Dayton Ohio) were used to mix the dough. The breads were baked in a Conventional General Electric oven (Louisville, KY) (Model J336B1DC) at 425 degree celsius for 20 minutes.

All ingredients except for millet flour and yeast were stored in air tight containers throughout the study. The millet flour was stored in a air tight plastic containers in a Fridgedaire refridgerator to prevent rancidity. The yeast was stored in a plastic container in the refridgerator according to the manufacturer's instructions.

#### PROXIMATE COMPOSITION

Whole millet, millet flour, and wheat flour were analyzed to determine their proximate composition. Moisture content was determined by oven drying at 128 degrees celsius for 4hrs. Ash content was determined by oven drying at 105 degrees celsius followed by decomposition in a muffle furnace at 550 - 620 degrees celsius for 12hrs. The fat content was determined by soxhlet extraction using petroleum ether. The protein content was determined by micro - Kjeldahl procedure (AOAC, 1984) using a conversion factor

of 6.25 for whole millet and millet flour and 5.7 for wheat flour. The carbohydrate content was determined by difference. All analyses were performed in triplicate.

#### DOUGH RHEOLOGICAL PROPERTIES

The rheological properties of dough made from composite flours was investigated using a farinograph (C.W. Brabender Instruments South Hackensack , N.J.) using the AACC method 54-21 (AACC, 1983). The resistance of the dough to mixing was evaluated by arrival time, mixing time, departure time, mixing stability and mixing time index.

#### COLOR

The crust and crumb color of the baked bread were analyzed by a Hunter lab - scan spectrophotometer (Reston, Virginia). Three inch slices of crust and crumb portions were placed over the aperture that supplies the light source. The 'L', 'b' and  $\Delta E$  values were recorded.

#### VOLUME

The volume of the baked breads for each treatment were determined using a rapeseed displacement method (Brys and Zabik, 1976).

**TENDERNESS** Objective evaluation of bread crumb tenderness was determined using a Stevens - LFRA Texture analyzer (Model T A 100, Texture Technology Corp; Scarsdale, New York). Specifications were determined during a pilot study. The following Specifications were used for measurements:

- A. TA 11 probe was used.
- B. The depth of penetration was 5mm.
- C. The penetration speed of the probe was 2mm/sec.

#### **DIFFERENTIAL SCANNING CALORIMETRY (DSC)**

A differential scanning calorimeter (DSC) with micro processor controller (Perkin - Elmer - 4 system, Norwalk, Ct) was used to study the starch gelatinization and protein denaturation of millet flour and wheat flour. The staling of the bread crumb made from various composite flours was also studied using the DSC. The instrument was calibrated with an indium standard. For the staling test, breads were baked on a Monday and DSC analysis was done on the following Tuesday (Day 1), Wednesday (Day 2), Friday (Day 4) and Monday (Day 7). Bread crumb samples were weighed into the DSC stainless steel pans and distilled water was added with a microsyringe at a ratio of 2:1 two parts bread and one part water. Adding water increased the measured enthalpy of melting amylopectin crystallites and made their detection possible earlier during bread storage than thermogram determinations without

added water. The pans were then hermetically sealed to prevent explosion. The heating rate was 10 C/min, and the temperature range was 10-130 C. All samples were analyzed in duplicate.

## SENSORY EVALUATION

Sensory evaluation is defined as a scientific discipline used to evoke, measure, analyze and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, touch, taste and hearing (Stone and Sidel, 1985). The Quantitative Descriptive Analysis (QDA) method of Stone and Sidel, (1985) was used for the sensory evaluation. A trained panel of fourteen judges were selected from the graduate students of Human Nutrition and Foods. Panelist selected were not taking any medication that would interfere with taste acuity. Each panelist was assigned a number which was kept throughout the tasting period.

During the training session, each panel member was presented three slices of bread baked with 35% millet flour, and the panelist identified the sensory attributes of the bread. The attributes agreed upon by the panelists were: crust color, crumb color, moistness, cell size, after taste, cell uniformity, chewiness and bitterness. (See Figure 1 for sensory score card).

A nine point hedonic test was used to test the consumer acceptance of the bread made from various composite flours. Fifty students from the African Student Association were used as judges because the product is developed for use in Africa. (See Figure 2 for sensory score card).

#### STATISTICAL ANALYSIS

Statistical analysis was conducted on all main effects. Number cruncher (NCSS procedure, 1985) was used for the computations. Two-Way Analysis of Variance was done to determine if any significance exist between variables and multiple comparisons : Newman Keuls test was used to determine difference in means. Means were considered significant if p values were less than 0.05 ( $p < 0.05$ )

### SENSORY SCORE CARD

PANEL No \_\_\_\_\_

DAY \_\_\_\_\_

Please examine each slice of bread carefully according to the following attributes by placing a Vertical line with the corresponding number on the slice of bread the line.

CRUST COLOR: \_\_\_\_\_

LIGHT

DARK

CRUMB COLOR: \_\_\_\_\_

LIGHT

DARK

CELL SIZE: \_\_\_\_\_

SMALL

LARGE

CELL UNIFORMITY: \_\_\_\_\_

LESS

MORE

CHEWINESS: \_\_\_\_\_

LESS

MORE

BITTERNESS: \_\_\_\_\_

LESS

MORE

AFTER TASTE: \_\_\_\_\_

LESS

MORE

Figure. 1. Sensory score cards for bread samples. (QDA)

**SENSORY SCORE CARD**

PLEASE MAKE A SLASH ON THE HORIZONTAL LINE FROM 1 - 9  
ACCORDING TO YOUR PREFERENCE OF EACH SLICE OF BREAD WITH ITS  
CORRESPONDING NUMBER.

1 = DISLIKE EXTREMELY, 9 = LIKE EXTREMELY.

- |    |   |       |   |
|----|---|-------|---|
| 1. | 1 | ----- | 9 |
| 2. | 1 | ----- | 9 |
| 3. | 1 | ----- | 9 |
| 4. | 1 | ----- | 9 |
| 5. | 1 | ----- | 9 |
| 6. | 1 | ----- | 9 |
| 7. | 1 | ----- | 9 |

-----  
Numbers 1 - 7 = Bread variations

FIGURE. 2: CONSUMER TEST SENSORY SCORE CARD OF BREAD  
SAMPLES.

## CHAPTER 1V

### RESULTS AND DISCUSSION

The purpose of this study was to produce an acceptable loaf of bread with satisfactory quality attributes from a composite flour of wheat and pearl millet and to test the effect of vital wheat gluten on the baking qualities of this composite flour.

Seven different loaves of bread were prepared to compare the effects of replacing part of the wheat flour with pearl millet flour and the effect of vital wheat gluten on the baking quality of these flours. Objective and sensory tests were performed to judge the quality of the different bread variations. The objective tests that were performed included dough rheology, loaf volume, moisture content, tenderness, lightness or darkness of crust, crumb color and bread crumb staling (see Appendix A for time table of study). The sensory attributes judged by taste panelist were crust colour, crumb colour, cell size, cell uniformity, chewiness, bitterness and aftertaste (see Appendix B for sensory evaluation design).

### PROXIMATE COMPOSITION

#### MOISTURE CONTENT

The percent of moisture that a food contains can be determined on the basis of the amount of water and volatile

compounds which will evaporate under specific drying conditions. Efficient flour milling requires knowledge of the moisture content of the grain before processing, and of the distribution of water in various parts of the kernel after conditioning and during milling. The amount of water that a grain contains is economically significant and may result in certain advantages or disadvantages at various stages of marketing.

Millet flour had a significantly higher ( $p < 0.05$ ) moisture content than whole millet (see Table 2). This was expected since the millet grain was tempered to a moisture content of 16% prior to milling. Wheat flour also had a lower moisture content than millet flour and was lower than that reported by Perten (1983). This may be attributed to the high gluten content of the Trump flour.

The objectives of milling are to separate endosperm from bran and germ, and subsequently to reduce endosperm particles into flour. The ash test can be used as an indicator of the purity of the flour, and the thoroughness of the separation of bran and germ from the rest of the wheat kernel. Analysis of the flours indicated that millet flour contained a significantly ( $p < 0.05$ ) higher ash content than the wheat flour (Table 2). Whole millet also had a significantly ( $p < 0.05$ ) higher ash content than millet flour. This was expected since the bran and germ fractions had not

been separated from the rest of the kernel in the whole millet. The results here were in agreement with that reported by Perten (1983) who detected similar differences in the ash content of wheat flour, whole millet and millet flour.

The millet flour also had a significantly higher fat content than wheat flour (Table 2). These results correspond with the findings of Khan and Eggum (1978) who reported a difference in the fat content of wheat flour and millet flour. Whole millet also had a higher ( $p < 0.05$ ) fat content than millet flour. This observation was expected since the bran and especially the germ fraction which contained most of the fat content of the cereal were removed during the milling process.

The protein content of wheat and wheat flour are extremely important because almost all flour properties (water absorption, mixing requirement, mixing tolerance, handling characteristics, loaf volume, and even bread crumb grain) are highly correlated with protein content (Pomeranz, 1980). Milling of the millet grain reduced ( $p < 0.05$ ) the protein content of the grain. Whole millet had a higher ( $p < 0.05$ ) protein content than millet flour (Table 2). This could be due to the removal of the bran and endosperm fractions of the grain during the milling process. These sections contain some of the protein contained in the grain.

TABLE 2 . MEAN PROXIMATE COMPOSITION OF WHOLE MILLET, MILLET FLOUR, AND WHEAT FLOUR.

	MOISTURE (%)	ASH (%)	FAT (%)	PROTEIN (%)	FIBER (%)	CHO (%)
WHEAT Flour	11.8 a	.08 a	1.0 a	14.9 a	0.4 a	71.8 a
Whole Millet	11.1 a	2.0 b	4.0 b	13.8 b	2.4 b	62.7 b
MILLET Flour	15.1 b	1.3 c	2.4 c	10.1 c	2.0 b	73.1 c

CHO = CARBOHYDRATE

Mean within the same columns with different superscripts are significantly different at  $p < 0.05$  level.

Wheat flour had a significantly ( $p < 0.05$ ) higher protein content than millet flour.

#### DOUGH RHEOLOGY (FARINOGRAPH)

Dough resistance is determined by its rheological properties, particularly viscosity. The farinograph measures the dough's resistance to mixing during successive stages of its development (Blocksman, 1984). The farinograms of the composite flours are illustrated in Figure 3, 4, and 5. The curves in each figure are a reflection of water absorption, dough development and dough breakdown.

Absorption of water is the one of the farinograph measurements and it is one of the most important physical factors affecting dough development and loaf volume. Absorption is defined as the amount of water required to center the farinogram curve on the 500 BU line for a flour - water dough. Table 3 lists the percent absorbance for each composite flour. Merritt and Stamberg (1941) have shown that absorption increases approximately 1.5% for each 1% increase in the protein content of the flour. Protein content of the composite flours was increased with the addition of 5% vital wheat gluten. An increase in absorption was observed in the farinograms of all the composite flours containing vital wheat gluten. Farinogram data of composite flours showed a significant ( $p < 0.05$ ) decrease in absorption compared to the

TABLE 3. Mean Farinogram Data for Composite Flour and Trump Wheat Flour (control).

COMPOSITE FLOUR	WATER ABSORPTION (%)	PEAK TIME (min)	DOUGH STABILITY (min)	MIXING INDEX (Bu)
30% w/o	61 a	3.25 a	4.5 a	80 a
30% w/g	68 b	3.88 b	5.2 b	70 a
40% w/o	62 a	3.38 a	4.0 a	100 b
40% w/g	66 b	3.5 ab	4.5 a	100 b
50% w/o	62 a	2.5 c	3.7 c	100 b
50% w/g	65 b	3.38 a	4.1 a	85 a
CONTROL	75 c	8.50 d	9.0 d	40 c

w/o = without vital wheat gluten

w/g = with vital wheat gluten

Means in the same column with different superscripts are significantly different at  $P < 0.05$  level.

