Biochemical and Sensory Evaluation of Wheat Bran Supplemented Sorghum Kisra Bread

By

Limya Osman Husain Mallasy

B.Sc. Cairo University

1991

A thesis Submitted in Partial fulfillment of the requirements for the Degree of Master of (Agric.)

Department of Food Science and Technology

Faculty of Agricluture

University of Khartoum

May, 1998

Dedication

To my Parents ..
to my brothers,
sister
to my friends..
with love

Contents

CHAPTER FOUR

CHAPTER FIVE

List of Tables

List of Figures

Acknowledgements

~~I am~~ My special praise and unlimited thanks are to ALLAH, who supplied, helped and gave me health and patience to complete this study. I wish to express special appreciation to Professor A.H.El Tinay and Professor A.R.Abdel ElHalim supervisor and Co-supervisor, respectively, for their continuous interest, help, encouragement, guidance, advice and cooperation in this investigation.

I am grateful to Mr. Abo Baker Hassan Daoud and Abd El Aziz Mirgany Shaban for their keen and continuous assistance.

Thanks are also extended to Mr. El Rasheed Ahmed Salim for carrying out the statistical analysis and continuous assistance.

Special thanks to my dear sister Jihan for her help and encouragement.

My Thanks are extended to the family of Food Science and Technology Department, in particular to Dr. B.E. Mohamed the Head of the Department of Food Science and Technology, I would like to extend my deep appreciation to my friends and colleagues for their valuable assistance and continous encouragement.

I am deeply indebted to my family for their great patience and tolerance to all the inconveniences resulting from being so patient in the course of carrying out this investigation .

Finally, I wish to acknowledge the assistance given by Sardonyx Team, in particular Mr. Ahmed Abd El Seed for typing this Thesis.

Abstract

Studies were carried out on the effect of addition of wheat bran to sorghum flour (Dabar cultivar) at two levels extraction rates (72% and 80%).

Samples were fermented for 14hr according to the traditional method used at home and the PH, titratable acidity, crude fibre, protein, total solid, total soluble solids and reducing sugars of the fermented batter were determined at 2hr intervals. Results indicated that addition of wheat bran either before or after fermentation increased the pH compared to the control. Concomitantly with increase in pH there was decrease in titratable acidity. Reducing sugar contents decrease as a result of addition wheat bran. The percent decrease was 75.6% compared with control at the end of fermentation period. Addition of wheat bran resulted in significant increase in protein content compared to the control (15.7%, 19.0% and 20.7% for control, 80%S/WB and 72% S/WB. respectively at the end of fermentation).

There was a highly significant ($P \leq 0.05$) increase in crude fibre content as a result of addition wheat bran. The increase was from 0.8 to 5.2 and from 0.5 to 5.3% for the 80%S/WB and 72%S/WB blends respectively.

Addition of wheat bran to sorghum batter either before or after fermentation was accompanied by significant increase ($P \leq 0.05$) in viscosity (from 145.1 cp for control to 203.1 cp and 209.8 cp for 80%S/WB and 72%S/WB blends respectively). Addition of wheat bran significantly decreased spreadability in line with increase in viscosity.

The moisture content of kisra bread containing wheat bran was significant higher ($P \leq 0.05$) compared with control.

Kisra bread containing wheat bran before fermentation showed an increase in protein content compared to the control.

The increase was 14.4%, 18.2% and 19.7% for control, 80%S/WB and 72%S/WB blends respectively. However, addition of wheat bran after fermentation resulted in higher increase in protein content. The increase was 21.8% and 24.1% for 80%S/WB blend and 72%S/WB blend, but was lower than that of the batter at the end of fermentation period. Kisra bread containing wheat bran was lower in reducing sugars 7.42% for control to5.2% and 4.2% and 4.5% for kisra containing wheat bran. Kisra bread containing wheat bran before fermentation showed significant increase ($P \leq 0.05$) in starch content (from 43.8% for control to 45.6% and 49.4% for 80%S/WB blend and 72%S/WB blend respectively. However, addition of wheat bran to batter after fermentation resulted in higher retention in starch compared to addition before fermentation (57.5% and 61.88%).

Total carbohydrates of kisra bread was 75.1%, 69.4% and 66.6% for control, 80%S/WB and 72%S/WB, respectively. A higher reduction in total carbohydrate was observed in samples containing wheat bran added after fermentation (65.1 and 60.7% for 80%S/WB and 72%S/WB blends respectively). Kisra containing wheat bran before fermentation gave significantly lower ($P \leq 0.05$) in vitro protein digestibilities (83.6% for control, 82.3% and 80.0% for 80%S/WB blend and 72%S/WB blend respectively). Addition of wheat bran after fermentation resulted in still lower decrease in IVPD compared to addition before fermentation (80.7% and 77.5% for 80%S/WB and 72%S/WB blends). Similar results were obtained for in vitro starch digestibility (45.7% for control, 43.8% and 40.5% for 80%S/WB blend and 72%S/WB blend respectively). However, addition of wheat bran after fermentation resulted in a more prounced reduction in IVSD compared to addition before fermentation (39.1%) and

38.0% for the two blends). Kisra bread containing wheat bran was significantly ($P \leq 0.05$) lower in available calories calculated from total carbohydrate, soluble readily absorbable reducing sugars and digestibility coefficient of starch.

Sensory evaluation of kisra containing wheat bran indicated significant preference for kisra containing wheat bran compared to the control kisra.

Chapter One

Introduction

Introduction

Sorghum is the most important cereal crop in Sudan and is the basic food in many parts of Africa and Asia. In the developing countries, cereals constitute up to 80% of the total food intake, where they act as a major source of protein, calories, B-vitamins, minerals and crude fibre. The importance of sorghum and millet has recently increased due to the drought and desertification that hit some of the African countries leaving behind hunger and complicated nutritional problems. FAO (1973) reported that, wheat, rice, sorghum and maize provide 50% of the calories and protein of the people of Africa and more than 60% of the protein and calories of people of China. The nutritional value of sorghum is affected by the presence of phenolic compounds that interfere with protein digestibility. Tannins are polymeric phenols of high molecular weight containing sufficient phenolic hydroxyl groups. Tannins cause gastrointestinal inflammation and are tumerogenic in experimental animals. Tannins can be counteracted by eliminating the testa by decortication or by alkali treatment.

In rural areas of the Sudan sorghum flour is used predominantly for preparation of local indigenous fermented beverages, acida and kisra breads. Kisra is a fermented sorghum bread, which constitutes the staple diet of the Sudanese. It is estimated that kisra provides up to 75% of the dietary calories. Some foods, particularly whole grain cereals, pulses and some fruits and vegetables, contain substantial amounts of fibre. Sorghum bran (Fibre), being rich in polyphenols was reported to be deleterious compared to the dietary fibre of wheat bran. The latter fibre is nutritionally recommended as a cure of some nutritional disorders.

Fibre has recently been the key word in health and fitness diets. Many previous diet plans and recipe books have focused on whole wheat bbran.

There are two different types of fibre diets. The high carbohydrate-high fibre (HCF) diet provides adequate amounts of both insoluble (wheat bran) and soluble materials (in oats and legumes).

Insoluble fibre, or roughage, promotes growth of bacteria of the intestine that results in soft bulky stool. Insoluble fibre fractions are not absorbed into the body; instead they add bulk to feces which is beneficial to health helping to prevent constipation. Efficient working of the intestine prevents many diseases of the gut, and can help to reduce the amount of cholesterol in the blood. Dietary fibre has significant gastrointestinal effects and is a mainstay of treatment for constipation and hemorrhoids.

Insoluble fibre, such as wheat bran, decreases excretion of glucose in urine, plasma glucose concentration and plasma cholesterol. Also dietary fibre delays gastric emptying of liquid and solids. However, fibre can also decrease the absorption of certain nutrients especially some of the minerals.

The differences in disease spectra in the industrialized nations were suspected to be related to decreased consumption of fibre compared to developing countries. Wheat bran could lower blood glucose and hence was found helpful for diabetic patients. The American Diabetes Association recommends the use of fibre in treatment of diabetic patients because increase in fibre results in reducing the postprandial blood glucose.

The objective of this investigation was to study the effect of replacing sorghum bran with wheat bran in sorghum batter for the manufacture of kisra bread and to determine nutritional quality and acceptability of the resulting kisra with reference to diabetic patients.

Chapter Two

Literature Review

Literature Review

2.1 *Nutritive value of sorghum:*

2.1.1 *Proximate composition:*

Eggum et al. (1983) analyzed three sorghum varieties grown in Sudan and found the protein content of whole grains of Tetron, Dabar and Feterita varieties as lO.9%, 11.6%, 13.4%respectively. While, Marhoum (1987) reported the following ranges 7.3 % for moisture, 12.8% for protein, 1.8% for ash, 1.7% for crude fibre, 74.2% for carbohydrate. Ahmed (1988) analysed three different varieties of sorghum and gave the following ranges: moisture 6.3-6.9%, ash 0.6-1.8%, protein 8.8-13.8%, fat 3.7- 4.0% and crude fibre 1.0-1.2%. Yousif and Magboul (1972) reported the following ranges: 5.7-10.4 for moisture, 6.9-12.8% for protein, 3.1 -4.1 for fat, 1.2-2.6% for crude fibre, 1.3-1.8% for ash for fifteen sorghum cultivars grown in Sudan. Eastoe and Taylor (1974) suggested that the assessment of the nutritive value of sorghum as a source of protein, could be attained by considering the pattern of essential amino acids in relation to human requirement.

Wall and Ross (1970) stated that sorghum like corn is low in fibre and ash because the glumes are readily removal.

2. 1.2 *Carbohydrate content:*

Miller and Kneen (1941) reported starch content for sorghum grain to range from 68% to 73%. Ahmed (1988) analysed sorghum varieties grown in Sudan and found total sugar ranging between 1.4 and 1.7% and carbohydrate 75.3-78.7%. El Tinay et al. (1979) analysed three local sorghum varieties grown in Sudan and reported that they contained 70.8-72.9% starch. Khattab and Hadari (1969) found that in Gezira and

Managil areas, cereals (primarily sorghum) provided 80.6% of the protein and, together with carbohydrate, 84.4% of the calories in the diet. Kent (1972) reported that carbohydrates form about 83% of the total dry matter of.sorghum, which includes starch, cellulose, hemicellulose, dextrins and sugars.

2. 1.3 *Tannin content of sorghum:*

Tannins are polymeric phenols of high molecular weight (mw500-5000) containing sufficient phenolic hydroxyl groups to permit the formation of stable cross links with proteins (Swain, 1965). Most plant tissues contain a wide range of secondary products such as polyphenols. The significance of these secondary plant products is a matter of wide speculation and it has been suggested that some may serve to protect the plant from pests, diseases and natural predators (Hulse et al; 1980).

The greater tendency of tannin to form complexes with proteins more than with carbohydrates and other food polymers is attributed to the strong hydrogen bond affinity to carboxyl oxygen of peptide groups (Russel et al., 1968)

Sorghum cultivars with pigmented testa and dark colored pericarp are always higher in tannin than light colored cultivars (Harris, 1969; Shadad, 1989). Mohammad and Ahmed (1987) reported a negative correlation between the tannin content and nutritive value of sorghum grain.

Strumeyer and Mallin (1975) isolated and charaeterised them as condensed tannins.Tannins, in sorghum grain are located in the outer pigmented testa and pericarp (Maxon and Rooney, 1972; Maxon et al; 1973; Chibber et al; 1978).

2.2 Effect of sorghum tannins in human nutrition

Consumption of tannin of grain sorghum and other plant materials has been indicated in many areas of the world as a possible factor in the incidence of oesophogial cancer. Tannins can cause gastrointestinal inflammation and are tumerogenic in experimental animals (Singleton and Kratzer; 1973).

Lease and Mitchell (1969) reported a marked decrease in blood hemoglobin in rats fed 5% tanninic acid. They proposed that this phenomenon was due to the formation of tannin-iron complex which reduces the availability of iron. Moreover, Belavady (1977) investigated the effect of sorghum tannins in human nutrition, using labeled iron and found a marked reduction in iron absorption from sorghum grain containing 0.15% tannins. Shadad (1989) reported that there is a negative correlation between tannin content and in vitro protein digestibility.

Schaffert (1972) studied the relation between in vitro dry matter digestibility (IVDMD), and in vitro protein digestibility (IVPD), and tannin content for three sorghum varieties and one hybrid. In all cases, high tannin content was associated with low IVDMD and IVPD. Chavan et al; (1979) attributed the low protein digestibility of the grain to its tannin content, while Hulse et al. (1980) suggested the influence of other antinutritional and toxic factors on digestibility of sorghum protein . Compared to other cereals, sorghum has been reported to be nutritionally inferior to wheat (Sur et al; 1955) and maize (Kemmerer and Heywang, 1965).

Neucer et al. (I978) reported that the tannin protein complexes are responsible for growth depression, low protein digestibility, decreased amino acid availability and increased faecal nitrogen. Sorghum was reported to possess some other deleterious constituents such as phytic acid and enzyme inhibitors, which are known to create some nutritional problems in human nutrition. Imbalance in amino acids and trace metals were associated with incidence of pellagra and fluorosis reported with sorghum consumers (Ahmed, 1987). In general low digestibility is a major nutritional problem of high tannin sorghum cultivars, whose protein digestibility for different animal species varied from 30% to 80% depending upon the tannin content (PAG, 1975).

Removal of tannin through chemical and physical treatment was found to improve the in vitro protein digestibility and weight gain, but removal or lowering the content of tannin through genetic means is an important goal in cereal improvement (FAO, 1981).

2.3 Fermentation and nutritive value of sorghum:

Sorghum has low protein content and shortage in some essential amino acids particularly Iysine (El Tinay et al., 1985). Increased protein content as a result of fermentation was attributed to the microbial activity (El Tinay et al 1979; Chavan et al. 1988)

Achi (1990) found that percentage lactic acid appeared to increase gradually as fermentation progressed. Odunfa and Adeyele (1985) found that lactic acid increased throughout the steeping and souring of Ogi -baba which resulted in a gradual fall in pH.

Au and Field (1981) studied natural sorghum fermentation and found that the pH of fermented sorghum plummeted from 6.7 to 3.6 during the first 2 days and gradually leveled off on the third and fourth day. Adeyemi (1988) reported that titrabale acidity of the dough increased during fermentation.