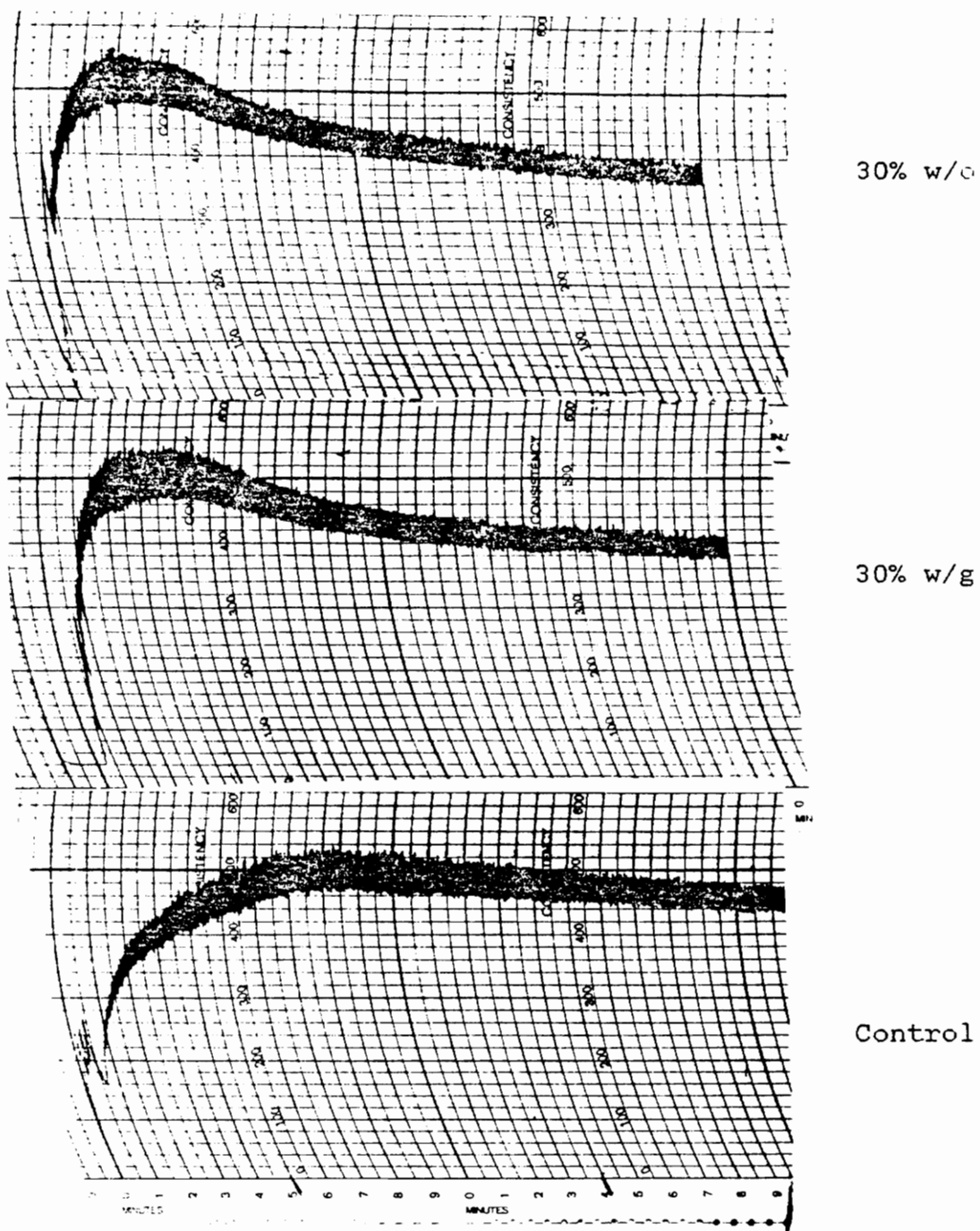


Figure 3. Farinograms of control flour and composite flours.

w/g = with gluten.

w/o = without gluten

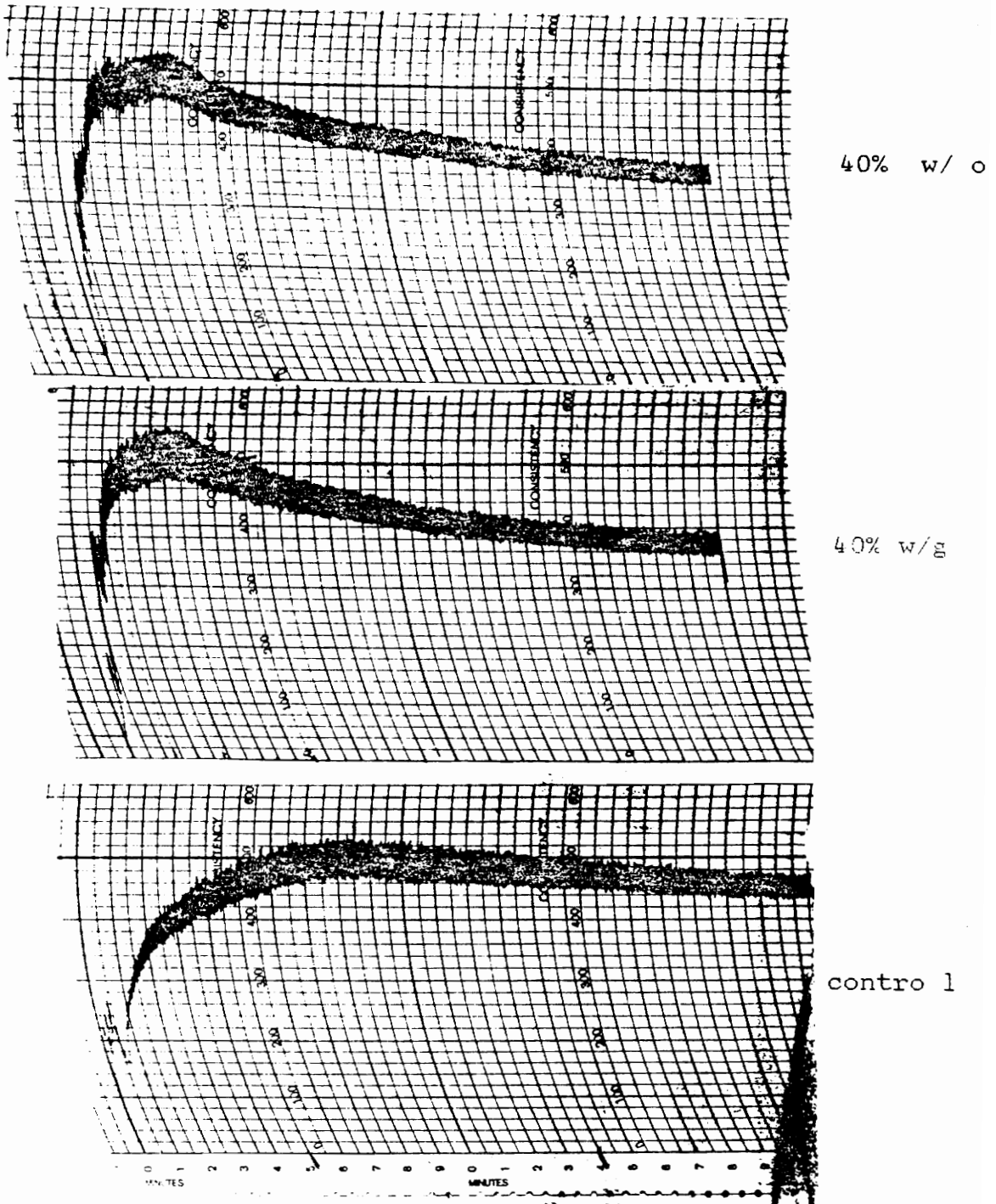


Figure 4. Farinograms of control flour and composite flours.

w/g = with gluten.

w/o = with out gluten.

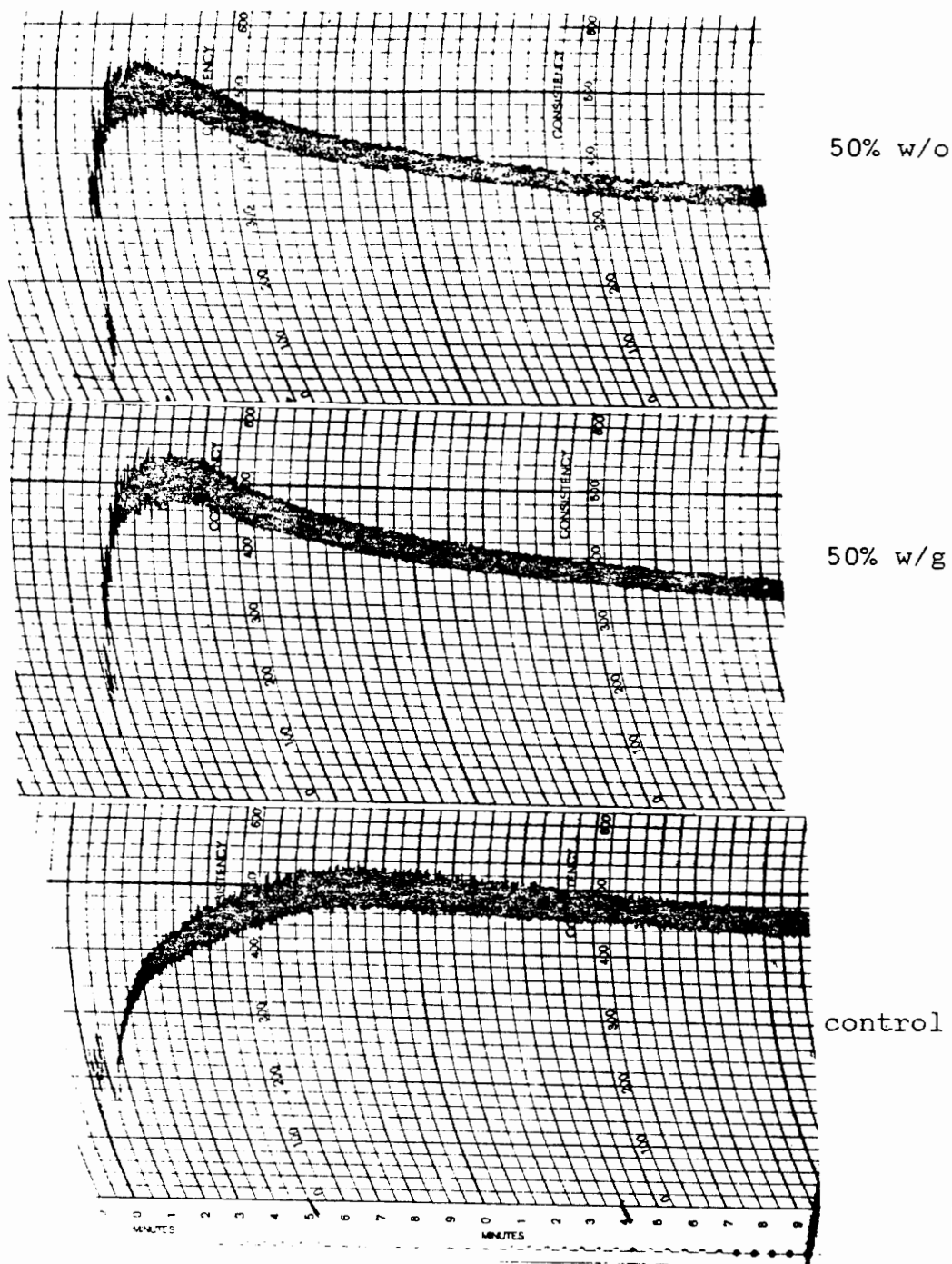


Figure 5. Farinograms of control flour and composite flours

w/o = with out gluten.

w/g = with gluten.

control. However no significant differences ( $p < 0.05$ ) were observed as the amount of millet flour increased. These results are in agreement with those reported by Lorenz and Dilsaver (1980) who reported a decrease in absorption in composite flours with Proso millet when compared to the control.

The peak time or dough development time, is a measure of the time needed for the curve to reach it's peak or point of maximum dough consistency. The peak time is an indication of dough development, strong flours yield a longer peak time than weak flours. Table 3 lists the peak time of the composite flours. A significantly higher ( $p < 0.05$ ) peak time was observed in the composite flour containing gluten than with those not containing gluten at the 50% millet flour level. However, this relationship vanishes as the percentage of millet flour decreased. Vital wheat gluten appears to have no effect on the peak time of the composite flours at low levels of millet incorporation.

Farinograph dough stability is defined as elapsed time in minutes between the point at which the top of the curve first intercepts the 500-BU line (arrival time) and the point at which the top of the curve leaves the 500-BU line (departure time). This value is an indication of the flour's tolerance to mixing. Vital wheat gluten did not affect the mixing time stability of the composite flours except at the

30% level. This result indicates that gluten proteins did not increase the mixing tolerance of the composite flour at high levels of millet flour replacement. Table 3 also lists the dough stability for each composite flour. Increment of pearl millet flour lowered the dough stability of the composite flours. This result was similar to that observed by Lorenz and Dilsaver (1970) who reported a decrease in dough stability with increasing level of proso millet flour.

The mixing tolerance index (MTI) was calculated as the value in Brabender Units (BU), between the top of the curve at the peak and the top of the curve measured in minutes after the peak is reached. Generally, flours with good tolerance to mixing have a low MTI value while a higher MTI value indicates a weaker flour. The above relationship was observed in this investigation. Statistical analysis did not indicate that vital wheat gluten had any significant ( $p < 0.05$ ) effect on the MTI value of the composite flours except at the 50% millet flour level. Composite flours with 30% millet flour had a significantly ( $p < 0.05$ ) lower MTI than composite flour containing 40% millet flour. However, this relationship did not occur at the 40% and 50% millet flour levels. A possible explanation for this could be that the quantity of protein does not affect the MTI of the dough after a certain percentage of protein has been reached but the quality of the protein exerts a greater effect on the

mixing tolerance of the dough.

The addition of vital wheat gluten appears to have an effect on the rheological properties of the composite flours. Longer mixing times were required for composite flours containing vital wheat gluten. Replacing part of wheat flour with millet flour also influenced the rheological properties of doughs made from composite flours. Dough stability decreased with increasing content of millet flour. It is possible that overmixing of doughs made from these composite flours may exert a negative effect on the baked product. Shorter mixing times may therefore be required for composite flours containing increasing amounts of millet flour. Overmixing of these doughs may cause the gluten to break down.