El Tinay et al. (1979) found that total sugar content of sorghum varieties Dabar and Mayo decreased during the first hours of fermentation and then increased again. Kazanas and Field (1981) found that reducing sugars increased during the fermentation of sorghum meal. Taur et al. (1984) found that reducing sugars increased from zero time till the end of fermentation period, which extended for 5 days for all varieties of sorghum studied. Pederson (1971) reported that starch content dropped to 68.7% after 6 hours of fermentation. This decrease continued till the end of fermentation. It could be due to the action of ∝- and ß - amylases. These digestive enzymes may be produced by micro -organisms or are indigenous to the flour. Van-Holdt and Brand (1960) stated that at the beginning of the fermentation process the starch content was 71% and at the end of the seven day fermentation the starch decreased to 53.5% .The naturally fermented flour showed a significant increase in reducing sugars, free amino acids and ascorbic acid content in 24 hours fermentation at 25C°, and there was a highly significant starch loss (Taur et al; 1984).

The protein content, free amino acids, soluble proteins and in vitro protein digestibility were markedly increased within 24 hours fermentation of sorghum (Chavan et al; 1988). Also, Parada et al (1985) reported that fermentation reduced tannin content and improved the protein nutritional value (in vitro protein digestibility).

Fermentation processes have a role in improving nutritional value and acceptability by contributing to the degradation of toxins and antinutritional factors present in many plant foods (Reddy et al; 1986). Fermentation develops a new flavour in food products and is also utilized as a technique of preservation (Desroier, 1959).

2.4 *Sorghum fermented foods:*

There are 30 different fermented sorghum foods and beverages prepared in the Sudan. Sudan has some solid food products that are traditionally produced from sorghum or millet, in addition to beer (Dirar, 1996). Kisra is a thin bread made from the sorghum sour dough (Dirar, 1996). It is a fermented sorghum bread which constitutes the staple diet of the Sudanese people (El Tinay et al; 1979). Ahmed (1987) reported that kisra is a thin or pancake bread prepared from fermented sorghum meal similar to the South Indian dosa.

Abdel Gadir and Mohamed (1977) defined the term kisra as a colloquial name given to abread made from fermented sorghum meal. According to El Hidai (1978), kisra fermentation was mainly due to lactic acid bacteria Lactobacillus sp, and to a lesser degree to a yeast, acetic acid and butyric acid fermentations. Hamad (1992) studied kisra fermentation and found that the most important microorganisms involved in the fermentation were homo-and hetero - fermentative lactic acid bacteria. Kisra fermentation for three popular sorghum varieties was investigated by El Tinay et al. (1979). Their results indicated a slight increase in protein content and an appreciable drop in starch as a result of kisra fermentation. Total and non-reducing sugars decreased markedly at the commencement of the fermentation process, while crude fibre content increased. El Hidai (1978) found that the concentration of acetic and butyric acids, produced during fermentation of the sorghum dough, decreased as a result of baking.

Abdel Gadir and Mohamed (1983) reported that baking increased asparagine, threonine and serine. Badi et al. (1987) reported that kisra provides over 80% of the calories intake in some areas of the Sudan.

2.5 *Supplementation of sorghum for food purposes :*

Abdel Gadir and Mohamed (1977) and Eggum et al. (1983)

recommended supplementation of fermented sorghum foods due to the nutritional inadequacy. El Tinay et al. (1985) reported significant improvement in both protein content and lysine of kisra supplemented with legume protein isolates. The addition of rice polishing concentrate to a diet based on sorghum was found to increase the protein content of the diet and the rate of weight gain (Saxena et al. 1968).

Sorghum diet was also supplemented with cottonseed flour, fish meal, coconut meal, fenugreek seed flour, groundnut flour and soybean flour (Ali et al. 1964a; 1964b; Bookwalter et al. 1977). Ray et al. (1983) reported that addition of fibre decreased excretion of glucose in urine and decreased plasma glucose concentration.

2.6 Dietary role of wheat bran:

Some foods, particularly whole grain cereals, vegetables and some fruits, contain substantial amounts of fibre (non-starch polysaccharides). Anderson (1984) reported that there are two different types of fibre and the importance of high carbohydrate-high fibre (HCF) diet is that it gives adequate amounts of both; insoluble fibre (in wheat bran) and soluble fibre (in oat and legumes). Rendleman (1982) gave the following value for wheat bran: moisture 10.4%, crude fibre 8.9%, protein 14.3% fat 5.2%, pectin 3%, starch 17.4% and invert sugar 7.0% Stanyon and Costello (1990) used wheat bran to enhance the nutritional quality of baked products such as cakes, yeast bread and muffins. The addition of wheat bran affects the physical and sensory properties of the baked products.

Wheat bran is an important source of dietary fibre, it is rich in insoluble fibre but also contains soluble fibre. Fibre in wheat bran is mainly the hemicellulose (D'Appolonia et al. 1971; Saunders, 1978).

Kies and Fox (1977), and Vahoung and Krichevsky (1980) reported that generally, water-soluble fibre improves glucose tolerance and lowers plasma lipids, but such an effect has not been observed with wheat bran because most of it's dietary fibre is insoluble.

The Dietary Guidelines for Americans (1987) advocates increased consumption of fibre in the diet because of beneficial effects such as the reduced absorption of harmful substances associated with colon cancer, increased water content of the stool with a decreased transit time and intracolonal pressure. The fecal water content as well as fecal wet and dry weight increases with the addition of bran to the diet (Cumminges et al. 1976; Kay and Truswell, 1977).

Gray (1995) found that wheat bran is most effective treatment for constipation and hemorrhoids. Moreover, any increase in dietary fibre intake should be accompanied by an increase in water intake. Jenkins et al. (1978) reported that the insoluble fibers, are largely responsible for increasing the bulk of feces.

Sharafetdinov et al. (1993) compared various sources of food fibers (citrus pectin and wheat bran) for efficacy in correction of disorders associated with carbohydrate and lipid metabolism. The results showed a hypocholesterolemic effect of citrus pectin and hypoglycemic effect of wheat bran.

Anderson (1984) found that the insoluble fibre, or roughage, promotes growth of bacteria in the intestine causing soft bulky stool. Efficient working of the intestines prevents many diseases of the gut.

Jenkins et al. (1980) reported that the rate of starch digestion, however, can not be explained by the amount of fibre alone since, some legumes have similar fibre contents as certain cereal products, and yet are digested at very different rates (in vitro).

Liener et al. (1980), and Dunaif and Barbara (1981) reported that several dietary fibers can decrease the activity of human pancreatic amylase, lipase and trypsin. Sommer et al. (1980) found reduced activities of amylase, trypsin and lipase in intestinal aspirates in response to a test meal supplemented with pectin or wheat bran. Trowell (1978).and Anderson et al. (1979) reported that addition of fibre in the diet improved the control of blood glucose in the case of diabetic patients. James (1985) reported that the high carbohydrate-high fibre diet (HCF) lowers blood sugar and insulin needs. The diet also lowers the blood fats that are a danger to the arteries, and help in weight loss. For the insulin-dependent diabetics, it smoothes out the blood sugar by slowing down its absorption.

Jenkins et al. (1976), and Miranda and Horwitz (1978) reported that addition of plant fibers to the diets of patients with diabetes is accompanied by significant reduction in postprandial hyperglycemia. Diets containing fibre are associated with significant reductions in the quantity of glucose excretion in the urine (Jenkins et al; 1977).

Roth and Mehlman (1978) and Vahouny and Kritchevsky (1980) made the hypothesis that dietary fibre (DF) is protective against diabetes, heart disease, obesity and colon cancer. Trowell (1986) reported that dietary fibers are beneficial to both diabetic and heart patients because DF lowers both blood sugar and serum cholesterol.

Mani et al. (1987) reported the effect of wheat bran supplement decreases sugar concentration in fasting and postprandial. Liu et al. (1989) reported that wheat bran decreased blood glucose and increased Zn absorption but Ca, Cu and Mg balances were not affected. Ray et al. (1983) reported that addition of fibre decreased excretion of glucose in the urine and decreased plasma glucose concentration. Addition of fibre also delayed gastric emptying of liquids and solids.

Harold et al. (1985) found that wheat bran diet reduced peak blood glucose concentration and peak insulin infusion rate in comparison with baseline and cellulose diets. The dietary fibres are slowly absorbed and fermented by intestinal flora, thus causing a laxative effect, however, the crude fibre content of the supplementary food should not exceed 5% (FAO, 1985). Rinfel et al. (1990) found that addition of diet wheat bran decreased the levels of blood glucose. Fibre supplement studies with guar gum, wheat bran, and apple fibre, reported to lower glucose and cholesterol and glucosuria. This diet reduces insulin requirements, lowers serum cholesterol and triglycerides values (Anderson et al; 1987).

Vaaler et al. (1986) reported that patients with diabetes mellitus treated with different dietary fibre: guar gum and wheat bran showed a decrease in postprandial blood glucose levels. Aaron et al. (1988) suggested that soluble fibre supplements may offer some improvement in carbohydrate metabolism, lowers total cholesterol and low-density lipoprotein (LDL). Himsworth (1935) showed that in normal healthy subjects the ingestion of diet high in carbohydrate improves glucose tolerance. This was attributed to increased insulin sensitivity. Anderson et al. (1976) and Anderson (1980) showed that diabetic subjects fed a diet high in carbohydrate and fibre reduced blood glucose levels and diminished insulin requirement. Jenkins et al. (1980) reported that addition of purified viscous fibre to metabolic diet resulted in reduced urinary losses of glucose and ketone bodies.

American (1979), Canadian (1981) and British Diabetes Associations (1982) recommend use of fibre in treatment of diabetes because of the increased reduction in postprandial blood glucose. American Diabetes Association (1979) recommended reducing the intake of fat and increasing that of complex carbohydrate to 50% of the total calories with the ingestion of foods high in fibre as desirable. Aretaeus (1985) advised people with the symptoms of diabetes to eat a diet consisting of milk, cereals and fibre. American Diabetes Association (1979) recommended that individuals with diabetes mellitus should increase the amount of dietary fibre in their diets in order to reduce the excretion of blood glucose and insulin following meals.

Chapter Three

Materials and Methods

Materials And Methods

3.1 Materials

3.1.1 Food Materials:

Sorghum flours (Dabar) whether a whole meal, 80% or 72% extraction were obtained from the Food Research Center, Shambat. Wheat bran was obtained from Ahlia Flour Mills Co Ltd, Khartoum North.

3.1.2 Chemicals and Reagents:

Technical grade chemicals and reagents were used.

3.1.3 Preparation of raw materials:

3.1.3.1 Wheat bran:

Wheat bran was further milled and seived to pass a 355 μm screen.

3.1.3.2 Addition of wheat bran to Sorghum flour:

Pearson Square was used (Ihekoronye and Ngoddy, 1985) to calculate the amount of fibre in the form of wheat bran to be added to sorghum flour of 80% and 72% extraction rates (Fig. 1). Wheat bran was added to decorticated sorghum flour before or after fermentation.

a) To 64g of 72% extraction sorghum flour, 35g of wheat bran were added plus 5g starter batter (Total crude fibre = 4%).
b) To 65g of 80% extraction sorghum flour, 30g of wheat bran were added plus 5g starter batter (Total crude fibre =4%).

3.1.3.3 Fermentation process:

Whole sorghum meal (control) and sorghum flours containing wheat bran added pre- fermentation or post fermentation, were fermented with traditional starter (5% of old fermented sorghum dough) at ambient temperature (37± 5C°) for 14 hrs with monitoring of physicochemical changes during fermentation every two hours. Fermented samples were taken and oven dried at 70C° for 4-6hrs. Dried materials were then powdered and kept in clean jars for further analyses.

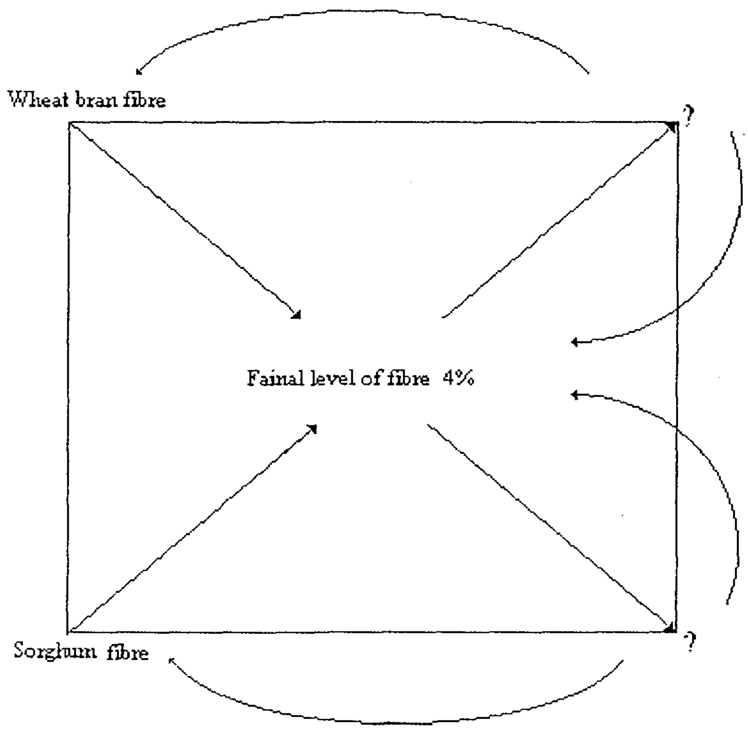


Fig.(1): Pearson Square

3.1.3.4 Preparation of kisra bread:

Kisra bread samples were prepared from sorghum batter and sorghum batter containing wheat bran, added pre- or post fermentation, periods of 6,10 and 14 hr. Fermented batters were baked into kisra sheets on a hot plate (160-170 C°) for 30-60 sec . Oven dried (70 C°) kisra was powdered and kept in clean jars for further analyses.

3.2 Methods:

3.2.1 Proximate analysis

3.2.1.1 Moisture content

Moisture was determined by the AOAC method (1984).A 2g from each sample were placed in preheated, pre-weighed crucibles, each crucible with its sample was dried in an oven at 105C° overnight. The crucibles were transferred to a desicator, left to cool and weighed. The moisture content of each sample was calculated according to the following equation:

$$\text{Moisture \%} = \frac{\text{Weight loss (g)} \times 100}{\text{Weight of the sample (g)}}$$

3.2.1.2 Fat content

Total fat was determined according to the AOAC method (1984). A 2g of sample was extracted with petroleum sprit for 8 hr. in Soxhlet apparatus.

$$\text{Fat \%} = \frac{\text{Weight of extracted oil} \times 100}{\text{Weight of sample}}$$

3.2.1.3 Protein Content

Nitrogen content was determinated by the micro-Kjeldahl technique following the method of the AOAC (1984). 0.2g of the sample was weighed accurately into a micro-Kjeldahl flask ; 0.4g of catalyst mixture and 3.5 ml of concentrated sulphuric acid were added. The sample and content were heated on an electric heater for 2 hr and cooled, then the sample was placed into the distillation apparatus. 20 ml of 40% NaOH were added. The ammonia evolved was received in 10ml of 2% boric acid solution. The trapped ammonia was titrated against 0.02N HCl using Universal indicator (methyl red + bromo cresol green)

$$N\% = \frac{\text{volume of HCl} \times 0.02 \times 14 \times 100}{\text{Weight of sample} \times 1000}$$

3.2.1.4 Fibre content:

Crude fibre was determined according to the AOAC method (1984). A 2g of fat free samples were treated successively with boiling solution of 0.36 N H_2SO_4 and 0.23N NaOH. The residue was separated by filtration washed, dried, weighed and ashed at 450 C°. The loss of weight resulting from ashing corresponds tso crude fibre.

$$\text{Crude fibre } \% = \frac{(W_1 - W_2) \times 100}{\text{Sample weight}}$$

Where:

W_1 = The weight of oven dry sample after treatment with H_2SO_4 and NaOH.