## OBJECTIVE TEST OF BREADS

### VOLUME

The loaf volume of breads baked in this study (figure 4) seems to be dependent on two factors : (a) increasing the amount of the millet flour significantly decreased ( $p < 0.05$ ) the volume of bread; and (b) vital wheat gluten did not cause a significant increase ( $p < 0.05$ ) in loaf volume. Figures 5, 6, 7, and 8 show the photographs of the breads baked in this study. Badi et al (1976) also reported a reduction in loaf volume when greater than 10% pearl millet

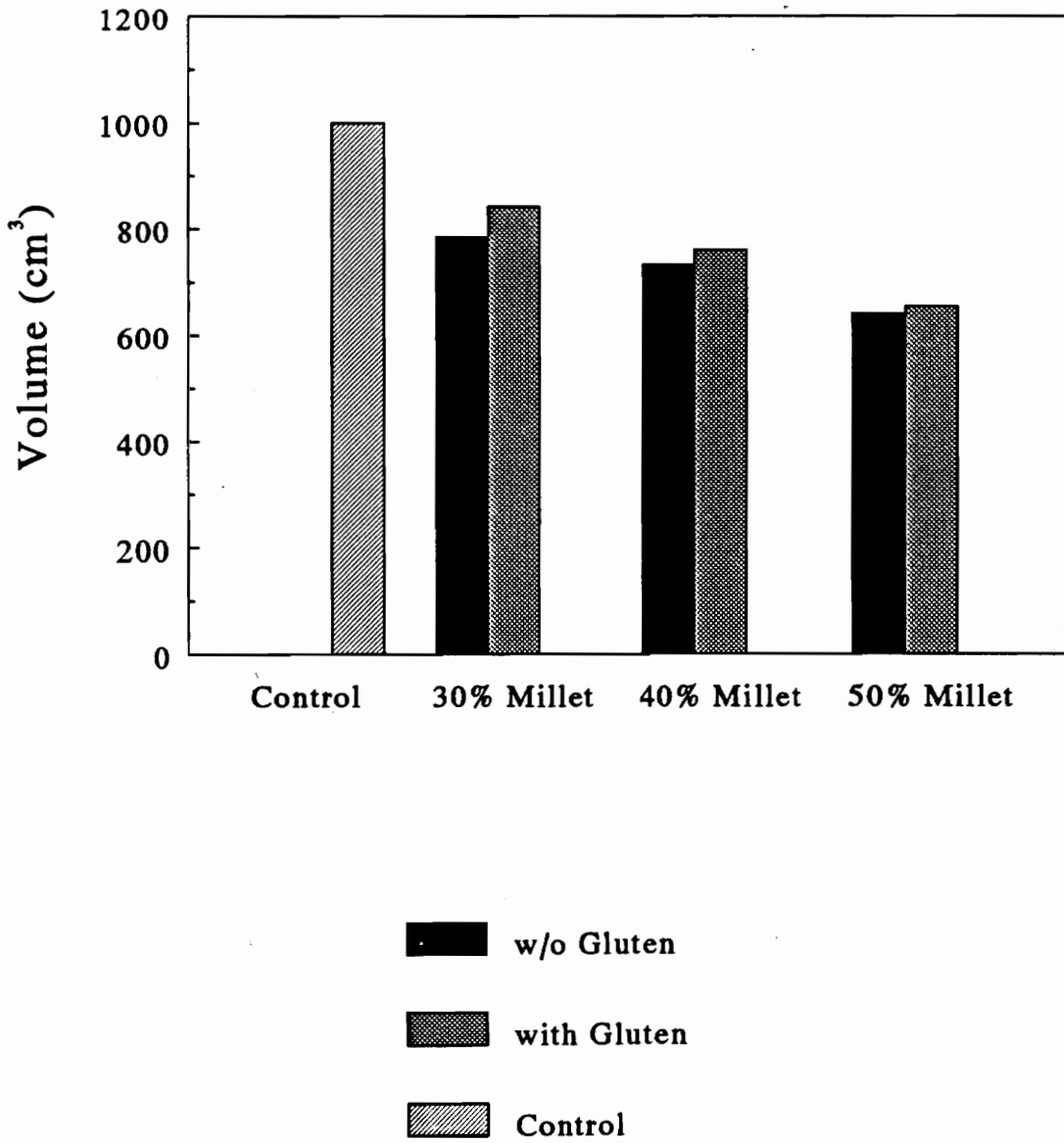


Figure 6. Loaf volume of control breads and breads baked from various composite flours.

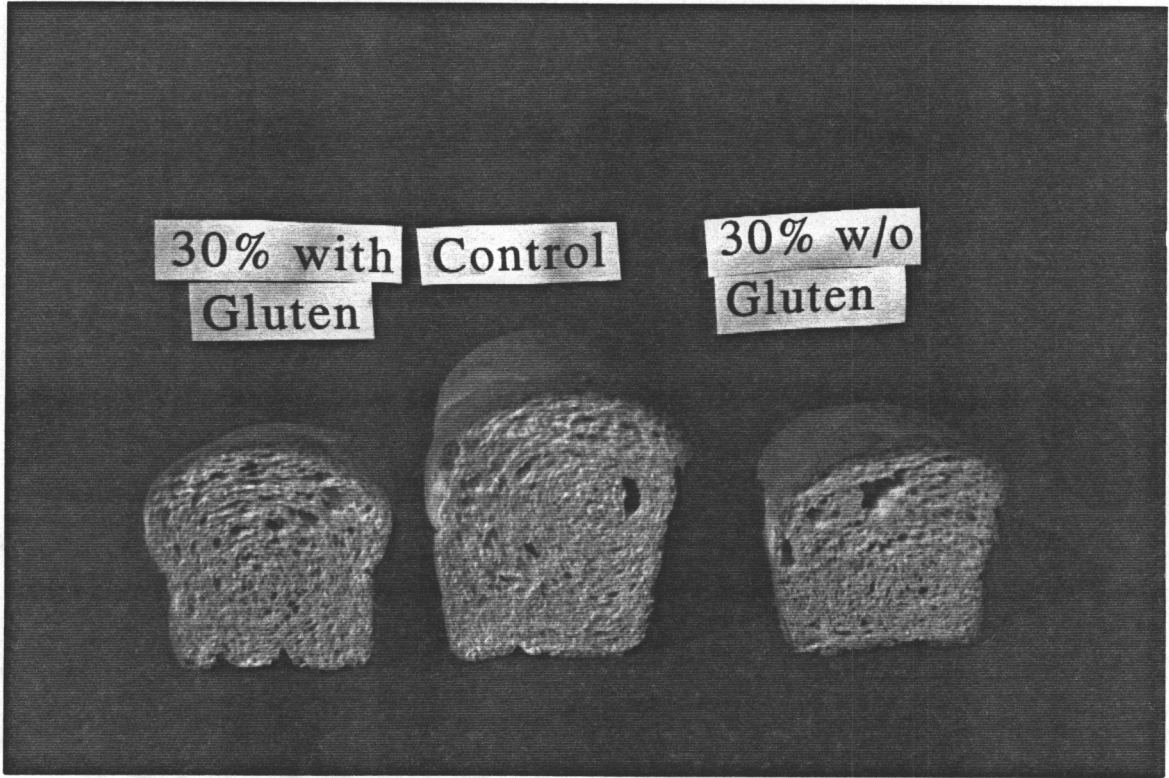


Figure 7. Photograph showing breads baked from 30% millet flour variation and control.

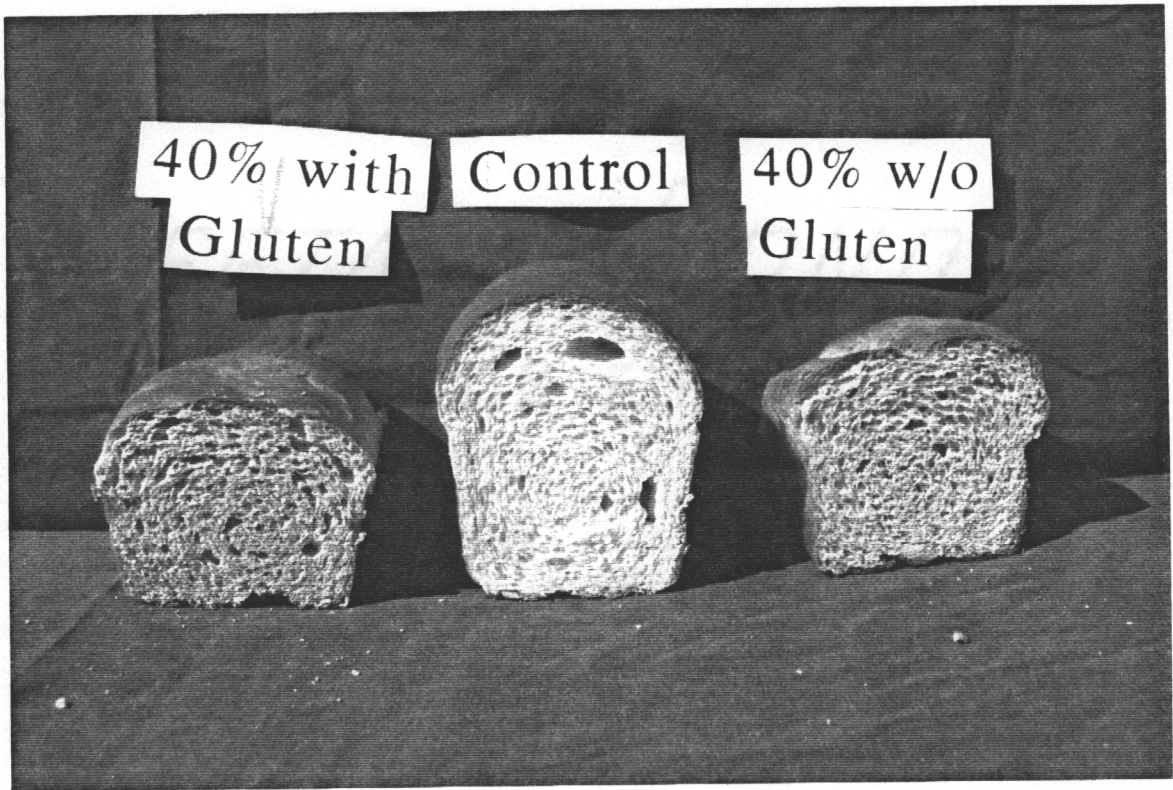


Figure 8. Photograph showing breads baked from 40% millet flour variation and control.

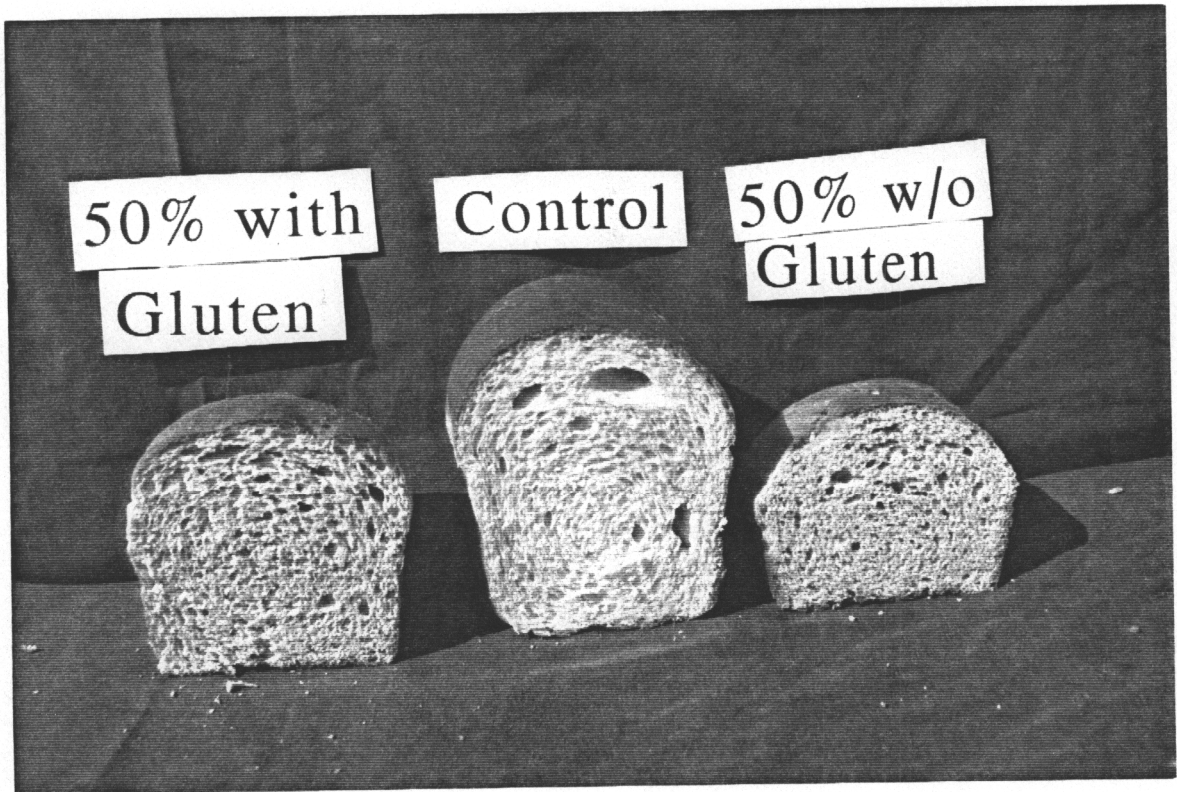


Figure 9. Photograph showing breads baked from 50% millet flour variation and control.

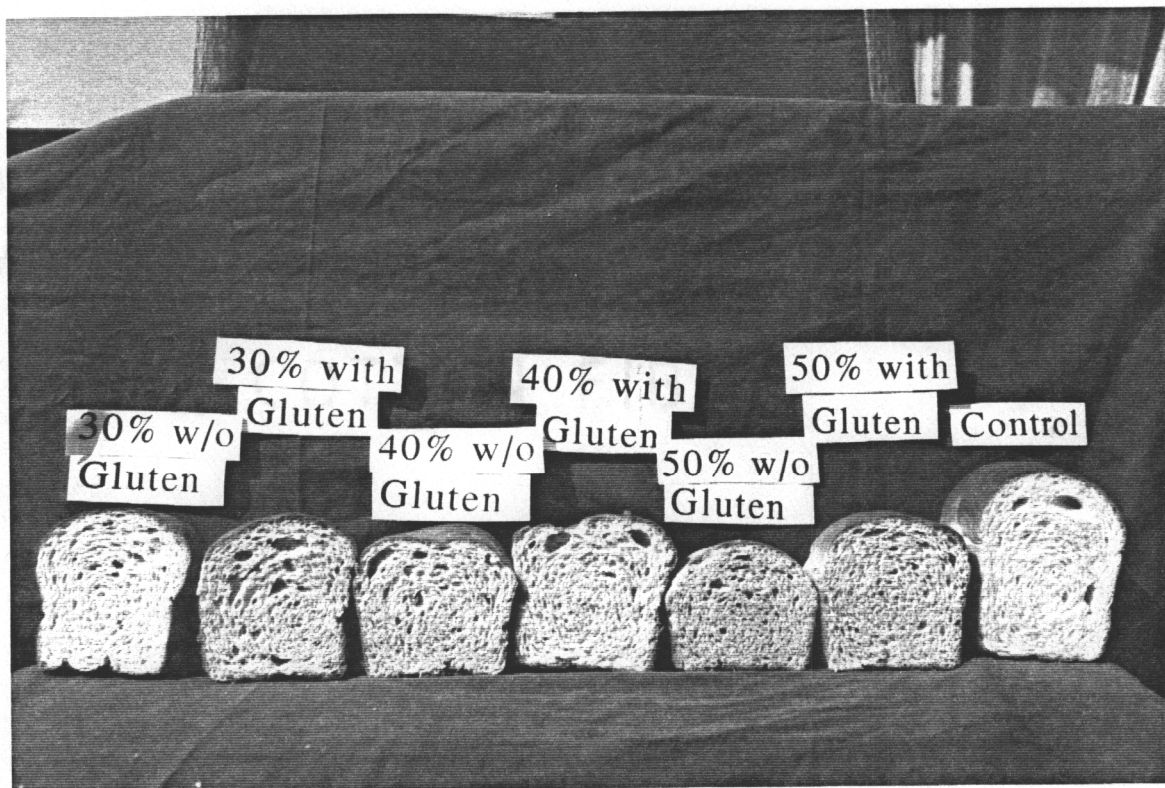


Figure 10. Photograph showing breads baked from all seven variations.

flour was incorporated into the bread baking procedure. Although the addition of vital wheat gluten did not show a significant increase ( $p < 0.05$ ) in loaf volume, slight increases in volumes were observed. It is possible that higher levels of vital wheat gluten fortification may be required to significantly increase loaf volume.

#### MOISTURE CONTENT

Significant differences ( $p < 0.05$ ) were found in moisture content of bread loaves baked from control and composite flours. The control was found to be less moist than loaves made from composite flours. The addition of vital wheat gluten and increasing amount of millet flour seem to affect the moisture content of the breads. Variations prepared with a higher percentage of millet flour had a higher moisture content than breads prepared with lower percentages of millet flour (see figure 11). Vital wheat gluten did not significantly ( $p < 0.05$ ) affect the moisture content of the breads. However, a slight increase in moisture was observed with the addition of vital wheat gluten except at the 50% variation. The high water absorption capacity of gluten may have contributed to this increase in moisture content.

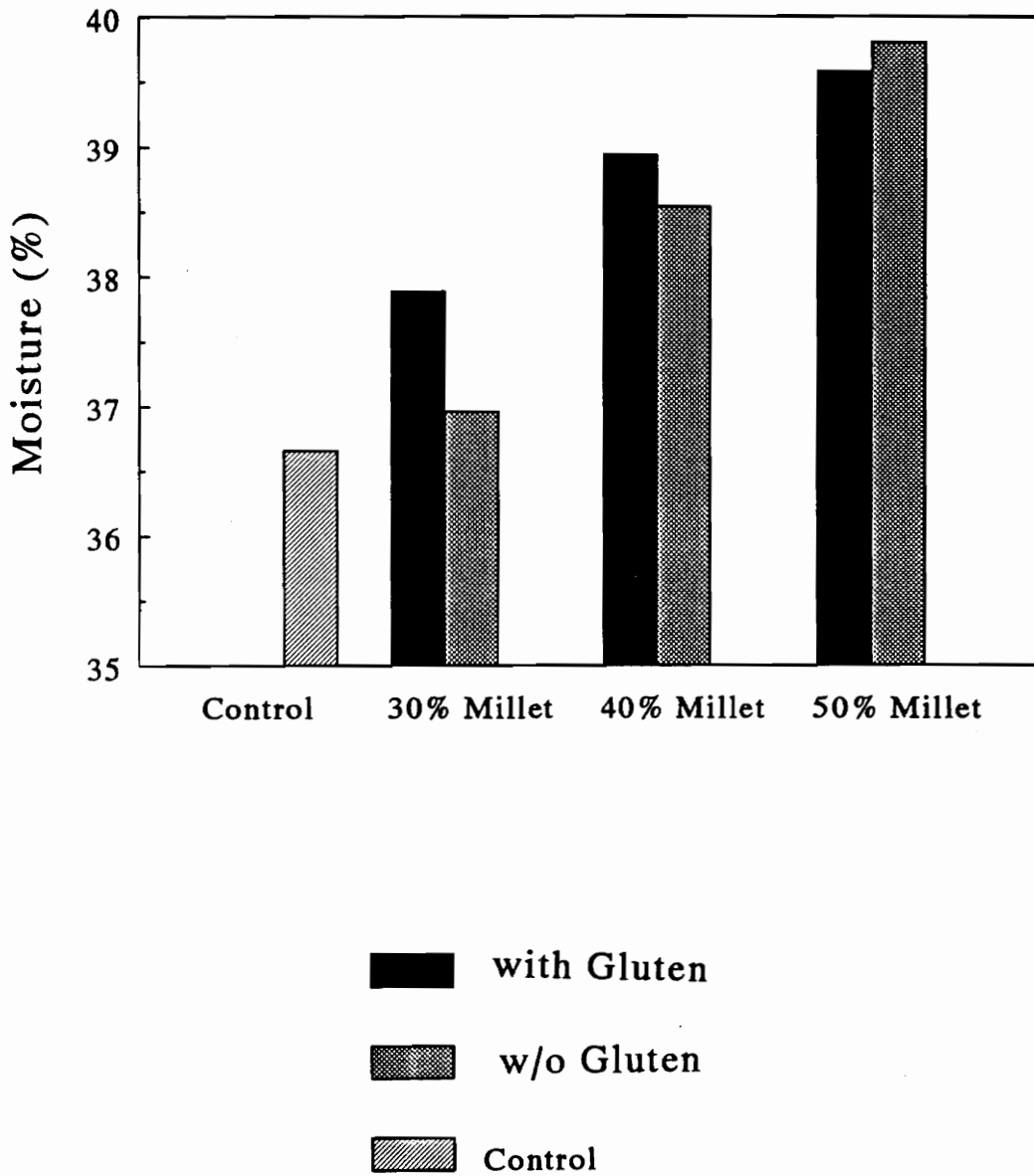


Figure 11. Moisture content of control breads and breads baked from various levels of composite flours.

## TENDERNESS OF THE BAKED PRODUCT

A tender baked product has a soft or yielding texture. The texture analyzer measures the force in grams required to penetrate a specific depth. The value (gm) derived is a measure or indicator of the tenderness of the baked product (bread). The greater the force required the less tender the product. Tenderness was affected by increasing the amount of millet flour and by the addition of vital wheat gluten (Figure 12). Baked products showed a significant decrease ( $p < 0.05$ ) in tenderness with increasing amounts of millet flour. The addition of vital wheat gluten slightly increased the tenderness of the breads except at the 30% millet flour level, where an increase ( $p < 0.05$ ) in tenderness was observed.

## CRUMB AND CRUST COLOUR

A Hunter labscan spectrophotometer was used to measure the crumb and crust color of the bread variations. The values used for crumb and crust color evaluation were : L, b, and  $\Delta E$ . These values correspond to the degree of lightness (L), yellowness (b) and the difference or change in color compared to a standard  $\Delta E$ . A significant decrease was observed ( $p < 0.05$ ) in lightness of the crumb or L value, with increasing amounts of millet flour (See Table 3). A progressive increase was also observed in lightness of bread

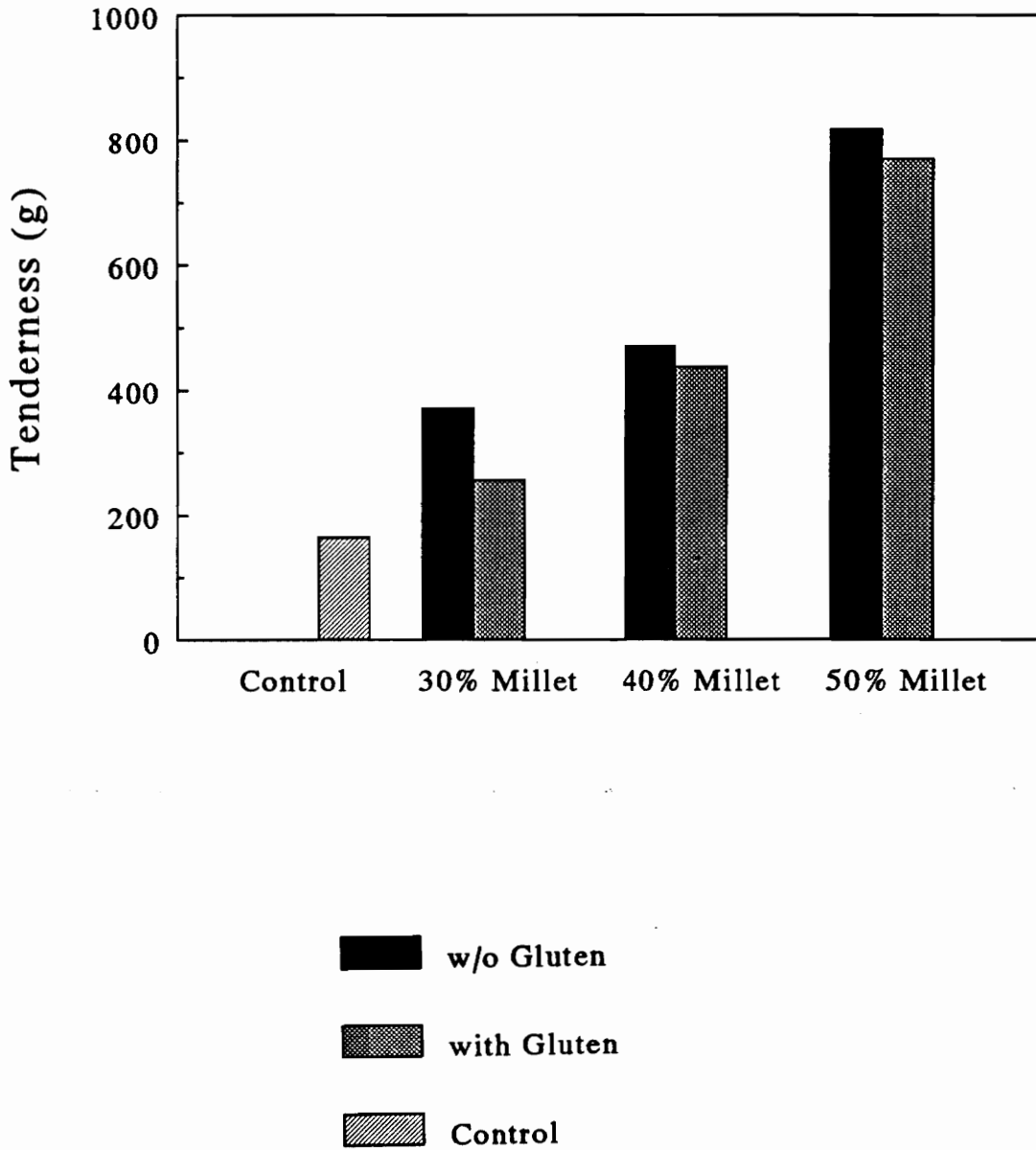


Figure 12. Objective tenderness of control breads and breads baked from various composite flours.

crust where increasing amounts of millet flour was used in bread baking. The light yellow color of the millet flour may have contributed to the decrease in the L value of the crumb when higher levels of millet were incorporated in the composite flour. Bread crumbs with a higher percentage of millet flour had higher b values. The degree of yellowness (b values) may be dependent on the amount of tannin and carotenoid pigments present in the cereal. Pearl millet appears to contain higher amounts of tannin and carotenoids than wheat. Sawaya et al (1984) reported that pearl millet contains 0.17% of tannin, a pale yellow pigment.

Vital wheat gluten appears to decrease the L color of the crumb. No significant ( $p < 0.05$ ) differences were observed in the crumb colour of the 30% and 40% variations. However, there were decreases ( $p < 0.05$ ) in crumb color at the 50% level. These results coincided with changes in the b (yellow) values of the crumb. The beige color of vital wheat gluten may have contributed to the color difference in the bread crumb.