W_2 = The weight of the treated sample after ashing.

3.2.1.5 Ash content:

Total ash was determined according to the AOAC method (1984). A 2g of sample was ignited at 500C° in a muffle furnace (overnight).

$$\text{Ash } \% = \frac{\text{Weight of ash} \times 100}{\text{Weight of sample}}$$

3.2.2 Reducing Sugars:

Sugar content was determined by the modified Schneider method described by the ICUMSA (1979). A 10 g material was extracted with 70% ethanol for 6hr in Soxhlet apparatus, the solution was evaporated to 100ml. The solution was clarified by 2ml of lead acetate and 3ml of sodium oxalate and filtered. 10ml of Fehlings' solution (Fehling A + B) were pipetted into conical flasks. Sugar solution was placed in a burette and 15ml was run into Fehling solution (A+B) and mixed well and then heated to boiling in an electric heater. The liquid was kept boiling for 2 min, then 4 drops of methylene blue were added. The titration was then completed by addition of sugar solution until the colour of the indicator was discharged completely and to a bright orange appearance.

$$\text{Reducing sugars (\%)} = \frac{\text{mg of sugars 100ml of solution} \times \text{Dilution} \times 100}{1000 \times \text{weight of the sample}}$$

Fehling solution(A): 6.928g $CaSO_4$ / 100ml distilled water

Fehling solution(B): 34.69g Rochell salt and 10g NaOH / 100ml distilled water

3.3.3Total carbobydrate:

Total carbohydrates were determined by difference [100-(moisture + protein + fat + ash)].

3.4.1 Physicochemical changes during fermentation:

3. 4.1.1 pH

Samples were taken from the fermented batter at 2hr interval, and their pH was measured using glass electrode pH meter.

3.4.1.2 Titratable acidity:

The titratable acidity was determined by titrating a known weight of fermented batter in presence of phenolphthalene indicator with 0.1N NaOH solution to a faint pink colour (Au and fields 1981). The acidity was calculated as lactic acid from the following equation

$$\% \text{ Titratable acidity} = \frac{\text{ml of } 0.1N \text{ NaOH} \times 0.009 \text{ g} \times 100}{\text{Weight of sample (g)}}$$

- 0.009 g =Weight of lactic acid equivalent to 1ml of 0.1N NaOH.

3.4.1.3 Total soluble solids:

The total soluble solids were measured according to Ahmed (1987) by centrifuging 10g batter at 300 rpm and drying 10ml of supernatant.

$$\%\text{Total soluble solid} = \frac{\text{Weight of dry matter in 10ml supernatant} \times 100}{\text{Weight of sample}}$$

3.4.1.4. Total solids:

Total solids were determined according to the AOAC method (1970). Clean aluminum dishes and lids were dried in the oven. The dishes were then cooled and weighed. Five grams of fermented batter were placed in the dishes and dried in the oven at 105 C° overnight

$$\% \text{ Total solids} = \frac{(W_1 - W_2) \times 100}{\text{Weight of sample}}$$

Where:

W_1 = Weight of dishes with sample before drying
W_2 = Weight of dishes with sample after drying

3.4.1.5 Apparent viscosity:

The apparent viscosity (AV) was estimated by the method of Quinn and Beuchat (1975).A 20g material whether suspended from a dry matter or taken intervally during fermentation (2-14) with wheat bran added before or after fermentation was used to determine the AV with a Brookfield Viscometer using spindle No.4 at 100 rpm. The value was multiplied by the factor specified for the spindle (Viscometer pamphlet). Viscosity was expressed in centipoise (CP).

3.4.1.6 Spreadability:

Spreadability of the batter was determined by the method of Bookwalter et al (1968). The materials used for measuring apparent viscosity were used for measuring spreadability. A stainless steel sheet with circular areas underneath was used to record the distance (cm) traveled by the batter in 5 sec.Which was taken as spreadability value.

3.4.1.7 Starch determination:

Starch was determined by dispersal in $CaCl_2$ followed by iodine spectrophotometry (Kerr, 1950). The sample was ground to pass 40-mesh screen. A 2g were taken in suspension of 10 ml water in a glass beaker stirred with a glass rod; 60ml of 1.2 % $CaCl_2$ and 2ml of aqueous solution of acetic acid (0.8%) were added to the sample suspension with continuous stirring. Water was added during boiling to compensate for loss by evaporation. The solution was cooled to room temperature and then 4 ml of 4% stannic chloride were added with stirring. The liquor was then transferred to 100ml volumetric flask and brought up to volume by addition of $CaCl_2$ solution. After filtration 5ml portion was placed in one liter volumetric flask containing about 700 ml of water. Then 20 ml of iodine-potassium iodide aqueous solution was prepared by adding 0. 5g of iodine to 0.75 g of potassium iodide and the volume was adjusted with distilled water to 100ml in a volumetric flask. The volume was made to one litre using distilled water. The blue colour intensity was measured at 610nm using WPA SIOI Spectrophotometer. Reasonable spectrophtometric reading were reported for samples of 50% starch concentration; if starch content was more than 50% then dilution may be necessary.

Standard curve was prepared by first dissolving 2g pure starch in 100 ml of $CaCl_2$ - $SnCl_4$ solution. Then 5ml of this solution with 20ml of iodine-potassium iodide solution were added and the volume was made up to one litre with distilled water.

Different dilutions were made. The percentage of light absorption was measured at 610 nm. Iodine without starch was used as blank for zero absorption. The optical density was plotted against starch concentration. The starch equivalent of the different samples was used to calculate the starch percentage.

Calculation:

$$\text{Starch \%} = \frac{C \times df \times 100}{\text{Samples weight (g)}}$$

Where:

C = concentration corresponded to absorbancy
df = dilution factor

3.4.2 Evaluation of kisra bread

3.4.2.1 Nutritional assessment

3.4.2.1.1 Calorific value

Calorific values were determined as described by Maynard (1944).

Calculation:

1g of carbohydrate provides 4 calories

1g of fat provides 9 calories

1g of protein provides 4 calories

3.4.2.1.2. Determination of in vitro starch digestibility:

In vitro starch digestibility of samples was determined using pancreatic amylase (Singh et al; 1982). Fifty mg of defatted sample were dispersed in 1.0 ml of 0.2M phosphate buffer (pH=6.9). Twenty mg of pancreatic amylase were dissolved in 50 ml of the same buffer and 0.5ml from it were added to the sample suspension and incubated at 37C° for 2hr. Two ml of 3.5dinitrosalicylic acid (10% aqueous solution) were added and the mixture was heated for 5min in a boiling water bath. After cooling, the solution was made up to 25 ml with distilled water and filtered prior to measurement of the absorbance at 550nm. A blank was run simultaneously by incubating 1.0 ml of 0.2 M phosphate buffer and 3.5 dinitrosalicylic acid was added before the addition of the enzyme solution. Maltose was used for the standard curve determination and the in vitro starch digestibility values were expressed as percent in the sample.

$$\% \text{ in vitro starch digestibility} = \frac{\text{mg maltose in 50 mg sample} \times 100 \times 100}{50 \times \text{starch content in 100g sample}}$$

3.4.2.1.3. Determination of in vitro protein digestibility:

In vitro protein digestibility was carried out by the method of Maliwal (1983) with modification by Monjula et al (1991). A known weight of sample containing 16mg nitrogen was taken in triplicate and hydrolysed with one mg pepsin in 15ml of 0.1M HCl at 37C° for 18 hr. The reaction was terminated by the addition of 15 ml of 10%w/v trichloroacetic acid (TCA). The mixture was then filtered quantitatively through Whatman No. 1 filter paper. The TCA soluble fraction was assayed for nitrogen using the micro-Kjeldahl method. Digestibility was calculated using the following formula.

$$\text{Protein digestibility (\%)} = \frac{(\text{N in supernatant - enzyme N}) \times 100}{\text{N in sample}}$$

3.4.2.2 Organoleptic evaluation

The kisra breads prepared were assessed organoleptically (Form 1) by the ranking tests according to the procedure described by Ihekoronye and Ngoddy (1985). Fifteen panelists (Food Research Centre staff) were served coded samples in dishes and were asked to evaluate appearance, flavor, taste, texture and to rank preference (1 extremely like ; 5 extremely dislike.).Sums of ranks were statistically analyzed at 5% level of significance.

Form 1: Examine the following kisra samples carefully and
Rank them according to attributes mentioned on the table,
giving Best sample 1 and Least sample 5

Sample	Appearance	Flavour	Taste	Texture (chewing)	Preference

Chapter Four

Results and Discussion

Results and Discussion

4.1 Proximate composition of sorghum and wheat bran

4.1.1 Moisture

The moisture content of whole sorghum (WS), 80% extracted sorghum (80%S) and 72% extracted sorghum (72%S) were 6.9, 6.5 and 6.2% respectively (Table 1). These values are within the range of 6.8 - 7.8% reported by El Hidai (1978). The moisture content of wheat bran (WB) was 10.2%, almost similar to that reported by Rendleman (10.4%; 1982). The moisture content of WB is higher than 7.9% reported by Thompson and Weber (1979), but lower than 12.8% reported by Springsteen et al. (1977).

4.1.2 *Fat content*

Table 1 shows the fat content of WS, 80%S, 72%S and WB. Fat contents of WS, 80%S and 72%S were 3.5,3.0 and 2.7%, respectively. These values are within the range of 2.5-5.1 and the range of 2.5-3.5% reported by Shepherd (1970) and El Tinay et al. (1979) respectively.

The fat content of WB was 7.2%. This value is higher than those reported by Springsteen et al. (1977), Thompson and Weber (1979) and Rendleman (1982); 3.6,3.5 and 5.2% respectively).

4.1.3 *Crude protein content.*

The crude protein content of WS, 80%S, 72%S and WB is shown in Table 1.Protein content of WS, 80%S and 72%S were 12.3, 11.9 and 11.5% respectively. These values are within the range of 8.9-16.9% reported by Shepherd (1970) but higher than the range of 8.8-11.6% reported by El Tinay et al. (1979).

The protein content of WB was 15.0%. This value is similar to the value (14.3%) reported by Rendleman (1982), but higher than 12.5

reported by Springsteen et al. (1977) and lower than 17.8% and 18.0% reported by Thompson and Weber (1979) and Ellis (1981), respectively

4.1.4 *Crude fibre content*

Table 1 shows the fibre content of WS, 80%S, 72%S and WB. Fibre contents of WS, 80%S and 72%S were 1.6, 0.7 and 0.5%, respectively. These values are within the range of 1.2-1.9% reported by El Tinay et al. (1979). Fibre content of WB was 10.4% which is lower than 13.6% reported by Ellis (1981) but higher than 8.9% reported by Rendleman (1982).

4.1.5 *Ash content*

Table 1 shows the ash contents of WS, 80%S, 72%S and WB. Ash contents of WS, 80%S, and 72%S were 1.9, 1.0 and 0.8% respectively. These values are within the range of 1.1-2.7% reported by Shepherd (1970) and the range of 1.3-1.9% reported by Yousif et al. (1972). The ash content of WB was 10.3% which is higher than 6.7, 7.0 and 5.8% reported by Springsteen et al. (1977) and Thompson and Weber (1979) and Ellis (1981), respectively.

4.2 Physico chemical changes in the fermented batter

4.2.1 *Total soluble and insoluble solids.*

Tables 2 and 3 show the total soluble solids (TSS) and total solids (TS) content of WS, 80%S containing WB and 72%S containing WB .

Addition of 30 and 35% of WB to 80%Sand 72%S, respectively showed significant ($P \leq 0.05$) increase in total solids (TS) compared to WS. The 72%S/WB blend gave significantly higher ($P \leq 0.05$) TS than 80%S/WB blend. During fermentation there was a decreasing trend in TS from 96.8 to 90.3%, from 97.1 to 92.4% and from 98.2 to 93.1% for the WS, 80%S/WB and 72%S/WB blends, respectively with increasing fermentation time (0.0 - 14 hr).

Table 1 : Chemical composition of Sorghum flour and wheat bran.

Sample (S)	Moisture(%)	Fat(%)	Protein(%)	Fibre(%)	Ash(%)
Whole Sorghum	6.9	3.5	12.3	1.6	1.9
80 % Sorghum	6.5	3.0	11.9	0.7	1.0
72 % Sorghum	6.2	2.7	11.5	0.5	0.8
Wheat Bran	10.2	7.2	15.0	10.4	10.3

Table 2: Effect of wheat bran on total soluble solids (%) of fermented sorghum batter.

Sample	Fermentation Time (hr)							
	0	2	4	6	8	10	12	14
Whole sorghum	4.2^{a}	6.3^{a}	7.9^{a}	8.6^{a}	9.1^{a}	9.7^{a}	9.8^{a}	10.2^{a}
80% S+ WB*	6.1^{b}	6.3^{a}	6.7^{b}	7.3^{b}	7.6^{b}	8.1^{b}	8.5^{b}	8.7^{b}
72% S+ WB*	5.9^{b}	6.1^{a}	6.4^{b}	6.5^{c}	6.7^{c}	7.0^{c}	7.2^{c}	8.9^{b}
L.S.D	0.5	0.3	0.9	0.5	0.5	0.4	0.03	0.61

Mean values with different superscript letter (s) differ significantly ($P \leq 0.05$)
WB* = Wheat bran added before fermentation.
80 % S = Sorghum extraction
72 % S = Sorghum extraction

Table 3: Effect of wheat bran on total solids (%) of fermented sorghum batter.