Bread variations prepared with 50% millet flour level were lighter ( $p < 0.05$ ) in crust color than other variations. No differences in crust color were observed in bread variations containing 30% and 40% millet and the control. The observed decreases in crust color with increasing millet content may be due to the fact that pearl millet is

TABLE 4. MEAN RESULTS FOR CRUMB COLOR OF THE CONTROL AND BREADS FROM VARIOUS COMPOSITE FLOURS

FLOUR	L	b	$\Delta E$
30% w/o	71.67 a	+ 19.59 a	74.01 a
30% w/g	70.98 ab	+ 19.65 a	73.72 a
40% w/o	68.26 b	+ 20.33 b	71.18 b
40% w/g	69.16 b	+ 19.65 a	71.79 b
50% w/o	65.47 c	+ 21.07 c	68.75 c
50% w/g	66.33 c	+ 21.20 c	69.58 bc
control	76.50 d	+ 15.02 d	77.89 d

w/o = with out gluten, w/g = with gluten

L = 100 = white ; 0 = black

b = + = yellow ; - = blue

Mean in the same column with different superscript are significantly different at  $p < 0.05$ .

TABLE 5. MEAN RESULTS FOR CRUST COLOR OF THE CONTROL AND BREADS BAKED FROM VARIOUS COMPOSITE FLOURS.

FLOUR	L	b	$\Delta E$
30% w/o	44.83 a	+19.51 a	50.16 a
30% w/g	44.66 a	+19.44 a	51.21 a
40% w/o	45.67 a	+19.69 a	52.69 b
40% w/g	44.47 a	+19.50 a	57.66 c
50% w/o	49.30 b	+20.50 b	54.50 b
50% w/g	48.49 b	+20.59 b	50.48 a
control	53.97 c	+22.98 c	62.21 c

w/o = with out gluten , w/g = with gluten.

L = 100 = white ; 0 = black

b = + = yellow ; - = blue

Means in the same column with different superscript are significantly different at  $p < 0.05$ .

deficient in lysine an amino acid that readily participates in Maillard Browning reactions. Another possibility could be caramelization, which occurs when sugars are heated. Since sucrose was used in the baking formula, the enzymes elaborated by the yeast may have cleaved the nonreducing sucrose into fructose and glucose which would increase caramelization. Vital wheat gluten appeared to have no effect ( $p < 0.05$ ) on the crust color of the various bread variations. Since there is no information at present on the kinds of sugars found in pearl millet, it can not be conclusively stated that browning of the crust color was due to caramelization.

#### DIFFERENTIAL SCANNING CALORIMETRY OF WHEAT FLOUR AND MILLET FLOUR

Figure 13 shows the DSC thermograms and maximum temperature for the starch gelatinization endotherm of millet and wheat flour. Millet flour appears to gelatinize at a higher temperature than wheat flour. These observations corresponded with those of Donovan(1977) who investigated the role of gelatinization of starch in baked products. Starch gelatinization has two functions during bread baking (Allen, 1977); (a) swelling of the starch granules takes place to form the "bricks" which combine with gluten (mortar) to form the final crumb structure and (b) excess

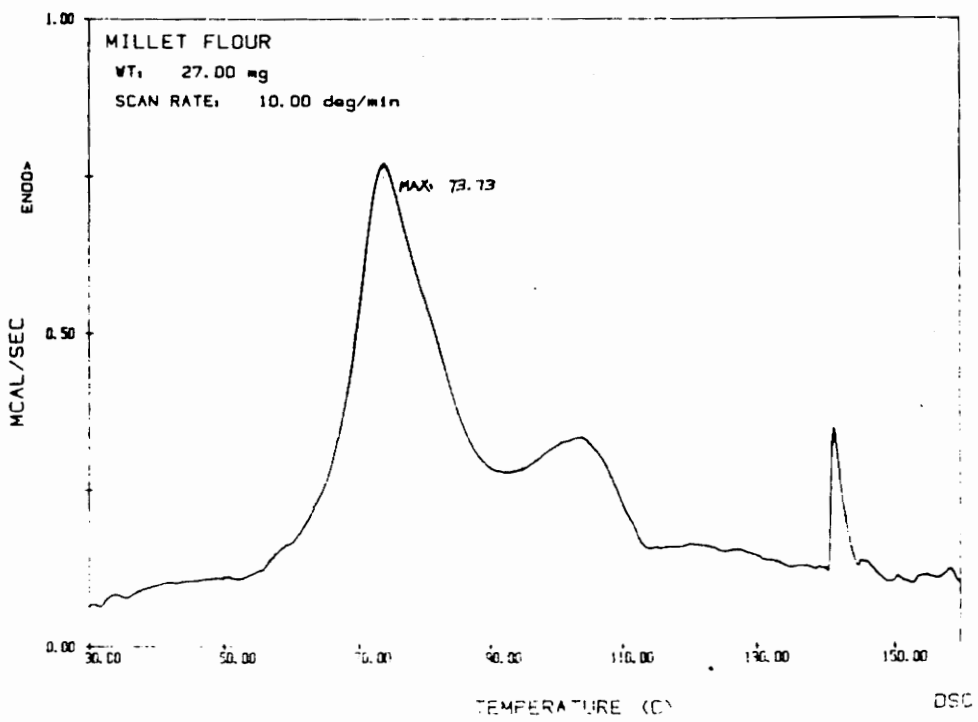
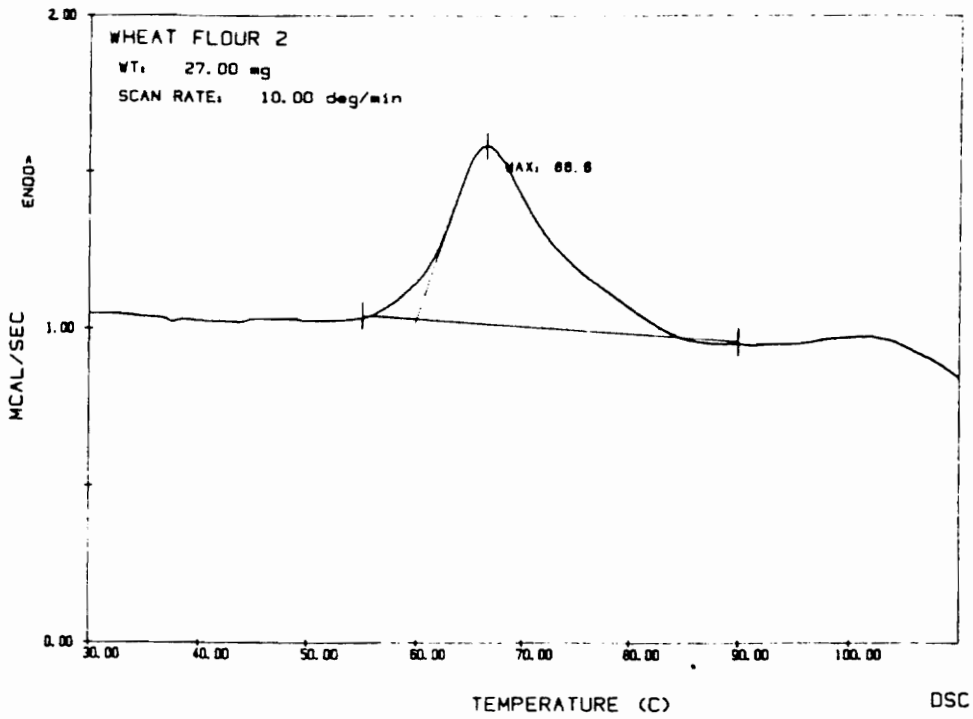


Figure 13. DSC thermograms of wheat and millet flour

water is removed from the crumb via starch gelatinization. Donovan (1977) found that gelatinization of the starch occurred roughly simultaneously with the denaturation of the major portion of the protein in egg white. Therefore, it can be postulated that the gelatinization of the starch in these flours occurred simultaneously with the denaturation some of the flour proteins. The dough attains maximum volume when the starch in the flour and the proteins intermesh simultaneously to form the "structural frame work" of the bread. According to these observations, dough made with millet flour may need higher baking temperatures than those made with wheat flour if the maximum loaf volume is to be attained since the gelatinization temperature is higher for millet flour.

#### BREAD CRUMB STALING WITH THE DIFFERENTIAL SCANNING CALORIMETRY (DSC)

Bread has only a limited shelf life because it is subject to deterioration in quality referred to as bread staling. The crisp and brittle crust becomes soft and leathery and the soft crumb turns hard and crumbly. The pleasant aroma typical of freshly baked bread becomes unpleasant. The primary cause of staling is considered to be retrogradation or crystallization of the starch. The roles of the two starch components, amylose and amylopectin, in bread staling

have been a source of intense discussion (Kulp and Ponte, 1981; D'Appolonia and Morad 1981). Lin (1982) concluded that amylopectin plays a more important role in bread staling than amylose. When stale bread is heated in the DSC a "staling endotherm" appears on the thermogram as a result of the melting of crystallized amylopectin (Eliasson, 1985). The enthalpy,  $\Delta H$  in cal/g calculated from this endotherm is proportional to the amount of the retrogradated amylopectin. Significant increases ( $p < 0.05$ ) in enthalpy were observed in all bread variations as they aged from day 1 to day 7. Czuchajowski and Pomeranz (1989) reported similar results when they used the DSC to measure water activity, and moisture content in bread crumb during staling. The extent and rate of staling in breads as measured by the DSC are illustrated in Figure 14, 15, and 16. During the first two days of storage, retrogradation was significantly greater ( $p < 0.05$ ) in breads baked from 50% millet flour than in breads from 30% and 40% millet flour. The reversed situation was observed on day 4 and 7.

The results from this research suggest that increasing the amount of millet flour retarded retrogradation by day 7. A possible explanation for this could be that millet flour may have a secondary effect on retrogradation due to its high water content. Zelenzak et al (1986) reported that retrogradation in wheat starch gels is controlled by the

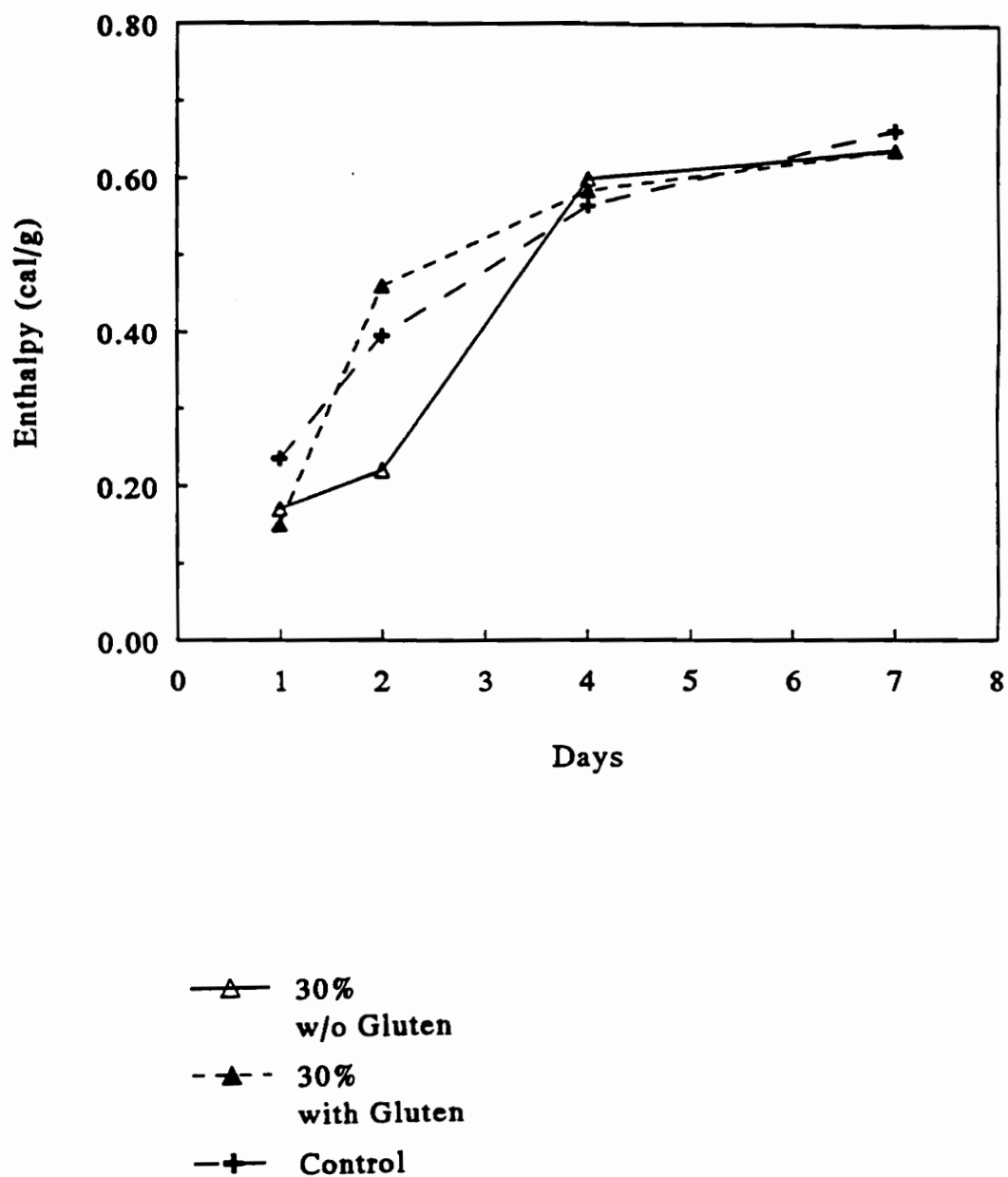


Figure 14. Extent and rate of staling of breads as measured by the DSC.

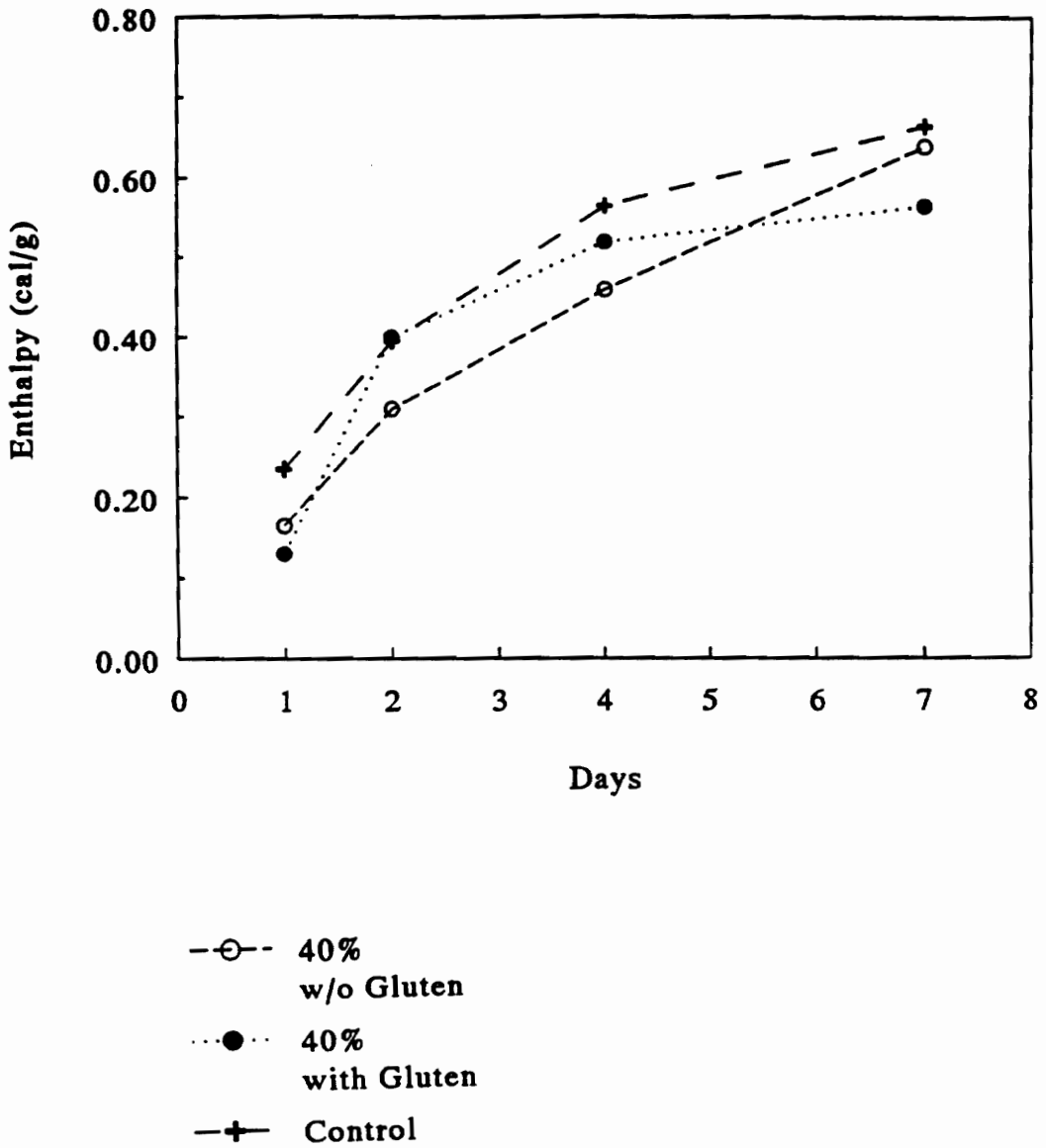


Figure 15. Extent and rate of staling of breads as measured by the DSC.

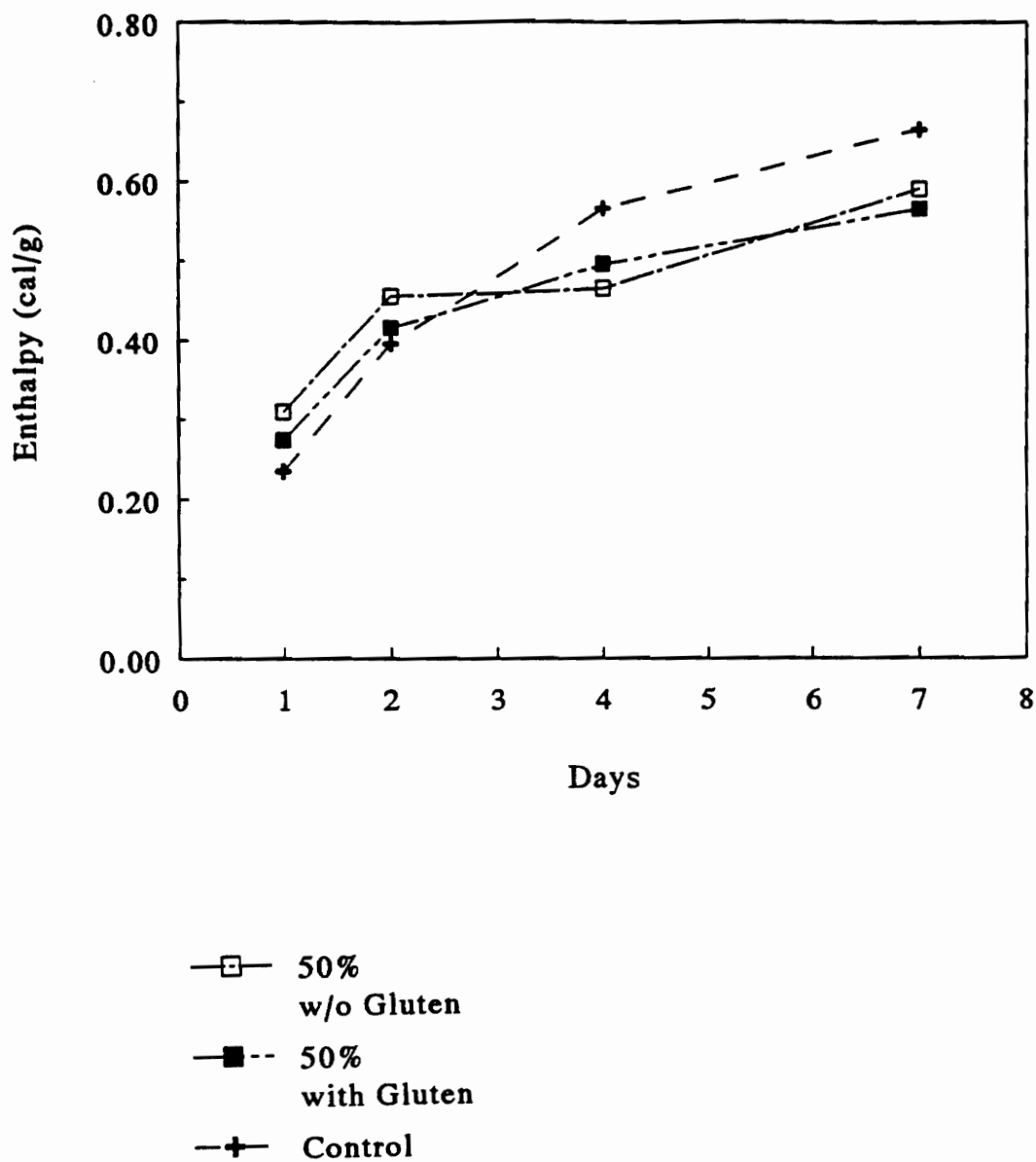


Figure 16. Extent and rate of bread staling as measured by the DSC.

amount of water present during aging. Proximate analysis results from this investigation indicate that millet flour is more moist than wheat flour and that breads baked from composite flours with increasing amount of millet were also more moist. Bread variations with higher moisture content had lower enthalpies on day 7. Czuchajowska and Pomeranz (1989) also observed enthalpy increases with decrease in moisture content of bread crumb during storage. Changes that take place in a baked bread are very complex as they involve, interactions between crumb and crust, starch and gluten and spatial arrangement of water molecules with different mobilities. Thus it is difficult to speculate on the effect of millet flour on bread staling. The differences in enthalpy due to millet flour variations remains a subject for further investigation.

Vital wheat gluten did not significantly ( $p < 0.05$ ) affect the rate of staling of bread crumb during storage. Elliasson (1983) reported that gluten led to decreases in starch recrystallization during aging. The effects of gluten on starch gelatinization was attributed to small amounts of water available in the presence of gluten. This might also be one of the possible effects of gluten on starch recrystallization, that is the amount of water available to starch is changed by the presence of gluten. As mentioned earlier, baked bread is more complex than a starch gel.

Therefore in order to give a concise explanation of the effect of gluten on bread crumb it would be necessary to monitor the water activity in the bread crumb. In summary, DSC results indicated that the control bread staled faster than all the other bread variations and that bread containing 50% millet flour with gluten exhibited the least amount of staling by day 7. Millet flour with gluten seem therefore to retard starch retrogradation.

#### SENSORY EVALUATION (Q D A)

The discussion for this section will be divided according to the sense of vision and the sense of taste. Mean values for Quantitative Discriptive Analysis (QDA) of the breads are given in Table 6, and 7.

#### SENSE OF VISION

##### CRUMB AND CRUST COLOUR

The dictionary defines color as a visual perception that enables one to differentiate otherwise identical objects. The crumb colour of the breads was judged by the Q.D.A. panel members to be lighter as the percentage of millet in the composite flour increased. These results were not in agreement with the objective L (lightness) values for crumb color. However, objective b (yellowness) values of the crumb color were in agreement with the sensory scores. The

TABLE 6. MEAN SCORES FOR SENSORY ATTRIBUTES OF BAKED BREADS  
(1)

FLOUR	CRUST	CRUMB	CELL	CELL
	COLOR 1	COLOR 2	SIZE 3	UNIFORMITY 4
30% w/o	5.49 a	5.49 a	4.49 a	4.45 a
30% w/g	5.93 a	5.92 a	4.48 a	4.68 a
40% w/o	4.43 b	4.60 b	4.55 a	4.40 a
40% w/g	5.49 a	4.79 b	4.66 a	4.78 a
50% w/o	4.12 b	4.56 b	4.81 a	4.46 a
50% w/g	4.30 b	5.68 a	4.74 a	4.62 a
control	5.56 a	1.77 c	3.82 a	5.20 b

w/o = without gluten,

w /g = with gluten

1. 0 = Light ; 10 = Dark

2. 0 = Light ; 10 = Dark

3. 0 = Small ; 10 = Large

4. 0 = Less ; 10 = More

Means in the same column with different superscripts are significantly different at  $p < 0.05$ .

TABLE 7. MEAN SCORES FOR SENSORY ATTRIBUTES OF BAKED BREADS (II).

FLOUR	BITTERNESS 1	CHEWINESS 2	AFTER TASTE 3
30% w/o	3.69 a	5.20 a	3.58 a
30% w/g	3.63 a	5.80 a	3.84 a
40% w/o	4.47 b	4.73 b	4.41 b
40% w/g	4.36 b	4.84 b	3.94 ab
50% w/o	4.95 b	4.02 b	5.22 c
50% w/g	5.02 b	4.42 b	5.19 c
control	1.89 c	6.85 c	1.74 d

w/o = with outgluten , w/g = with gluten

1. 0 = less ; 10 = more

2. 0 = less ; 10 = more

3. 0 = less intense ; 10 = more intense

Means in the same column with different superscrits are significantly different at  $p < 0.05$ .

attribute here should have been the degree of yellowness instead of the degree of brownness as agreed upon by the judges. The panelists did not observe vital wheat gluten to have any effect on the crumb colour of the breads.

Breads with increasing levels of millet flour were judged to be lighter in crust color. This observation was supported by the objective results. The crust color of the breads with gluten were perceived by the panelists to be darker. These results corresponded in this case with the objective results.

#### CELL SIZE AND UNIFORMITY

Millet flour was found to increase the cell size of the bread in all variations. Vital wheat gluten apparently did not have a significant ( $p < 0.05$ ) effect on the cell size of the bread variations. The control bread was judged to be significantly ( $p < 0.05$ ) more uniform in cell size than the other breads. The panelists did not observe significant ( $p < 0.05$ ) differences in cell size and uniformity in breads made from composite flours with higher percentages of millet. Breads prepared with vital wheat gluten appeared to have a more uniform cell size. One of the functional properties of gluten is its ability to aid in the formation of a more uniform cell structure.

## SENSE OF TASTE

### BITTERNESS

Breads with higher levels of millet were judged to be more bitter (Table 7). "Nutty" may be a better attribute to describe the flavor of the breads. Lorenz (1980) reported the taste of millet to have a nutty character. During the sensory evaluation sessions, some panelist members commented that bitterness is the wrong attribute and that "nutty" would be more appropriate. Vital wheat gluten had no effect ( $p < 0.05$ ) on the bitterness of the breads.

### CHEWINESS

Chewiness was defined by the sensory judges as the amount of force used to masticate a piece of bread during tasting. Replacement of wheat flour with millet flour resulted in a significant ( $p < 0.05$ ) reduction in the chewiness of the bread (Table 7). Vital wheat gluten seemed to increase the chewiness of the bread. The crumb structure increased in firmness with increasing levels of millet flour. This firming effect may be attributed to a less tender bread crumb which was confirmed by the texturometer (see Figure 12).