Sample	Fermentation Time (hr)							
	0	2	4	6	8	10	12	14
Whole sorghum	96.8^{a}	95.9^{a}	94.1^{a}	93.6^{a}	93.3^{a}	93.0^{a}	92.0^{a}	90.3^{a}
80% S+ WB*	97.1^{b}	96.1^{b}	95.8^{b}	95.0^{b}	94.2^{b}	93.5^{b}	92.9^{b}	92.4^{b}
72% S+ WB*	98.2^{c}	97.0^{c}	96.1^{c}	95.3^{c}	95.2^{c}	94.8^{c}	93.5^{c}	93.1^{c}
L.S.D	0.2	0.2	0.4	0.13	0.7	0.6	0.6	0.5

Mean values with different superscript; letter(s) differ significantly ($P \leq 0.05$).
WB* = Wheat bran added before fermentation.

4.2.2 Titratable acidity and pH

The titratable acidity (TA) and pH of WS, 80%S/WB blend and 72%S/WB blend batter at 37±2C° for 14 hr (sampling at two hr intervals) is shown in Table 4. Addition of WB (30 and 3 5%) to 80%S and 72%S meal, before and after fermentation, gave significant ($P \leq 0.05$) decrease in TA compared to the control (Table 4). 72%S/WB blend showed lower values for TA than 80%S/WB blend. The TA significantly ($P \leq 0.05$) decreased by addition of WB after fermentation. Addition of WB to 80%S and 72%S (30 and 35% respectively) batter before and after fermentation resulted in increase in pH. The general trend was increase in TA and decrease in pH as fermentation progressed. Results indicated that fermentation of sorghum batter caused an increase in TA and decrease in pH. This is in agreement with Au and field (1981), Kolarole et al. (1987), Adeyemi (1988) and Dirar (1992) who reported that the pH of sorghum batter decreased during fermentation. Addition of WB, before or after fermentation caused a decrease in TA and increase in pH

4.2.3 *Changes in protein*

The protein content of WS, 80%S/WB blend and 72%S/WB blend batter at 37±2C° for 14 hr fermentation (sampling at two hr intervals) is shown in Table 5. Addition of WB to 80%S and 72%S (30 and 35% respectively; before and after fermentation, showed significant ($P \leq 0.05$) increase in protein content compared with the control (15.7% at the end of fermentation). However, 72%S/WB blend showed significant ($P \leq 0.05$) increase in protein content (20.7%) compared to 80%S/WB blend (19.0%) at the end of fermentation. Addition of WB after fermentation significantly ($P \leq 0.05$) increased protein content to 22.8% and to 24.5% for 80% S/WB blend and 72%S/WB blend, respectively. Addition of WB

Table 4: Effect of wheat bran on Titratable acidity (% lactic acid) and pH of fermented sorghum batter.

Sample	Fermentation Time (hr)							
	0	2	4	6	8	10	12	14
Whole Sorghum	1.2^{a} (5.6)*	1.3^{a} (5.2)	1.4^{a} (4.9)	1.5^{a} (4.8)	2.1^{a} (4.4)	2.3^{a} (4.2)	2.9^{a} (4.0)	3.8^{a} (3.7)
80% S+WB**	0.8^{b} (5.8)	1.1^{b} (5.6)	1.2^{b} (5.2)	1.4^{b} (5.0)	1.8^{b} (4.8)	2.0^{b} (4.5)	2.3^{b} (4.3)	2.8^{b} (4.0)
72%S+WB**	0.7^{b} (6.0)	1.0^{b} (5.8)	1.2^{b} (5.5)	1.3^{c} (5.2)	1.6^{c} (5.1)	1.9^{c} (4.8)	2.1^{c} (4.5)	2.3^{c} (4.2)
L.S.D	0.14	0.16	0.06	0.03	0.1	0.06	0.13	0.08
80%S+WB***	1.1^{b} (5.3)	1.0^{b} (5.7)	1.1^{b} (5.4)	1.2^{b} (5.2)	1.6^{b} (5.0)	1.9^{b} (4.7)	2.1^{b} (4.5)	2.5^{b} (4.1)
72%S+WB***	0.8^{b} (5.2)	0.9^{c} (6.0)	1.0^{c} (5.7)	1.1^{c} (5.5)	1.4^{c} (5.2)	1.7^{c} (4.9)	1.9^{c} (4.7)	2.2^{c} (4.3)
L.S.D	0.10	0.06	0.06	0.06	0.14	0.08	0.09	0.05

Mean values having different superscript letter(s) differ significantly ($P \leq 0.05$).

* = Values between brackets represent pH values

WB** = Wheat bran added before fermentation.

WB*** = Wheat bran added after fermentation.

Table 5: Effect of wheat bran on protein content (%) of fermented sorghum batter.

Sample (s)	Fermentation Time (hr)							
	0	2	4	6	8	10	12	14
Whole Sorghum	12.4^{a}	14.5^{a}	14.3^{a}	14.9^{a}	15.1^{a}	14.4^{a}	14.0^{a}	15.7^{a}
80% S+WB*	16.1^{b}	16.6^{b}	17.2^{b}	16.0^{b}	17.0^{b}	17.5^{b}	17.0^{b}	19.0^{b}
72% S+WB*	17.4^{c}	19.5^{c}	19.7^{c}	19.1^{c}	19.3^{c}	20.3^{c}	19.6^{c}	20.7^{c}
L.S.D	0.29	0.26	0.16	2.4	0.35	0.16	0.16	0.16
80%S+WB**	16.2^{b}	19.8^{b}	20.3^{b}	21.8^{b}	20.5^{b}	20.6^{b}	21.4^{b}	22.8^{b}
72%S+WB**	17.5^{c}	20.4^{c}	21.4	22.1^{c}	20.8^{c}	21.7^{c}	22.8^{c}	24.5^{c}
L.S.D	0.01	0.23	0.34	0.23	0.2	0.23	0.34	0.2

Mean values with different superscript letter(s) differ significantly ($P \leq 0.05$)

WB* = Wheat bran added before fermentation

WB** = Wheat bran added after fermentation

before fermentation caused an increase in protein content to 19.0 and to 20.7% for 80%S/WB blend and 72%S/WB blend, respectively. During fermentation, there was an increase in the protein content with increasing time of fermentation.

The general trend was increase in protein content of the blends with increase in fermentation period.

Results revealed that protein content of sorghum batter can be improved by fermentation. El Tinay et al. (1979) and Kazanas and Fields (1981) reported an increase in protein in cereals and legumes meals due to fermentation. The increase in the protein content during fermentation was associated with weight losses in the form of non nitrogenous volatiles during fermentation, hence accounting indirectly for weight increase in other constituents including crude Protein (Wang et al, 1968; Van Veen et al, 1968; Quinn et al., 1975). Addition of wheat bran resulted in significant increase in protein contents of the blend compared to the control

4.2.4 *Changes in fibre content*

The crude fibre of WS, 80%S/WB blend and 72%S/WB blend batter(s) fermented at 37±2C° for 14 hr, is shown in Table 6.

Addition of 30 and 35% of WB to 80%S and 72%S, respectively, before and after fermentation, showed significant ($P \leq 0.05$) increase in crude fibre content compared to the control (WS). The 72%S/WB blend recorded significant ($P \leq 0.05$) increase in crude fibre content compared to the control (WS). The 72%S/WB blend was significantly ($P \leq 0.05$) higher in crude fibre compared to 80%S/WB blend. Addition of WB after fermentation showed significantly higher ($P \leq 0.05$) increase compared to addition before fermentation except for zero time (Table .6). In general, there was an increasing trend in crude fibre during fermentation period. Novellie (1966) found that during bouza fermentation fibre content increased. Results indicated that fermentation of sorghum batter resulted in an increase in crude fibre. This agrees with El Tinay et al. (1979). Wheat bran, as a by-product of the flour milling industry, is a readily available and inexpensive source of dietary fibre. The laxative properties of wheat bran are well documented (Cummings, 1978; Kelsay, 1978; Anderson and Chen, 1979). However, addition of wheat bran to bread does modify color, flavor and texture (Pomeranz et al, 1977). Cadden et al. (1983) reported that plant fibres were added to foods in order to dilute calories, improve gastrointestinal function, and prevent degenerative diseases. Lockhart et al. (1980) reported that a high dietary fibre level would tend to reduce the caloric value of the food. Wheat fibre has been reported to be the most effective for the alleviation of functional bowels disorders (Eastwood et al., 1980; Painter, 1982; Spiller et al., 1982). Shutler, et al. (1987) reported that high dietary fibre consumption has been correlated with decreased incidence of the so-called . diseases of affluence . (diverticular diseases, colon cancers, obesity, coronary heart diseases, diabetes etc.). Dietary fibre is reported to have a hypocholesterolemia effect (Shutler et al, 1987) as well as a hypoglycemic effect (Jensen and Jepsen,, 1982)since it leads to a decrease in intestinal transit time and also increases faecal bulk; it binds bile acids, and degrades it to short chain fatty acids in the large intestine; it increases viscosity and slows digestion (Passmor and Eastwood, 1986). Anderson et al. (1980) reported that high fibre diets have been very successful in improving diabetic control. These diets contain 70% carbohydrate and 35g dietary fibre /1000 Kcal; Ray et al. (1986) reported that supplementation of diet with wheat bran decreases excretion of glucose in urine. Gray (1995) found that wheat bran is the most effective treatment for constipation and hemorrhoids American Diabetes Association (1971) recommended that diabetic diet should be high in fibre.

4.2.5 *Changes in Sugar content*

Table 7 shows reducing sugars of WS, 80%S/WB blend and 72%S/WB blend batter fermented at 37±2C° for 14 hr (sampling at two hr intervals). Addition of WB to 80%S and 72%S (30 and 35% respectively before and after fermentation showed significant ($P \leq 0.05$) decrease in reducing sugars compared with control (WS). However, 72%S/WB blend was significantly lower in sugar content compared to 80%S/WB blend. Addition of WB before fermentation caused significant ($P \leq 0.05$) decrease in reducing sugars compared to addition after fermentation. The general trend was increase in reducing sugars during fermentation process (Table 7). Reducing sugars increased in the first 2 hr of fermentation and continued to increase towards the end of the process except for 8hr fermentation period in which it markedly decreased. Results indicate that addition of WB caused adecrease in reducing sugars which could be attributed to reduction in the activity of hydrolysing enzymes (amylases) which hydrolyze starch to disaccharides and mono saccharides. Dunaif and Barbara (1981) reported that wheat bran lowered the activity of amylases. Mani et al. (1987) also reported that wheat bran supplementation caused a decrease in sugar content. Liu et al. (1989) found that wheat bran decreased blood glucose levels. The increase in reducing sugars during fermentation was mainly due to reduction of starch through hydrolysis to simple sugars. Kazanas and fields (1981) and Taur et al. (1984) reported that reducing sugars increased during fermentation of sorghum flour. Pederson (1971) indicated that microorganisms, particularly lactic acid bacteria and yeast, used simple sugars as ready source of energy for metabolism; this could explain the reduction in reducing sugar at the 8hr fermentation period.

Table 6: Effect of wheat bran on crude fibre (%) of fermented sorghum batter.

Sample (s)	Fermentation Time (hr)							
	0	2	4	6	8	10	12	14
Whole Sorghum	1.7^{a}	1.8^{a}	1.9^{a}	$2.o^{a}$	2.1^{a}	2.3^{a}	2.4^{a}	2.7^{a}
80% S + WB*	3.9^{b}	4.2^{b}	4.4^{b}	4.4^{b}	4.7^{b}	4.9^{b}	5.0^{b}	5.2^{b}
72% S + WB*	4.0^{b}	4.2^{b}	4.5^{c}	4.8^{c}	4.9^{c}	5.0^{c}	5.1^{b}	5.3^{b}
L.S.D	0.16	0.16	0.08	0.28	0.12	0.07	0.16	0.16
80%S+WB**	0.8^{b}	4.2^{b}	4.5^{b}	4.7^{b}	4.8^{b}	4.9^{b}	5.1^{b}	5.2^{b}
72%S+WB**	0.5^{c}	4.5^{c}	4.6^{c}	4.8^{c}	4.9^{c}	5.1	5.2^{c}	5.3^{b}
L.S.D	0.13	0.17	0.09	0.15	0.12	0.10	0.08	0.14

Mean values with different superscript letter (s) differ significantly ($P \leq 0.05$)

WB* = Wheat bran added before fermentation

WB** = Wheat bran added after fermentation.

Table 7: Effect of wheat bran on reducing sugars (mg/100g) of fermented sorghum batter.

Sample (s)	Fermentation Time (hr)							
	0	2	4	6	8	10	12	14
Whole Sorghum	0.37^{a}	7.97a	6.18^{a}	7.65^{a}	4.88^{a}	4.67^{a}	7.02^{a}	5.75^{a}
80% S+WB*	0.11^{b}	3.83^{b}	3.69^{b}	4.32^{b}	2.25^{b}	1.92^{b}	3.98^{b}	2.07^{b}
72% S+WB*	0.11^{b}	1.48^{c}	1.75^{c}	1.95^{c}	185^{c}	1.67^{c}	1.29^{c}	1.4^{c}
L.S.D	0.02	0.02	0.25	0.09	0.13	0.14	0.3	0.01
80%S+WB**	0.11^{b}	3.98^{b}	4.14^{b}	4.7^{b}	4.15	4.5^{b}	4.41^{b}	4.15^{b}
72%S+WB**	0.11^{b}	3.34^{c}	2.88^{c}	3.69^{c}	3.44^{c}	3.82^{c}	3.56^{c}	3.45
L.S.D	0.01	0.02	0.23	0.02	0.14	0.14	0.37	0.01

Mean values with different superscript letter (s) differ significantly ($P \leq 0.05$).

WB* = Wheat bran added before fermentation

WB** = Wheat bran added after fermentation

4.3 *Rheological properties of batter*

4.3.1 *Changes in apparent viscosity*

The apparent viscosity of WS, 80%S/WB blend and 72%S/WB blend batter at 37±2C° for 14 hr fermentation (sampling at two hr intervals) is shown in Figs 2 and 3, respectively. Addition of WB to 80%S and 72%S (30 and 35%, respectively) showed significant ($P \leq 0.05$) increase in the viscosity compared to WS. However, 72%S/WB blend showed significant ($P \leq 0.05$) increase in the viscosity compared to 80%S/WB blend. Addition of WB after fermentation resulted in higher viscosity compared to addition before fermentation. The general trend was a decrease in viscosity as fermentation progressed.

Results indicated that fermentation of sorghum batter caused a decrease in viscosity with time which is in agreement with Francis (1984) who reported that the fermentation process caused decrease in viscosity of some food materials. The decrease in viscosity during fermentation can be attributed to decrease in the native starch content. This result agrees with that of El Tinay et al. (1979). Adeyemi (1988) reported a reduction in Starch due to fermentation of sorghum flour. Also, results indicated that addition of WB increased the viscosity of batter compared with whole sorghum (control).

Addition of WB after fermentation resulted in increase in fibre in sorghum batter causing significant increase in viscosity compared to addition before fermentation. These results are in agreement with those obtained by Gilles (1960) who reported that increase in viscosity could be attributed to the increase in water absorption capacity of the fibre constituents as a result of their large molecular size.