## AFTERTASTE

Aftertaste was judged to be more intense with increasing millet flour level (Table 7). Vital wheat gluten did not significantly ( $p < 0.05$ ) affect the aftertaste.

## SENSORY EVALUATION (PREFERENCE)

Bread variations made from 30% millet without gluten were judged by panelists to be the most accepted however no significant ( $p < 0.05$ ) differences were observed between breads made from 30% without gluten, 30% with gluten, 40% without gluten and the control (figure 17). Bread prepared from 50% millet flour level was judged to be the least preferred.

According to the Q.D.A. results, the control was judged to be more chewy. The judges on the preference panel did seem to like the light and fluffy texture of the control bread. Breads that were preferred by the consumer panel were rated by Q.D.A. panelist to be less bitter, more chewy and as having less intense aftertaste.

## CIRCULAR GRAPHS OF SENSORY ANALYSIS (Q D A )

Circular graphs (figures 18, 19, 20, and 21) were plotted from the Q.D.A. data. These circular graphs allow one to visualize the differences between the breads baked from the composite flours and the control. Each spoke of the web

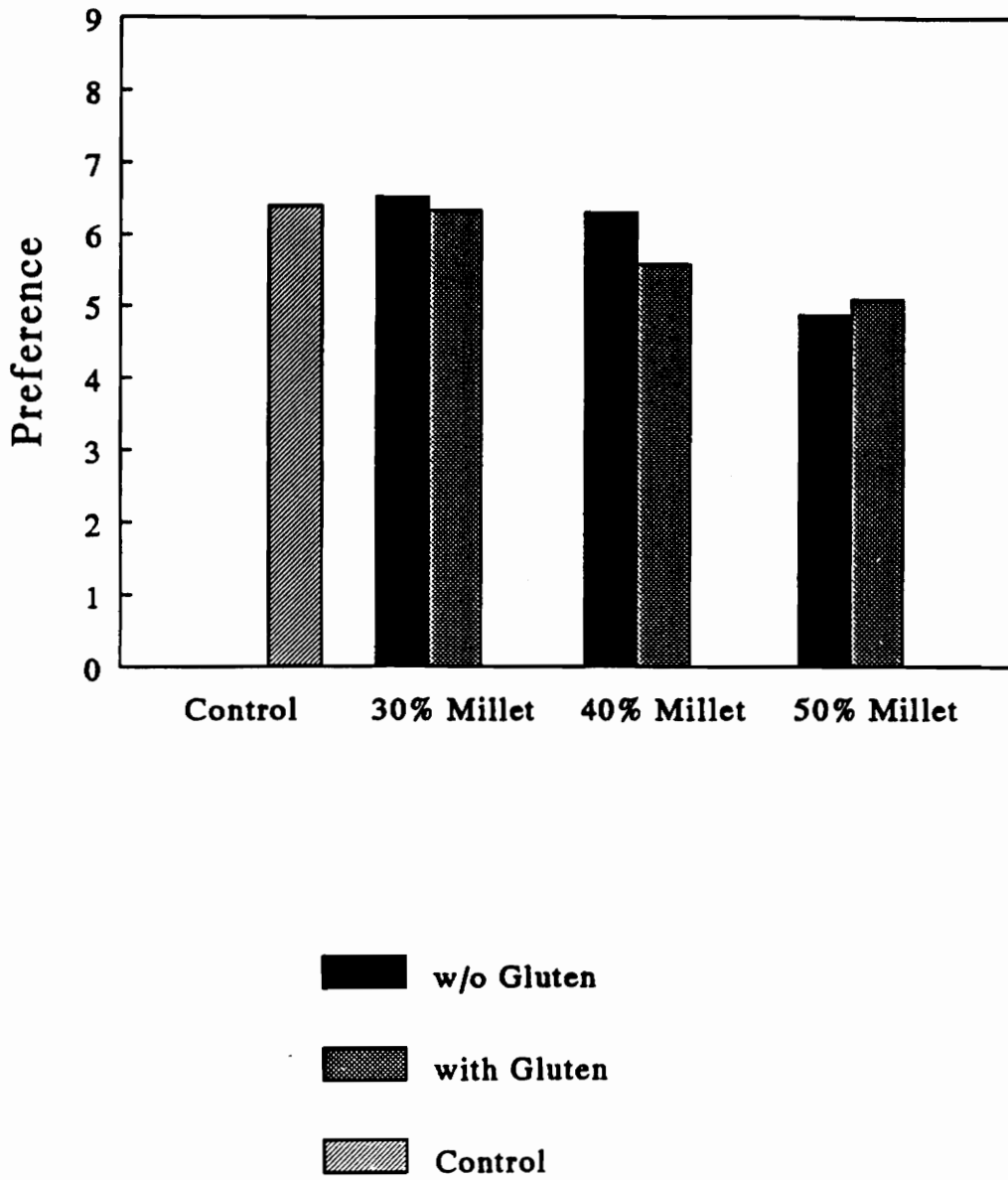


Figure 17. Mean result of consumer sensory evaluation.

represents a single sensory attribute. The distance from the center of the web to the end point of each spoke is proportional to the mean of the attribute.

In summary, breads with increasing levels of millet were darker in crumb and crust colour, larger in cell size, more bitter, less chewy, and had a more intense after taste. Vital wheat gluten, darkened crust colour, increased cell uniformity and improved chewiness.

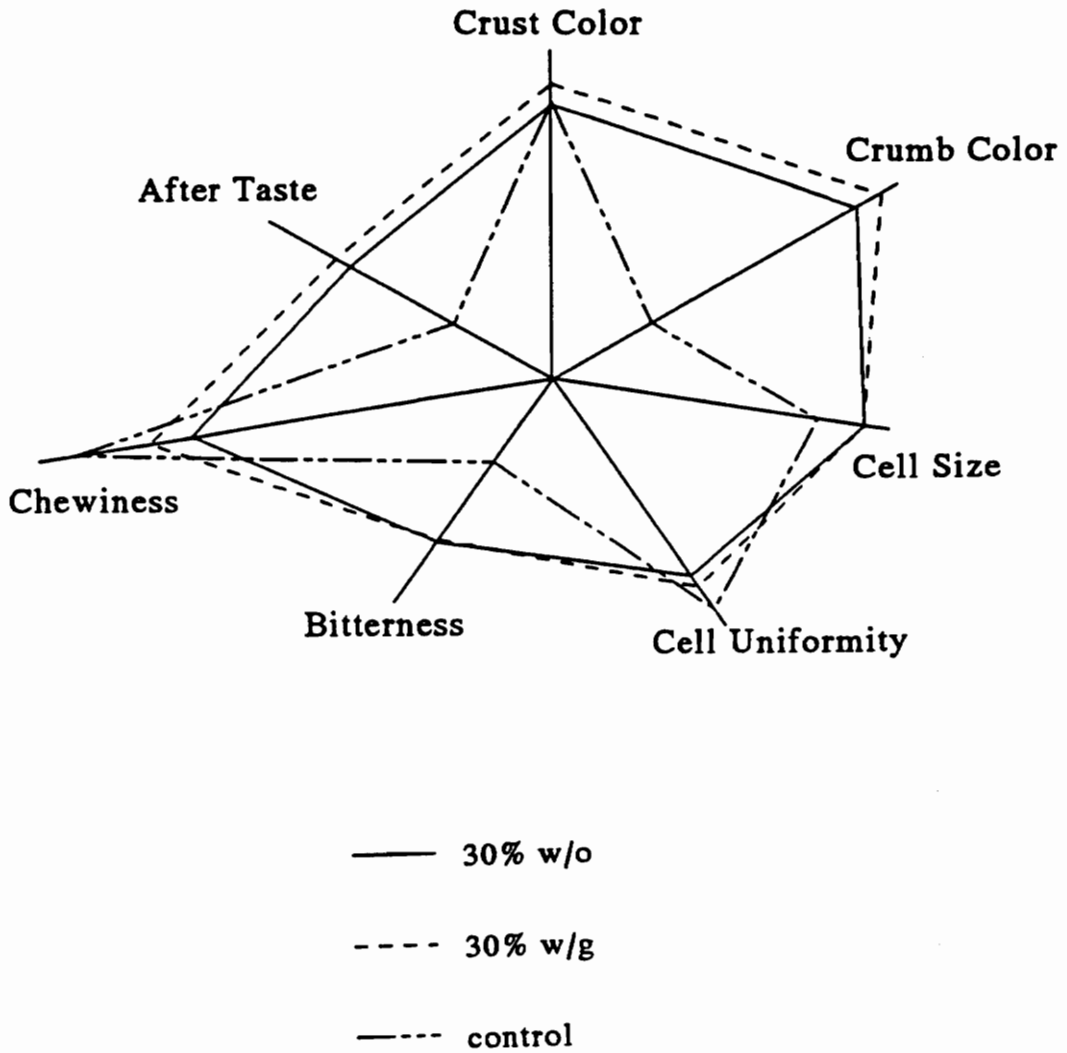


Figure 18. Circular graph showing 30% millet flour variations and control.

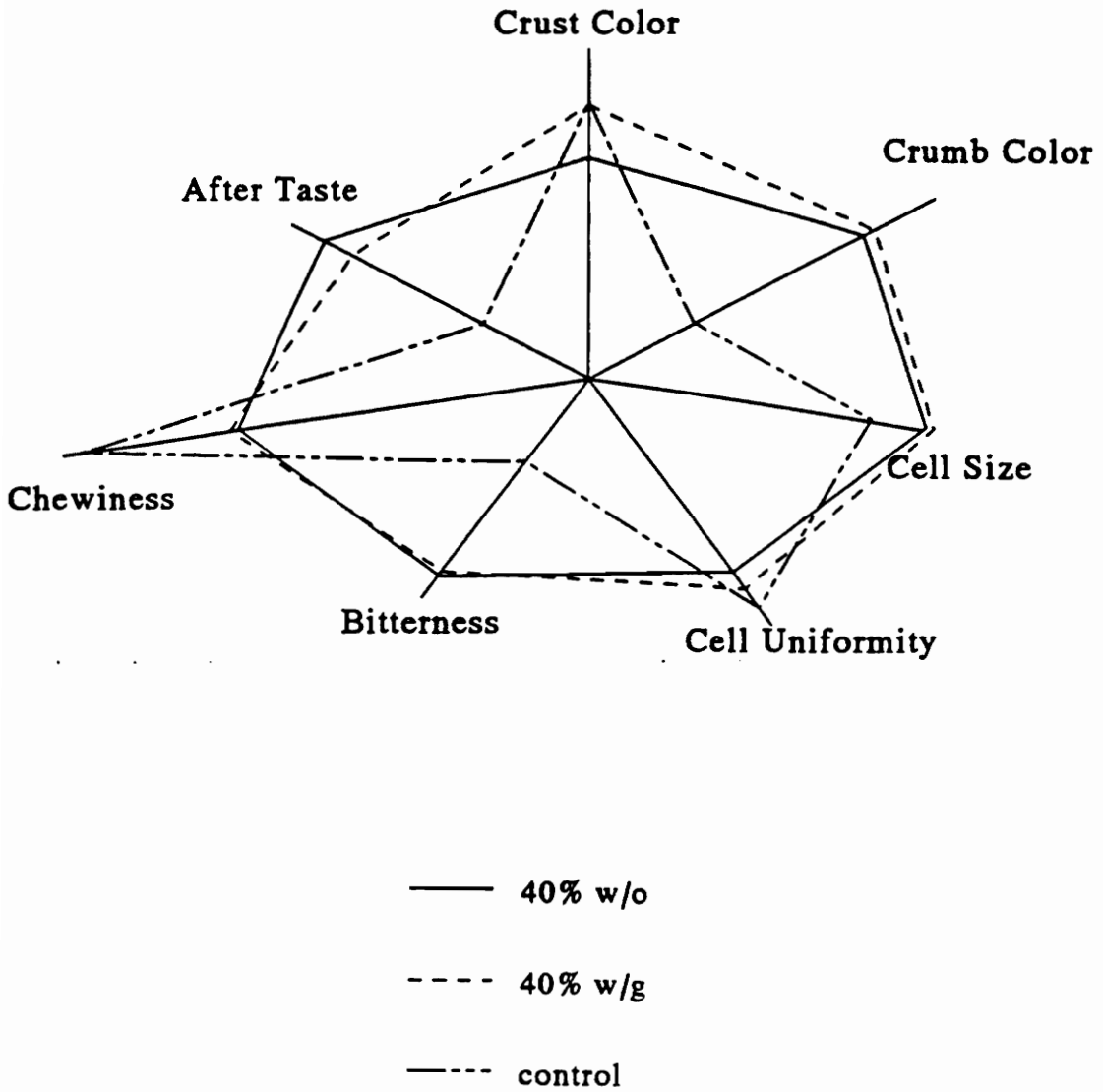


Figure 19. Circular graph showing 40% millet flour variations and control.