4.3.2 *Changes in spreadability*

The spreadability of WS, 80%S/WB blend and 72%S/WB blend batter at 37±2C° for 14 hr fermentation (sampling at two hr intervals) is shown in Figs. 4 and 5, respectively. The distance (cm) traveled by a known quantity of batter in 5 sec was taken as the spreadability. Addition of WB to 80%S and 72%S (30 and 35% respectively) showed significant ($P \leq 0.05$) decrease in spreadability compared to the control. However, 72%S/WB blend showed the least spreadability compared to 80%S/WB blend. Addition of WB after fermentation caused marked decrease in spreadability compared to addition before fermentation (Fig 4 and 5). The general trend was an increase in spreadability during fermentation.

The results indicated that fermentation of sorghum batter caused an increase in spreadability, which could be related to decrease in starch content that is accompanied by decrease in viscosity. The results also indicate that addition of WB decreased the spreadability compared with WS. Addition of WB after fermentation resulted in pronounced decrease in spreadability compared to addition before fermentation.

4.4 Proximate composition of kisra bread.

4.4.1 *Moisture, fat, protein, fibre and ash.*

The proximate composition of kisra bread made from whole sorghum (control), 80%S/WB blend and 72%S/WB blend is shown in Table 8. Addition of WB, before or after fermentation, caused significant ($P \leq 0.05$) increase in moisture, fat, protein, fibre and ash contents compared to the control. However, addition of WB after fermentation showed significant ($P \leq 0.05$) increase in proximate composition compared to addition before fermentation. The protein and fibre contents of kisra were lower than that of the batter at the end of fermentation (Tables 5, 6 and 8). Results indicated that kisra baking lowered the protein

Fig. 2 Effect of wheat bran (WB) on viscosity (cp) of fermented sorghum batter.

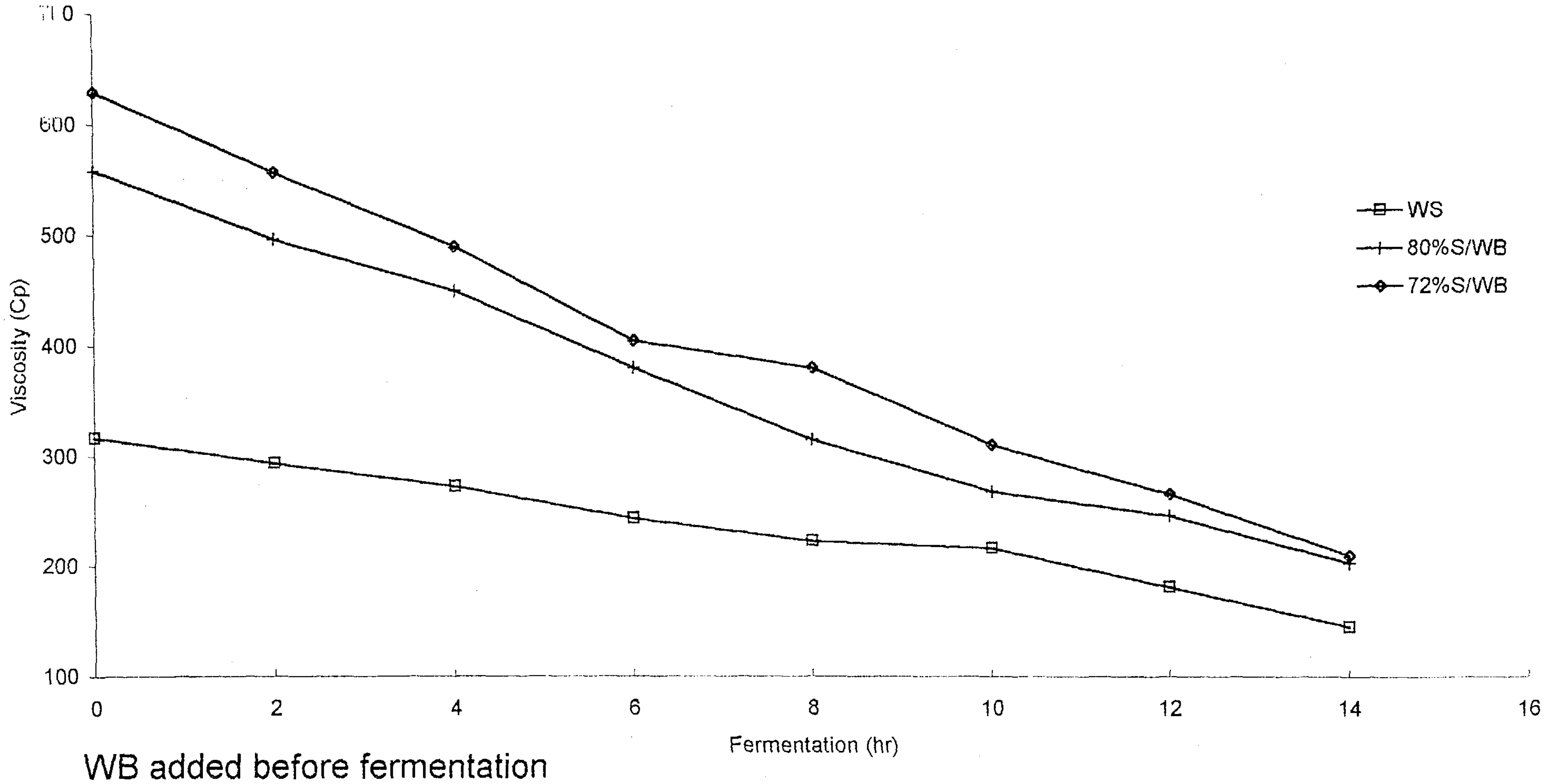
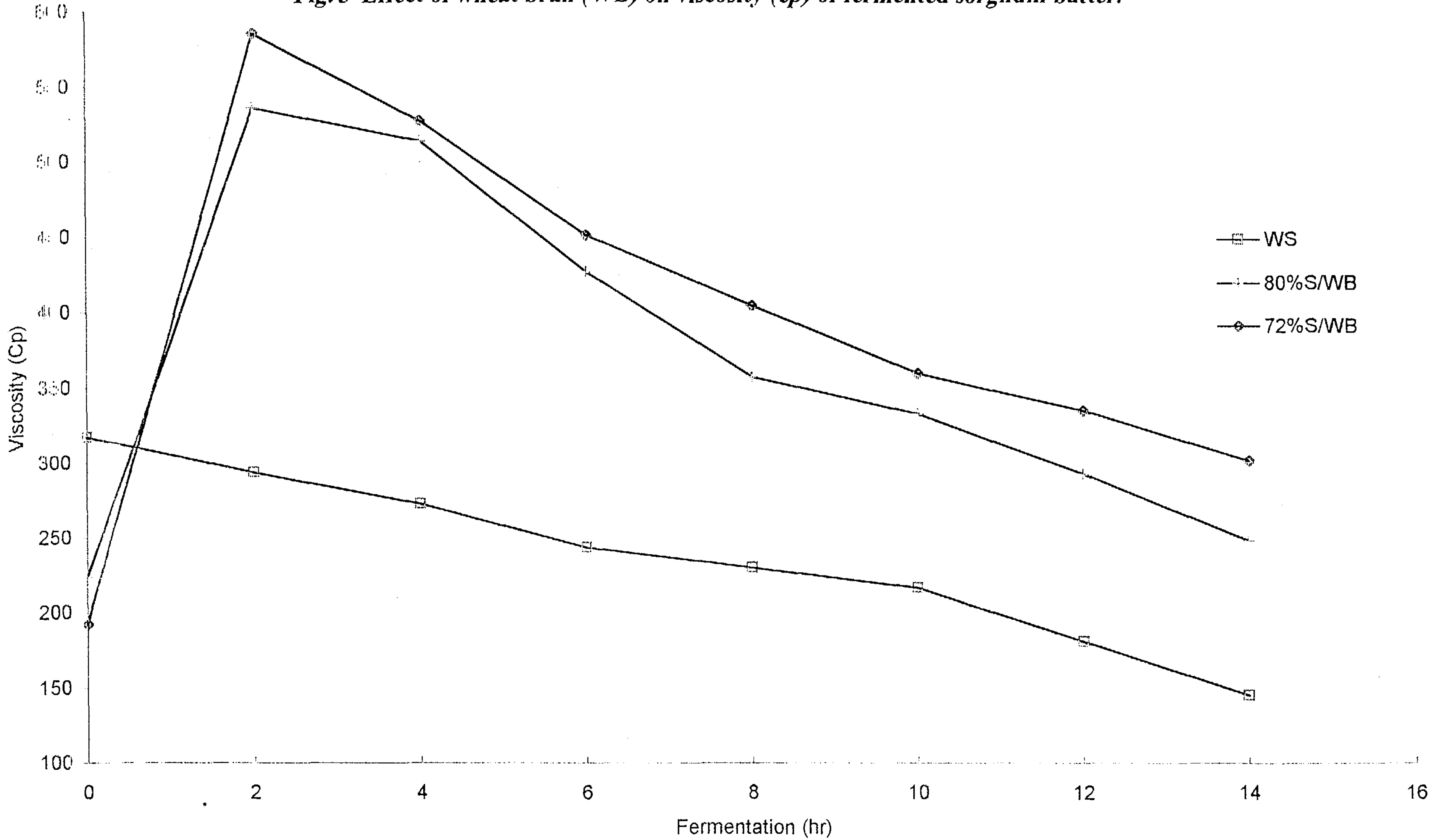
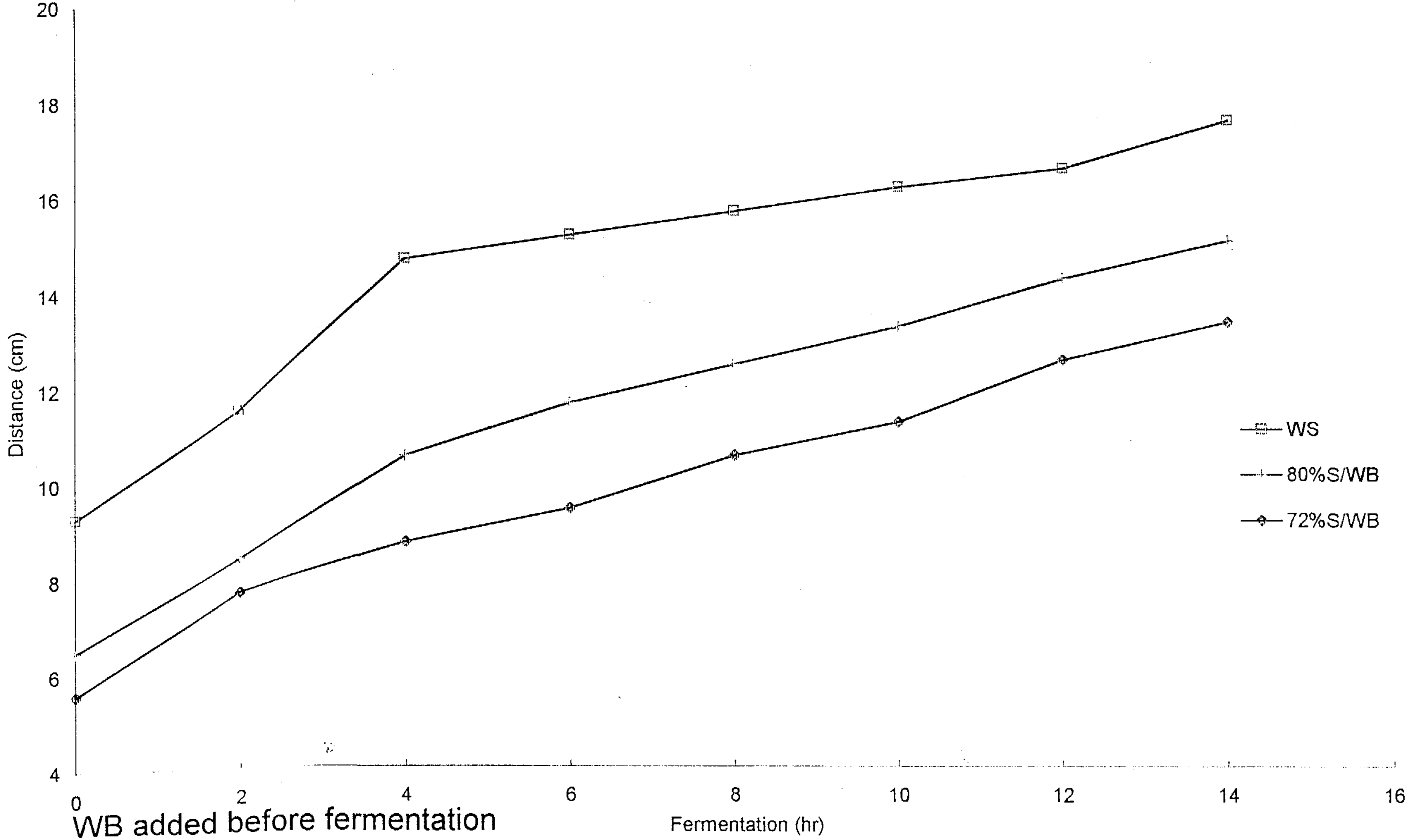


Fig. 3 Effect of wheat bran (WB) on viscosity (cp) of fermented sorghum batter.



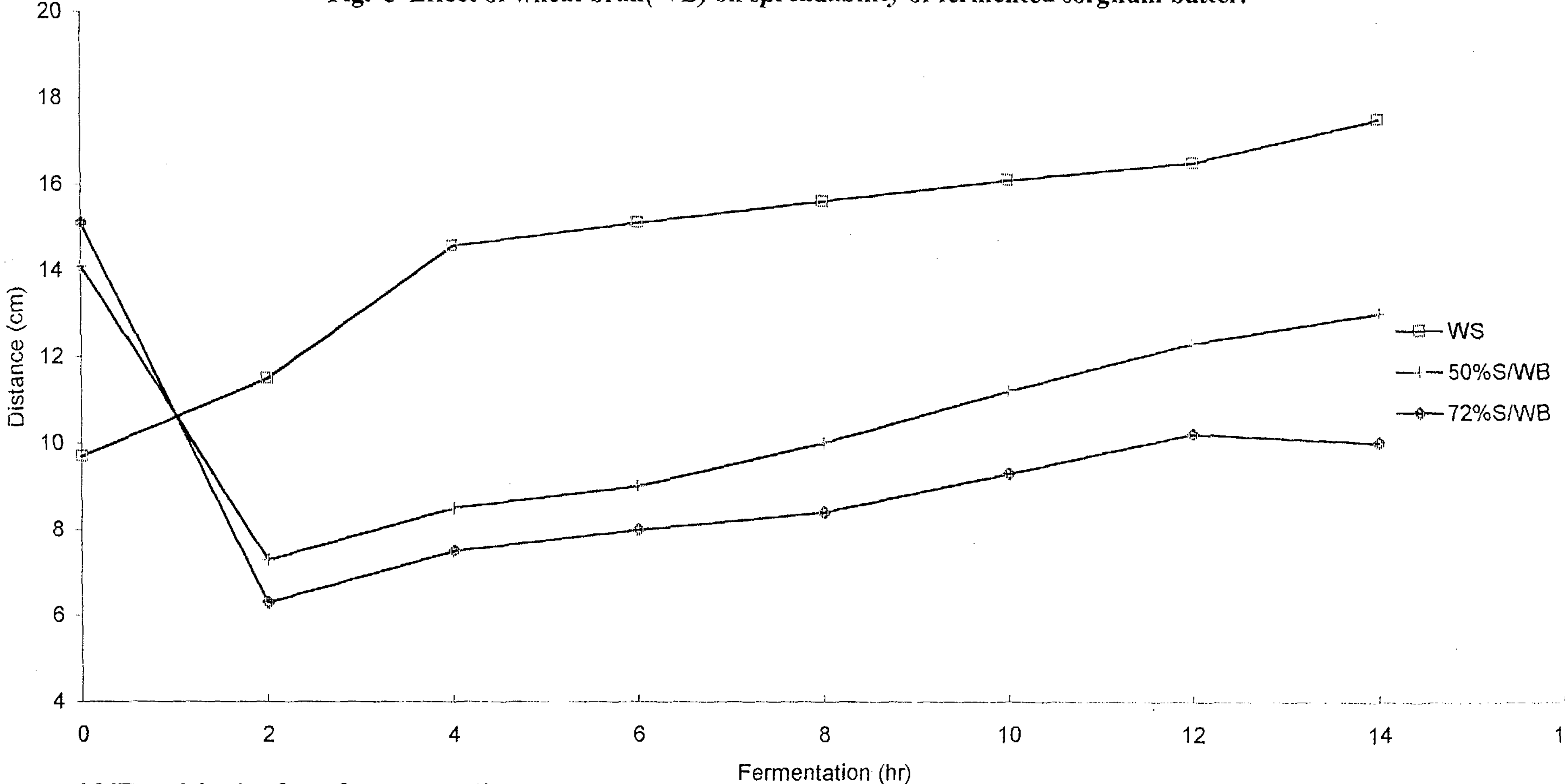
WB added after fermentation

Fig. 4 Effect of wheat bran (WB) on spreadability of fermented sorghum batter.



WB added before fermentation

Fig. 5 Effect of wheat bran(WB) on spreadability of fermented sorghum batter.



WB added after fermentation

Table 8: Effect of wheat bran on chemical composition of kisra bread

Kisra Source	Fermentation Time (hr)														
	Moisture(%)			Fat(%)			Protein (%)			Fibre (%)			Ash(%)		
	6	10	14	6	10	14	6	10	14	6	10	14	6	10	14
Whole sorghum	42.4^{a}	42.6^{a}	42.8^{a}	4.5^{a}	5.3^{a}	5.5^{a}	14.1^{a}	13.7^{a}	14.4^{a}	2.3^{a}	2.6^{a}	2.9^{a}	1.9^{a}	2.12^{a}	2.2^{a}
80% S+WB*	43.3^{b}	43.6^{b}	43.9^{b}	5.8^{b}	6.0^{b}	6.0^{b}	16.4^{b}	17.1^{b}	18.2^{b}	4.0^{b}	4.4^{b}	4.6^{b}	2.2^{b}	2.4^{b}	2.5^{b}
72% S+WB*	44.2^{c}	44.5^{c}	44.8^{c}	5.9^{b}	6.2^{c}	6.3^{c}	17.7^{c}	18.3^{c}	19.7^{c}	4.6^{c}	4.9^{c}	5.1^{c}	2.4^{b}	2.5^{b}	2.6^{c}
L.S.D	0.23	0.15	0.13	0.27	0.17	0.04	0.36	0.41	0.23	0.17	0.3	0.3	0.22	0.14	0.04
80%S+WB**	43.5^{b}	44.1^{b}	44.4^{c}	5.5^{b}	5.6^{b}	6.1^{b}	21.0^{b}	21.8^{b}	22.3^{b}	4.5^{b}	4.8^{b}	2.4^{b}	2.4^{b}	2.6^{b}	2.6^{b}
72%S+WB**	44.9^{c}	45.2^{c}	45.5^{c}	6.5^{c}	6.8^{c}	7.0^{c}	24.7^{c}	25.1^{c}	24.1^{c}	4.9^{c}	5.1^{c}	5.3^{c}	2.6^{b}	2.7^{b}	2.8^{b}
L.S.D	0.18	0.29	0.32	0.27	0.15	0.14	0.43	0.43	0.23	0.13	0.3	0.06	0.2	0.3	0.31

Mean values with different superscript letter (s) differ significantly ($P \leq 0.05$)

WB* = Wheat bran added before fermentation

WB** = Wheat bran added after fermentation

content (Table 5 and 8). El Tinay et al. (1979) reported that the protein content of kisra was lower than that of the batter at the end of fermentation.

4.4.2 *Starch content of kisra*

Table 9 shows the starch content of kisra from WS, 80%S/WB blend and 72%S/WB blend at various periods of fermentation. Addition of WB, before and after fermentation showed significant ($P \leq 0.05$) increase in starch content compared with the control (43.75% at the end of fermentation). However, kisra from 72%S/WB showed significantly ($P \leq 0.05$) higher starch content (49.38%) compared to kisra from 80%S/WB (45.63%). Addition of WB after fermentation resulted in kisras of significantly ($P \leq 0.05$) higher starch content. Results revealed that starch content of kisra bread could be increased by addition of WB.

4.4.3 *Reducing sugar content of kisra*

Table 9 shows the reducing sugars of kisra of WS, 80%S/WB and 72%S/WB, before and after fermentation. Kisra bread containing WB showed significant ($P \leq 0.05$) decrease in reducing sugars compared to the control. Addition of WB before fermentation caused significant ($P \leq 0.05$) decrease in reducing sugars compared to addition after fermentation. However, kisra from 72%S/WB blend was significantly ($P \leq 0.05$) lower in reducing sugars compared to kisra from 80%S/WB blend. Reducing sugar content of kisra was higher than that of the batter at the end of fermentation (Table 7 and 9). Results indicated that kisra containing WB was lower in reducing sugars compared to the control. Increase in reducing sugars of kisra bread over batter at the end of fermentation, could be attributed to starch hydrolysis as a result of baking. Similar results were reported by El Tinay et al (1979). Rinfel et al. (1990) found that addition of dietary wheat bran decreased the level of blood glucose. Ray et al. (1983) reported that addition of fibre decreased excretion of glucose in urine and decreased plasma glucose concentration. Liu et al. (1989) reported that wheat bran decreased blood glucose level.

4.4.4 *Total carbohydrate of kisra bread.*

Table 9 shows the total carbohydrates (CHO) of kisra bread from WS, 80%S/WB and 72%S/WB blends calculated by difference (Maynard, 1944). Kisra bread containing WB showed significant ($P \leq 0.05$) decrease in total CHO compared with control. However, kisra from 72%S/WB showed significant ($P \leq 0.05$) decrease in total CHO than kisra from 80%S/WB blend. Addition of WB after fermentation showed significant ($P \leq 0.05$) decrease in total CHO compared to addition before fermentation. Results indicated that addition of WB to kisra batter decreased the total CHO; this decrease could be attributed to increase in moisture, protein and ash contents by addition of WB (Table 8) Lockhart et al. (1980) reported that the caloric content of a food is related to its available carbohydrate content, except that a high dietary fibre level tends to reduce the caloric value of the food. Carbohydrates should be spread throughout the day and appropriate allowance adjustment made to insulin of oral hypoglycaemia drugtherapy (Sukkar, 1985).

4.5 Availability of macro nutrients in kisra bread

4.5.1 *In vitro protein digestibility (IVPD) of kisra*

Table 10 shows the in vitro protein digestibility (IVPD) of kisra from WS, 80 %S/WB blend and 72%S/WB blend. Kisra bread containing WB was significantly ($P \leq 0.05$) lower in IVPD compared to the control (WS). However, addition of WB after fermentation caused significant decrease ($P \leq 0.05$) compared to addition before fermentation (Table 10). Kisra from 72%S/WB blend showed significant ($P \leq 0.05$) decrease in IVPD

Table 9: Effect of wheat bran on carbohydrates of kisra bread as affected by fermentation.

Kisra Source	Reducing Sugars (%)			Starch (%)			Total CHO(%)***		
	6	10	14	6	10	14	6	10	14
Whole sorghum	6.54[a]	6.52[a]	7.42[a]	61.88[a]	56.25[a]	43.75[a]	77.1[a]	76.4[a]	75.1[a]
80%S+WB*	5.48[b]	4.71[b]	5.2[b]	66.88[b]	58.75[b]	45.63[a]	72.3[b]	71.0[b]	69.4[b]
72%S+WB*	4.06[c]	4.93[c]	4.51[c]	70.75[c]	60.63[c]	49.38[b]	69.8[c]	68.5[c]	66.6[c]
L.S.D	0.20	0.04	0.27	3.0	1.6	2.3	0.7	0.4	0.3
80% S+WB**	6.51[b]	5.48[b]	5.77[b]	72.5[b]	63.13[b]	57.5[b]	68.1[b]	66.7[b]	65.1[b]
72%S+WB **	6.12[c]	5.19[c]	4.93[c]	74.38[c]	65.63[c]	61.88[c]	61.3[c]	60.3[c]	60.7[c]
L.S.D	0.02	0.04	0.01	2.3	2.3	1.6	0.9	0.6	0.1

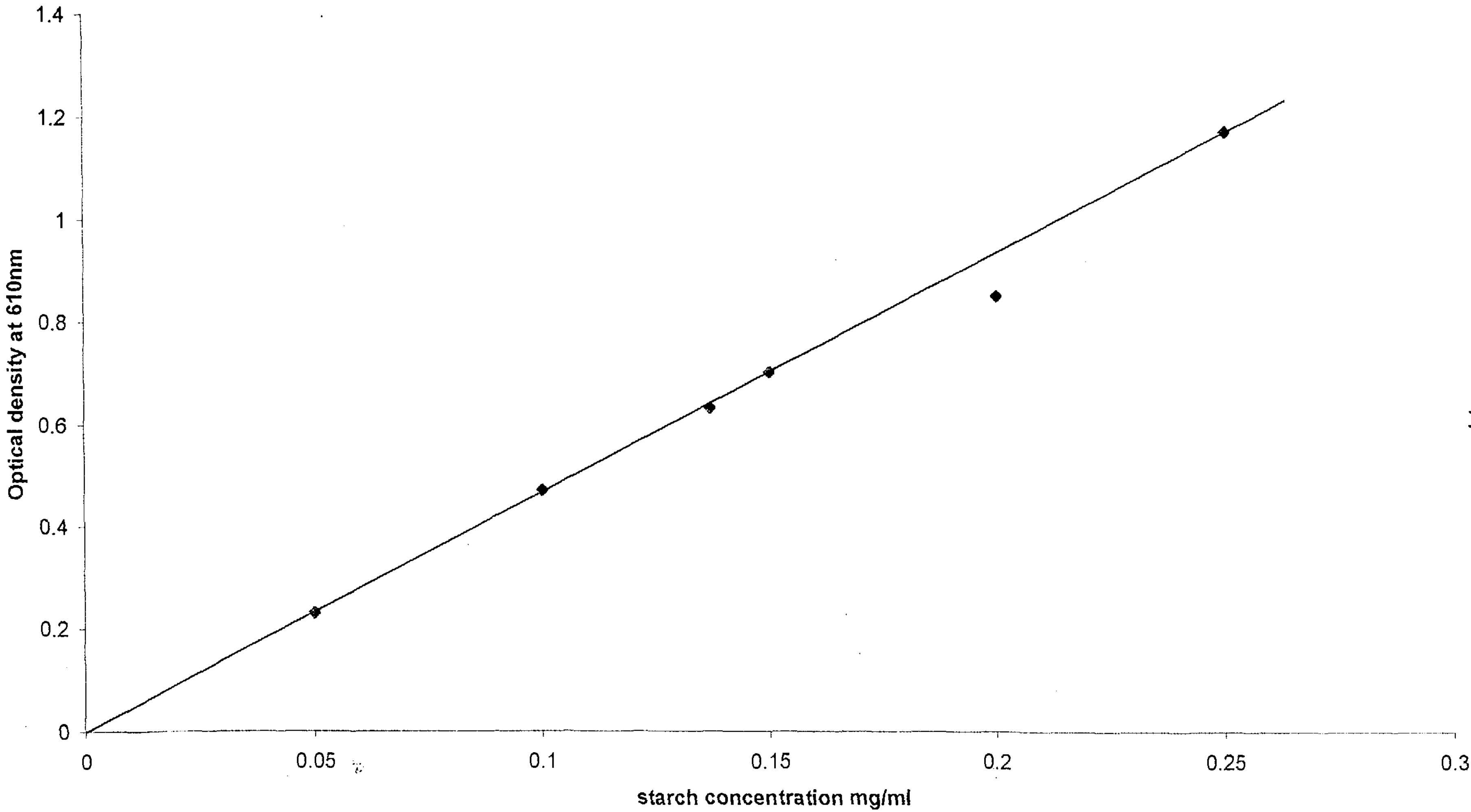
Mean values with different superscript letter (s) differ significantly ($P \leq 0.05$)

WB* = Wheat bran added before fermentation

WB** = Wheat bran added after fermentation

*** = Total CHO by differences (Pearson, 1976).

Fig. 6:The relationship between the Optical density at 610nm and starch concentration



than kisra from 80%S/WB when WB was added after fermentation (Table 10). The general trend was increase in IVPD with increasing time of fermentation. Results indicated that kisra bread containing WB was lower in protein digestibility. This decrease could be attributed to fibre in wheat bran, which decreases the activity of pancreatic enzymes. Sommer (1980), and Dunaif and Barbara (1981) reported that wheat bran lowered the activity of amylase, lipase and trypsin. Dietary fibre also increases viscosity and slows digestion (Passmor and Eastwood, 1986). Parada et al. (1985) reported that natural fermentation improved the IVPD. Chavan et al. (1988) found that the IVPD of sorghum grain increased markedly by fermentation for 24 hr, this could explain the increase in IVPD with increasing time of fermentation. Hassan and El Tinay (1995) reported that fermentation of sorghum batter caused a highly significant increase in IVPD. This improvement in IVPD could also be attributed to tannin degradation by microorganisms.