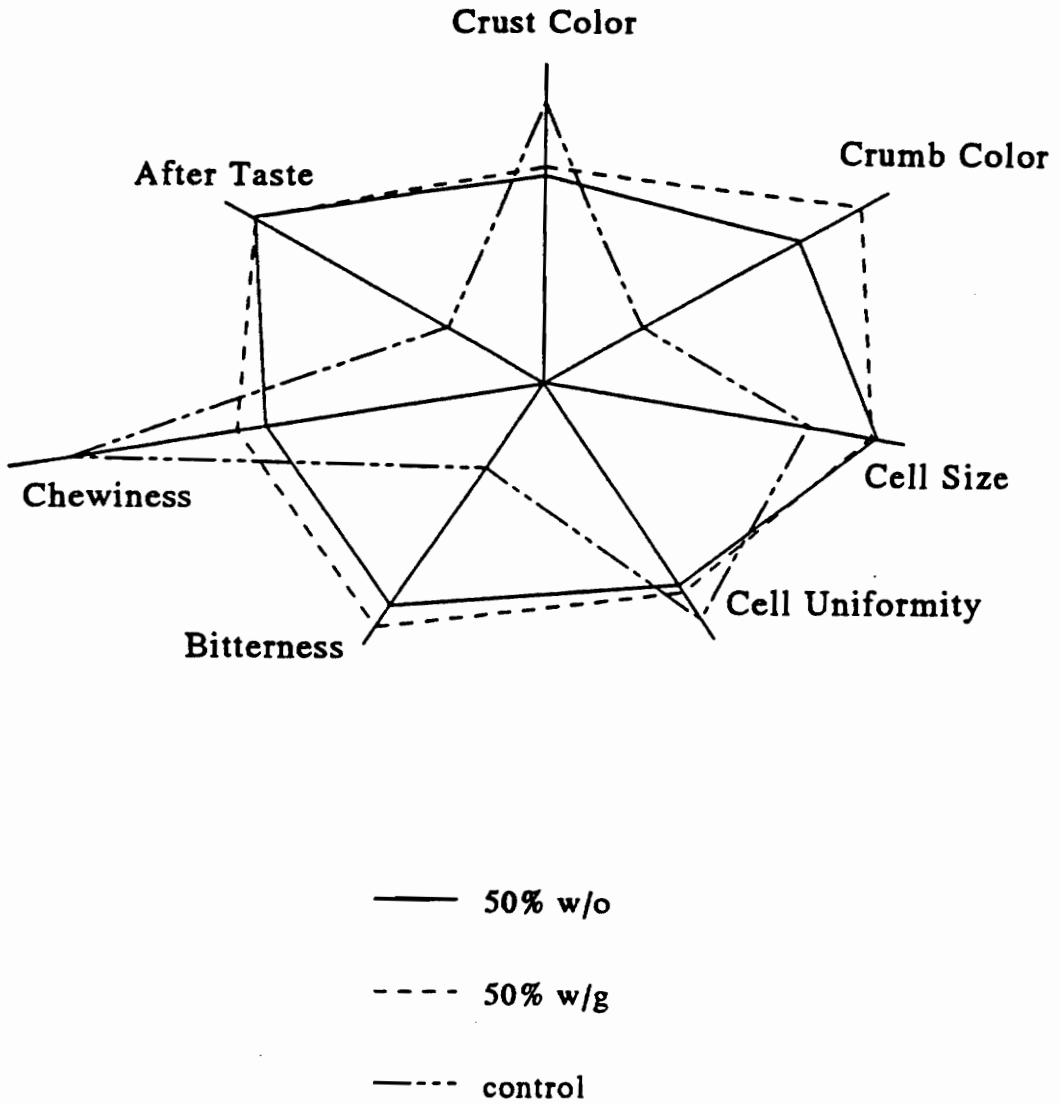


Figure 20. Circular graph showing 50% millet flour variations and control.

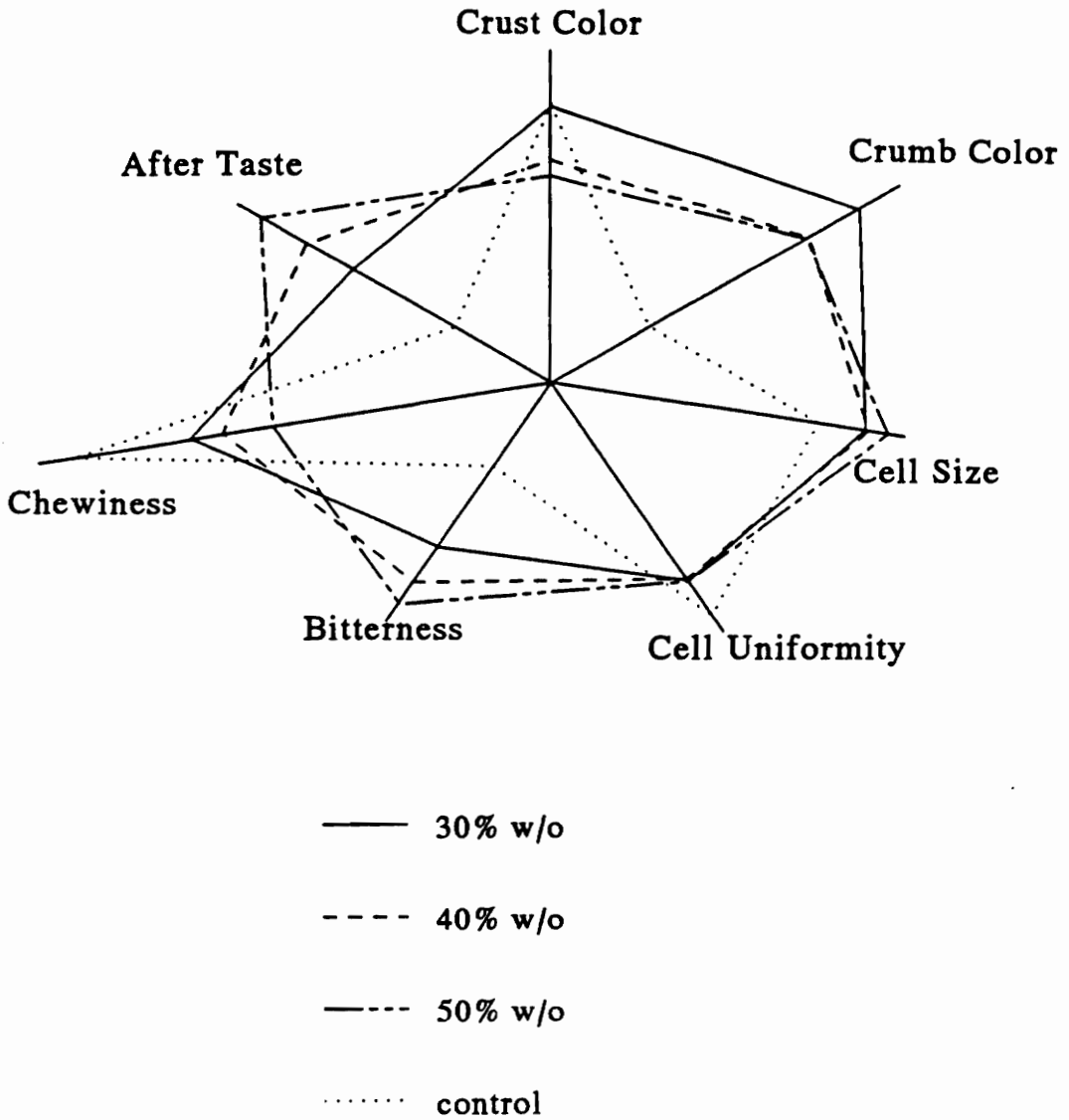


Figure 21. Circular graph showing composite flours with millet flour replacements.

### SUMMARY AND CONCLUSION

The quality attributes of breads baked from wheat- millet composite flours fortified with vital wheat gluten were studied using both objective measurements and sensory evaluation. The major finding of this study was that millet flour can be used to replace part of wheat flour in the bread making process and that fortification with vital wheat gluten is not necessary since its addition did not significantly affect most quality attributes.

Rheological studies of the composite flours indicated that mixing time and dough stability were decreased by the addition of millet flour.

Breads made from high percentages of millet were significantly higher in moisture content and had reduced loaf volumes. Vital wheat gluten decreased tenderness, but did not significantly increase loaf volume and moisture content.

The lightness of bread crumb decreased with increasing millet flour, however , the yellowness increased with increasing millet flour.

DSC results indicated that the starch in millet flour have a higher maximum gelatinization temperature than in wheat flour. The control bread staled faster than all the other bread variations and breads containing 50% millet flour with gluten exhibited the least amount of staling by

day 7.

Sensory analysis indicated that millet flour had a negative effect on the crust and crumb color, cell uniformity, bitterness, chewiness and after taste. Vital wheat gluten was judged to affect crust color, cell uniformity and chewiness. Bread variation prepared from 30% without gluten was judged to be the most preferred by the consumer panelists.

It can therefore be concluded that a composite flour containing 30% millet flour can be used to produce acceptable loaves of bread. This study indicated that millet flour can be used to produce bread in sub-Saharan African countries where it is grown. However, in countries where there is a total ban on imported agricultural products, a higher percentage of millet flour will have to be incorporated in the bread making process.

## RECOMMENDATIONS FOR FUTURE RESEARCH

1. A detailed study on the starch component of millet and its effect on bread retrogradation is needed.
2. The next phase of this investigation, the actual implementation of this study to see its acceptance in subsaharan Africa.
4. Repeat this investigation with another additive or a dough improver such as mono and diglycerides to see its effect on loaf volume.

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**APPENDIX A**  
**Baking, Objective Measurements, and Sensory Evaluation**  
**Schedule**

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Week	Sun.	Mon.	Tue.	Wed.	Thur.	Fri.	Sat.
1	-	M	F	F	F	-	-
2	B	S	O	O	B	S	-
3	B	S/O	B	S/O	B	S	-
6	M	B	A	A	-	A	M
7	-	A	-	-	-	C	C

---

A = D.S.C staling test

B = All seven variations were baked

C = Consumer sensory evaluation

F = Dough Rheology with the Farinograph

M = Milling of Millet flour

O = Objective measurements were done

S = Sensory evaluation were done

**Appendix B**

**Incomplete block design for sensory evaluation (Q.D.A)**

## GRID DESIGN FOR SENSORY EVALUATION

JUDGE	DAY				
	1	2	3	4	5
1	3567	1462	2347	1345	12567
2	1467	1357	1236	1345	23457
3	2357	2456	1467	1236	13457
4	1246	1345	3567	2567	12456
5	2347	3567	1345	1267	12456
6	1356	2347	2456	1257	13467
7	2456	1236	1357	2347	14567
8	3567	1467	1237	2456	12345
9	2465	1345	1367	2467	12357
10	1357	3467	2456	1257	12346
11	1346	2456	3567	2347	12457
12	2347	1257	1456	3567	12346
13	1457	3567	2347	1236	12456
14	2456	1236	1257	3457	13467

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1 = 40% without gluten

2 = 50% without gluten

3 = 30% without gluten

4 = 50% with gluten

5 = 30% with gluten

6 = 40% with gluten

7 = control

**Appendix C**

**Bread Formulations, Mixing and Baking Procedures**

Composite flours containing 30% Millet flour

INGREDIENT	WITH GLUTEN (gm)	WITHOUT GLUTEN (gm)
MILLET FLOUR	105	105
WHEAT FLOUR	227.5	245
SALT	5.5	5.5
SUGAR	20	20
NFDM	14	14
SHORTENING	11	11
YEAST	7	7
WATER (ml)	255	255
GLUTEN	17	-

## Composite flours containing 40% millet flour .

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INGREDIENT	WITH GLUTEN (gm)	WITHOUT GLUTEN (gm)
MILLET FLOUR	210	210
WHEAT FLOUR	192.5	210
SALT	5.5	5.5
SUGAR	20	20
NFDM	14	14
SHORTENING	11	11
YEAST	7	7
WATER (ml)	255	255
GLUTEN	17	-

---

## COMPOSITE FLOUR AT THE 50% MILLET FLOUR VARIATIONS.

INGREDIENT	WITH GLUTEN (gm)	WITHOUT GLUTEN (gm)
MILLET FLOUR	175	175
WHEAT FLOUR	157.5	175
SALT	5.5	5.5
SUGAR	20	20
NFDM	14	14
SHORTENING	11	11
YEAST	7	7
WATER (ml)	255	255
GLUTEN	17	--

## PROCEDURE FOR BAKING PUP LOAVES.

1. Sift together all dry ingredients into the mixing bowl. Add shortening.

2. In a 200 ml beaker, add active dry yeast and 50 ml warm water. Cover with a plastic wrap and allow to stand for 10 minutes.

3. Start the mixer (Hobart Kitchen Aid model K5-A) and then switch to speed number 2. Mix for 5 minutes. Dough was then removed from mixing bowl and placed in covered bowl for 50 minutes in a proofing oven.

4. After proofing, the dough was rolled out using two 0.08 cm dowels as guides. The dough was then folded in thirds, placed back in the bowl and placed in a proofing oven for 25 minutes.

5. After 25 minutes the above step was repeated. After 10 minutes, the dough was weighed out into three equal portions.

6. The dough was then rolled out on both sides and placed in the greased pup loaves pans.

7. Dough was then allowed to proof for 40 minutes in a proofing oven.

8. Loaf pans were then placed in at the center of the bottom rack in a preheated oven for 20 minutes at 425 degree Fahrenheit

9. After baking Loaves were then placed on wire racks to

cool for 30 minutes and then wrapped with plastic until objective and sensory test were performed.

## VITA

Kate Aferamor Elakhame was born on August 17th, 1964 in Nigeria. In 1982, she came to the United states to start her college education. She graduated from pratt Institute Brooklyn, New - York in 1986 where she studied Nutrition and Dietetics. She is corrently working on a Master of Science degree at Virginia Polytechnic institute and State University in the Department of Human Nutrition and Foods with the option in Foods and a graduate concentration in International Development. Upon completion of her degree she plans to pursue a career in International Development.

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