4.5.2 *In vitro starch digestibility (IVSD) of kisra*

Table 10 shows the in vitro starch digestibility (IVSD) of kisra from WS, 80%S/WB blend and 72%S/WB blend at various periods of fermentation. Kisra bread containing WB showed significant ($P \leq 0.05$) decrease in IVSD compared with control. However, kisra from 72%S/WB showed significant ($P \leq 0.05$) decrease in IVSD compared to kisra from 80%S/WB blend. Addition of WB after fermentation to kisra batter showed significant ($P \leq 0.05$) decrease in IVSD compared to addition before fermentation. The general trend was increase in IVSD with increasing time of fermentation. Results indicated that fermentation caused a significant increase in IVSD. Kazanas and Fields (1981) reported an increase in carbohydrate availability due to fermentation. Addition of WB to kisra batter reduced the IVSD. This decrease could be attributed to addition of wheat bran. Danaif and Barbara (1981) reported that wheat

Fig.7 The relationship between optical density at 550nm and maltose concentration

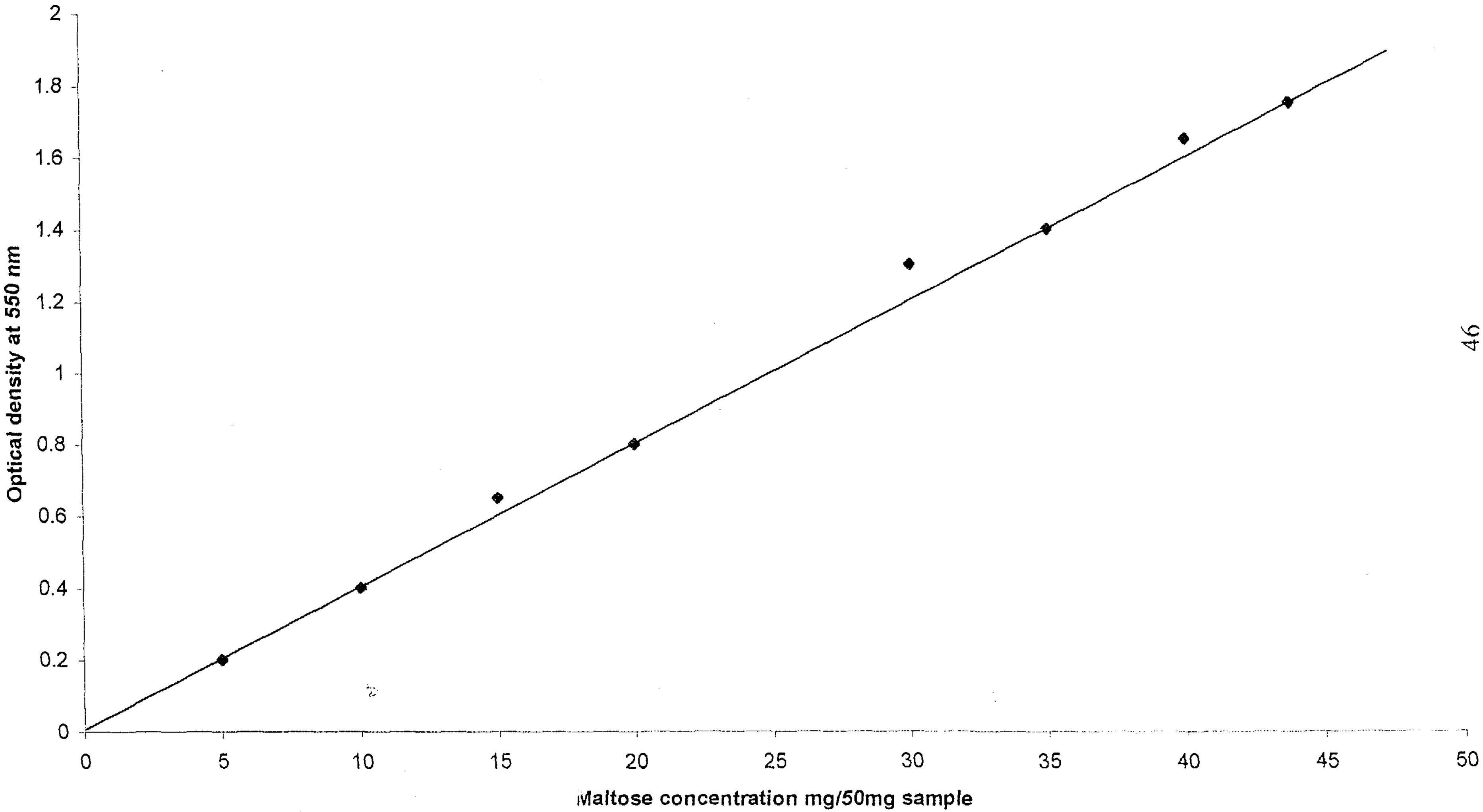


Table 10: In vitro digestibility on protein and starch of kisra.

Kisra Source	Protein digestibility(%)			Starch Digestibility (%)		
	6	10	14	6	10	14
Whole sorghum	78.1^{a}	80.5^{a}	83.6^{a}	36.4^{a}	40.9^{a}	45.7^{a}
80%S+WB*	75.2^{b}	78.5^{a}	82.3^{a}	33.6^{b}	38.3^{b}	43.8^{a}
72%S+WB*	73.3^{b}	77.5^{ab}	80.0^{b}	31.8^{c}	37.1^{c}	40.5^{b}
L.S.D	2.4	2.3	1.3	1.5	2.6	2.1
80%S+WB**	73.1^{b}	77.6^{b}	80.7^{b}	31.0^{b}	36.4^{b}	39.1^{b}
72%S+WB**	71.2^{c}	75.3^{c}	77.5^{c}	30.2^{b}	34.3^{b}	38.0^{c}
L.S.D	1.8	2.2	0.8	1.3	2.8	1.0

Mean values with different superscript letter (S) differ significantly ($P \leq 0.05$)

WB* = wheat bran added before fermentation

WB** = wheat bran added after fermentation.

Table 11: Total calories from total carbohydrate of kisra bread containing wheat bran.

Kisra source	Fermentation Time (hr)		
	6	10	14
Whole sorghum	242.5^{b}	247.5^{a}	247.7^{a}
80%S+WB*	241.9^{a}	246.4^{a}	244.6^{b}
72%S+WB*	243.2^{a}	243.5^{b}	241.9^{c}
L.S.D	2.45	1.43	1.08
80%S+WB**	243.2^{a}	241.5^{b}	238.3^{b}
72%S+WB**	242.9^{a}	242.7^{b}	240.1^{b}
L.S.D	1.8	2.05	3.97

Mean values with different superscript letter (s) differ significantly ($P \leq 0.05$)

WB* = Wheat bran added before fermentation

WB** = Wheat bran added after fermentation

bran lowered the activity of amylases. Liener et al. (1980) found that dietary fibre can decrease the activity of human pancreatic amylase, lipase and trypsin. Foritvieille et al (1988) reported that dietary fibre can decrease the in vitro digestibility of starch.

4.5.3 *Total calories from total carbohydrate of kisra bread containing wheat bran.*

Table 11 shows total calories calculated from total carbohydrate of kisra bread containing wheat bran. It was obvious that inclusion of wheat bran whether before or after fermentation of sorghum flour for 6 hr did not bring about any significant ($P \leq 0.05$) changes in the calorific value derived from total carbohydrates. However, extending fermentation time to 10 and 14 hr. caused significant ($P \leq 0.05$) changes in the calories of the different kisra preparations. Addition of wheat bran helped reduce calorific value expected to be available for whole sorghum meal fermented for extended time. Although traditional fermentation of sorghum flour for kisra preparation favours extended fermentation time to attain desirable souring, recent eating habits do not object to taking mildly sour kisra bread (low -acid/ high pH kisra bread).

4.5.4 *Available calories from starch of kisra containing wheat bran:*

Table 12 shows available calories calculated from digestibility coefficient of starch of kisra containing wheat bran. Presence of wheat starch in sorghum system did not alter the calorific feature of kisra bread fermented for 6 and 10hr. However, extending fermentation time to 14hr increased significantly ($P \leq 0.05$) availability of starch of sorghum system fermented before addition of wheat bran and baking. This suggests con-current fermentation of sorghum flour/wheat bran blend which obviously reduced available calories (~80) if fermentation is to be extended for more than 10hr.

Table 12: Available calories* from starch of kisra containing wheat bran.

Kisra source	Fermentation Time (hr)		
	6	10	14
Whole Sorghum	90.03^a	92.1^a	80.0^a
80%S+WB**	90.0^a	90.0^a	80.0^a
72%S+WB**	90.0^a	90.0^a	80.0^a
L.S.D	0.0	0.0	0.0
80%S+WB***	90.0^a	92.0^a	90.0^b
72%S+WB***	89.72^a	90.0^a	94.1^b
L.S.D	0.0	0.0	4.97

Mean values with different superscript letter (s) differ significantly ($P \leq 0.05$)

* = Calculated for starch from its digestibility coefficient (Table 10)

WB** = Wheat bran added before fermentation

WB*** = Wheat bran added after fermentation

Table 13: Available calories from reducing sugars of kisra containing wheat bran.

Kisra source	Fermentation Time (hr)		
	6	10	14
Whole sorghum	15.1^a	14.98^a	17.00^a
80%S+WB*	12.42^b	10.62^b	11.61^b
72%S+WB*	9.1c	9.5c	10.0^c
L.S.D	0.2	0.04	0.27
80%S +WB**	14.72^b	12.24^b	12.84^b
72%S +WB**	13.48^c	11.37^c	11.94^c
L.S.D	0.02	0.04	0.01

Mean values with different superscript letter (s) differ significantly ($P \leq 0.05$)

WB* = Wheat bran added before fermentation

WB** = Wheat bran added after fermentation

Table 14-a: Organoleptic guilty of kisra bread containing wheat bran.

Sample* Code	Sum of ranks **				
	Appearance	Flavour	Taste	Texture	Preference
A_1	43^a	60^a	53^a	35^a	53^a
B_1	44^a	41^b	41^a	49^a	40^a
C_1	31^b	38^b	39^a	36^a	28^b
D_1	46^a	43^b	37^a	43^a	39^a
E_1	61^c	45^b	55^a	62^b	63^c

(*A_1) Whole sorghum (control) time of fermentation 14 hr.
(*B_1) 72% S /WB added of WB after fermentation for 14hr.
(*C_1) 72%S/WB added of WB before fermentation for 14hr.
(*D_1) 72%S/WB added of WB after fermentation for 10hr.
(*E_1) 72%S/WB added of WB before fermentation for 10hr.
** Any two sum of ranks with different superscript letter (s) differ significantly ($P \leq 0.05$)

Table 14-b Organoleptic guality of kisra bread containing wheat bran .

	Sum of ranks **				
Sample* Code	Appearance	Flavour	Taste	Texture	Perference
A_2	42^a	61^a	57^a	37^a	61^a
B_2	42^a	31^b	25^b	48^a	29^b
C_2	34^a	35^c	34^a	32^a	21^b
D_2	46^a	39^c	42^a	46^a	47^c
E_2	61^b	59^a	67^c	62^b	67^a

(*A_2) Whole sorghum (control) time of fermentation 14 hr.
(*B_2) 80% S /WB added of WB after fermentation for 14hr.
(*C_2) 80%S/WB added of WB before fermentation for 14hr.
(*D_2) 80%S/WB added of WB after fermentation for 10hr.
(*E_2) 80%S/WB added of WB before fermentation for 10hr.
** Any two sum of ranks with different superscript letter (s) differ significantly ($P \leq 0.05$)

($P \leq 0.05$) superior in flavour and taste compared to the rest of the samples. It recorded overall preference following C_2, which recorded top preference by panelists. Sample E_2 recorded extremely unacceptable appearance, taste and texture, and shared the least preference compared to the control. Results indicated that panelists prefer inclusion of wheat bran in Sorghum kisra compared to the traditional kisra. It seems that fermentation time of 14hr was more acceptable than fermentation time of 10hr, irrespective of the order of wheat bran addition to sorghum batter. In this session, preference was obvious for C_2 and B_2.

Chapter Five

Conclusions

CONCLUSIONS

The results of the present investigations indicated that addition of wheat bran to sorghum batter, before or after fermentation resulted in significant ($P \leq 0.05$) increase in protein, ash, crude fibre and total solids. There was a significant ($P \leq 0.05$) decrease in titratable acidity, total soluble solids and reducing sugars.

Rheological properties of fermented sorghum batter were affected by inclusion of wheat bran. The viscosity significantly ($P \leq 0.05$) increased while spreadability significantly decreased. Inclusion of wheat bran in sorghum flour also affected the chemical composition of kisra bread. There was a significant ($P \leq 0.05$) decrease in reducing sugars content of kisra containing wheat bran compared with control kisra; the percent decrease was almost 40%. Addition of wheat bran before fermentation caused higher reduction in reducing sugars compared to addition after fermenttion. There was significant increase ($P \leq 0.05$) in starch content of kisra containing wheat bran compared to the control. Kisra bread containing wheat bran showed significant ($P \leq 0.05$) decrease in total carbohydrate. Addition of wheat bran to sorghum batter before or after fermentation showed significant ($P \leq 0.05$) decrease in calorific value derived from total carbohydrate and reducing sugars. There was a negative correlation between addition of wheat bran and the in vitro protein and starch digestibilites of kisra bread. The IVSD of kisra bread containing wheat bran decreased significantly suggesting suitability of the product for diabetic patients.

The newly developed wheat bran supplemented kisra bread scored higher preference and acceptability among panelists compared to the traditional sorghum kisra bread (control).

RECOMMENDATIONS

The nutritional characteristics of the newly developed wheat bran supplemented kisra bread encourages testing the product in vivo for;

a. Hypoglycemic properties

b. Resolution of colitis

c. Storage quality (Shelf-life) of new kisra product needs examination as well.

References

Aaron, I.V.; David, J.A.J.(1988). Dietary fibre in management of diabetis. Diabetis care, 11: 2-5.

Abdel Gadir, M. A. and Mohamed, M.(1977). Symposium of indigenous fermented foods, Bangkok, Thailand.

Abdel Gadir,M.A.and Mohamed, M. (1983). Sudanese kisra. In Steinkraus, K.H. (ed). Hand book of indigenous fermented foods. Microbiology series 9: Marcel Dekker, Inc, New York, PP.175-179.

Achi, Q.K. (1990). Microbiology of obiolor a Nigerian fermented non-alcoholic beverage. J. Applied Bacteriology 69: 321-325.

Adeyemi, A.J. (1988). Ogi quality of sorghum dry milled from fermented sorghum grains. J. Food Sci: 53; 2:641-642.

Ahmed, A. R.(1987).Physicochemical and nutritional studies on traditional Sudanese sorghum staple food (Kisra) supplemented with edible groundnut cake. Ph.D Thesis; University of Mysore, India.

Ahmed, S.B.(1988). Tannins content, amylase activity and cyanide content of germinated sorghum grain M.Sc Thesis, Faculty of Agriculture, University of Khartoum Sudan.

Ali, S.M.; Razzaq, A. and Jamil, M.(1964a), Pakist. J. Scient. Res., 16; 135-138.Cited by Ahmed, A.R.(1987) Physicochemical and nutritional studies on traditional Sudanese sorghum staple food (kisra) supplemented with edible groundnut cake. Ph.D Thesis, University of Mysore, India.

Ali, S. M;Razzaq, A. and Jamil, M. (1964b) Pakist. J. Sci; 16: 113-116. Cited by Ahmed, A.R. (1987). Physicochemical and nutritional studies on traditional Sudanese sorghum staple food (kisra) supplemented with edible groundnut cake. Ph.D Thesis, University of Mysore, India.

American Diabetes Association (1979). Committee on food and Nutrition. Principles of nutrition and dietary recommendation for individuals with diabetes mellitus. Diabtes Care 2: 520-523.

American Diabetes Association (1987). Nutritional recommendation and principles for individuals with diabetes mellitus. Diabetes care 10: 126-129.

Anderson, J.W; Kiehm, T. G.; Ward, K. (1976). Beneficial effects of a high carbohydrate, high fibre diet on hyperglycemic diabetic men Am. J.Clin Nutr. 29:895-899.

Anderson, J.W. and Chen, W.L. (1979) Plant fibre carbohydrate and lipid metabolism Am. J. Clin Nutri.32: 346-63.

Anderson, J.W.; Midgley, W.R and Wedman, B.(1979): Fibre and diabetes. Diabetes care 2 : 369-79,

Anderson, J. W.(1980). The role of dietary carbohydrate and fibre in the control of diabetes Adv Intern. Med 26: 67-96.

Anderson, J.W. Sieling, B (1980). High fibre diet for obese diabetic patient. Obesity Baritric Med.9: 109-17.

Anderson, J.W.(1984) Hypocholesterolemic effects of oat bran or bean intake for hypercholesterolemic men. Am J. clin Nutr.40: 1146-55.

Anderson, J.W.; Gustafson, N. J., Bryant, C. A. and Tietyen, C. J.(1987).Dietary fibre and diabetes: A comprehensive review and practical application. J.Am. Diet. Assoc. 87: 9,189-97.

AOAC (1970): Official Method of Analysis. Association of Official Analytical chemists, Washington, D. C.

AOAC (1984).Official Method of Analysis. Association of Official Agricultural Chemists, Washington D .C.

Aretaeus (1985). On the causes, symptoms and cure of acute and chronic diseases. Moffat S. Trans. London.

Au, P.M. and Fields, M.L.(1981) Nutritive quality of fermented sorghum. J. Food Sci. 49: 652-654.

Badi, S.E.M. and Monawar, L.Y. (1987). Sudanese sorghum and millet directory. Food Research Centre, Shambat, Sudan. Pamphlet 27.

Bata-Smith, E.C and Rasper, V.(1969). Tannins of grain sorghum. J. Food Sci, 34,203-209.

Belavady, B. (1977). International sorghum workshop, National Institute of Nutrition, Jamai Osmania, Hyderabad, India.

Bookwalter, G.N.; Peplinski, A. J. and Pfeifer, V.F. (1968) Cereal Sci. Today, 13, 11 Cited by Ahmed, A.R. (1987). Physico- chemical and nutritional studies on traditional Sudanese sorghum staple food (kisra) supplemented with edible groundnut cake. Ph.D. Thesis, University of Mysore, India.

Bookwalter, G.N., Warner, K., Anderson, R.A. (1977), Fortification of dry milled sorghum with oilseed protein. J. Food Sci. 42:969-73.

British Diabetic Association Medical Advisory Committee (1982). Dietary recommendation for the 1980 a policy statement by the British Diabetic Association Hum Nutr. Appl. Nutr. 36:378-86,

Cadden, A. M; Sosulski, F.W. and Olson J. P. (1983) Physiological responses of rats to high fibre bread diets containing several sources of hulls or bran. J. Food Sci., 48: 1151-56.

Canadian Diabetes Association (1980) Guidelines for the nutritional management of diabetes mellitus J. Can Diabetes Assoc 42 : 110-118.

Chavan. J.K., Kadam, S. S., Ghonsikar, C.P. and Salunkhe, D.K. (1979). Removal of tannins and improvement of in vitro protein digestibility of sorghum seeds by soaking in alkali. J. Food Sci. 44: 1319-21.

Chavan U. V., Chavan, J.K. and Kadam, S. S (1988). Effect of fermentation on soluble protein and in vitro protein digestibility of sorghum, green gram blends, J. Food Sci. 53(5); 1574-75.

Chibber, B.A.K., Mertz, E. T. and Axtell, J. D. (1978). Effect of dehulling on tannin content, protein distribution and quality of high and low tannin sorghum J. Agric. Food Chem. 26: 679-683.

Cummings, J.H. (1978). Nutritional implications of dietary fibre. Am. J. Clin Nutr.31, S21.

Cummings,J.H; Hill, M.J., Jenkins, D.J.A., Person, J.R. and Wiggins, H. S. (1979). Changes in fecal composition and colonic function due to cereal fibre. Am. J. Clin Nutr. 29: 1468-73.

D'Applonia, B.L. Gilles, K., Osman, E.M. and Pomeranz, Y. (1971). Carbohydrates. Wheat Chemistry and Technology pp: 301.

Desroier, N. W. (1959) The Technology of food Preservation 2th edn, Westport, Connecticut. The AVI Publishing Company INC.

Dirar. H.A.(1996). The fermented food of Africa: Their Potential Genetics. Engineering and Biotechnology, UNIDO.

Dunaif, G. and Barbara, O.S. (1981). The effect of diatary fibre on human pancreatic enzyme activity in vitro Am. J. Clin Nutr.34: 1034-35.

Eastoe, E.J. and Taylor, R.H. (1974). Composition of protein of sorghum grain grown in Botswana. J. Sci. Food and Agric.25 (5); 563-569.

Eastoweed, M. A., Brydon, W.G and Tadesse, K. (1980). Effect of fibre on colon function. In Medical aspects of dietary fibre on colon function. In Medical aspects of dietary fibre, P.17 Plenum, New York.

Eggum, B. O., Monowar, L.; Backhands, K.E.; Munch, L. and Axtell, A. (1983). Nutrition quality of sorghum and sorghum foods from Sudan, J. Cereal Sci. 1: 127-137.

El-Hidai, M.M.(1987) Biochemical and microbial investigation on kisra fermentation. M.Sc. Thesis, Faculty of Agriculture, University of Khartoum, Sudan.

Ellis, N. (1981) The Nutrient composition of Sudanese animals feeds. Ministry of Agriculture Food and Natural Resources. Centeral animal nutrition research. Ku Ku. Khartoum.

El Tinay, A.H.; Abdel Gadir, A..H. and El Hidai, M.M. (1979) Sorghum fermented kisra bread. Nutritive value of kisra. J. Sci. Food Agric 30: 859-863.

El Tinay, A.H.; El Mahdi, Z.M. and El Soubki, A.(1985) Supplementation of fermented sorghum kisra bread with legume protein isolates. J. Food. Tech. 20: 679-687.

FAO (1973). Food and Nutrition. in Africa, No.12, Regional Food and Nutrit. Commission for Africa, Accra, Ghana.

FAO (1981) Improvement of nutritional quality of food crops. FAO. Plant production and protection paper NO. 34: 45-52.Rome.

FAO (1985). Guidelines for development of supplementary foods for older, infants and young children. Report of the 14th. session of the codex committee on foods for special dietary uses. Appendix 12, Rome.

Froitvieille, A. M., Bornet, F; Rizkalla, S.W; Le-Francois, P., Pichard, P., Desplanque, N., Chevalier, A; Letanoux, M; verel, A.. Tchobroutsky, G. (1988). In vitro and in vivo digestibility and metabolic effect of 3 wheat flour products. Diabete. 14 (2); 92-96.

Francis, U. T. (1984). Ph.D. Thesis, University of Mysore, Mysore, India.

Gilles, K. A. (1960). The present status of the role of pentosans in wheat flour quality. Bakers Diq. 34 (5); 47-50.

Gray, D. S. (1995). The clinical uses of dietary fibre. Am. Fam-Physician. 1:51(2), 419-26.

Hamad, S.H. (1992). Personal communication, Food Research Centre, Khartoum North Sudan.

Harris, H. B. (1969). Bird resistance in sorghum. Ann-corn and sorghum Res. Conf., Proc, 24th. Chicago, III, 113-122.

Harold, M.R, Reeves, R. D., Bolze, M. S., Guthric, R.A; Guthric, D.W.(1985).Effect of dietary fibre in insulin-dependent diabetics. Insulin requirements and serum lipids. J. Am. Diet Asso, 85, (11); 1455-58.

Hassan. A.I. and El Tinay, A.H. (1995) Effect of fermentation on tannin content and in vitro protein and starch digestibilities of two sorghum cultivars. Food Chem. 53:149-151.

Himsworth, H. P.(1935).Dietetic factor determining glucose tolerance and sensitivity to insulin of health men. Clin Sci. 2, 67-94.

Hulse, J.H., Laing, E. M. and Pearson, O.E. (1980). Sorghum and the Millets. Their composition and nutritive value, Academic Press London, U.K.

Ihekornye, N.I. and Ngoddy, P. O.(1985). Integrated food, sci. and tech. for tropics. Macmillan Publisher.

James, W. A. (1984). The new high fibre, low-cholesterol way to keep slim. Handbook of high carbohydrate-high fibre diet.

Jenkins, D.J.A., Goff, D.V., Leeds, A.R., Alberti, K. G. M, Wlever, T.M.S., Gassull, M. A., Hockaday, T.D.R (1976). Unabsorbable carbohydrates and diabetes; decreased post-prandial hypergylcemia. Lancet 2: 172-174.

Jenkins, D.J.A., Wloever, T.M.S. and Hockaday, T.D.R. (1977) Treatment of diabetes with guargum. Lancet 2: 779-782.

Jenkins, D.J.A., Wolever, T.M.S., Leeds, A.R., Gassull, M.A., Haisman, P. Dilawarie, J. B. Goff, D.V., Metz,.G.L., Alberti, K.G.M.(1978). Dietary fibres, fibre analogues and glucose tolerance, importance of viscosity. Bri Med. J. 1: 1392-94.

Jenkins, D.J.A; Wolever, T.M.S., Taylor, R.H.(1980) Rate of digestion of foods and postprandial glycaemia in normal and diabetic subjects. Bri Med. J. 281:14-17.

Jensen, D.J.A and Jepson, E. M. (1982). Leguminous seeds and their constitutents in the treatment of hyperlipidemia and diabetes. In lipoproteins and coronary atherosclerosis, (G. Noseda, C. Fragiscomo, R. Fumigalli and R. Roaletti, eds.) PP 247-255, Elsevier Biomedical Press, New York.

Kay. R.M. and Truswell, A. S. (1977). The effect of wheat fibre on plasma lipids and faecal steriod exretion in man, Bri. J. Nutr 37:227-235.

Kazanas, N. and Fields, M. L. (1981). Nutritional improvement of sorghum by fermentation J. Food Sci,48: 819-821.

Kelsay, J.L. (1978). A review of research on effects of fibre intake on man. Am. J. Clin Nutr. 31:142- 145.

Kemmerer, A. R. and Heywang, B.W. (1965). A comparison of various varieties of sorghum as substitute for corn in practical chick diets. Poultry Sci. 44: 260-264.

Kent, N.L. (1972) Technology of cereal, 2nd ed Assoc. of British flour-milling, St. 1L bans, Hert.

Kerr, R.W. (1950). Chemistry and industry of starch. Academic Press. Inc., New York, N.Y

Khattab, A.H. and Hadari, A. M. (1969). Nutritional evaluation of diet in Gezira and Managil. Sudan Notes and Records 50: 160-164

Kies, C. and Fox, H.M. (1977). Dietary hemicellulose interactions influencing serum lipid patterns and protein nutritional status of adult men. J. Food. Sci. 42: 440- 443.

Kolawole, D. O.; Oguninwin. J.O. And Okwuosa, E. C. (1987). The microbiology of fermentation of guinea corn (sorghum biocolor Linn.) in the preparation of sorghum stout, J. Food Sci. Agric. 1:3-45.

Lease, E. J. and *Mitchell*, J.H. *1969*, 53, 7 *Cited* by Reddy, N.R. Sathe, S.K and slunkhe, D.K. (1985). Dry bean tannins review of nutritional implications. JAOCS. 62:541-549.

Liener, I.E., Kakade, M.L. Protease inhibitors (1980) Toxic constituents of plant food stuff . In: Liener, I.E 2nd. Academic Press.New York.

Liu, Z.O.; Chao, C.S.; Wu, H.W. (1989). Investigation of the effect of diet with wheat bran on the metabolic balances of Zn, Cu, Ca and Mg in diabetics. Chinese. J. of Internal. Medicine 28:12, 741-744, 769.

Lockhart, H.B. Lee, H.S.; O'Mahony, S.P., Hensley, G.W. and Houlihan, E.J.(1980). Caloric value of fibre-containing cereal fractions and breakfast cereals. J. Food Sci. 45: 372-375,

Maliwal, B.P. (1983). In vitro method to asses the nutritive value of leaf concentrate. J. Agric. Food chem. 31:315-319.

Mani, I.; Patel, J.J.; Mani, U.V (1987). Studies on the effect of wheat bran fibre on serum and urinary amino acids and amino acids in non-insulin dependent diabetic patients. J. Clin. Bio.Chem. Nutr.3: 2, 143-148.

Marhoum, O.A. (1987). Biochemical and Microbiology of Hulumur fermentation. M.Sc. Thesis, Faculty of Agric. University of Khartoum, Sudan.

Maxon, E. D. and Rooney, L.W. (1972b) Crop. Sci, 12: 253. Cited by Ahmed A. R. (1987). Physicochemical and nutritional studies on traditional Sudanese sorghum staple food (kisra) supplemented with edible groundnut cake. Ph.D. Thesis, University of Mysore, India.

Maxon, E.D., Rooney, L.W., Lewis, R.W., Clark, L.E. and Johnson, J.W. (1973) Nutr. Rep. Inter.8: 145. Cited by Ahmed, A.R. (1987) Physicochemical and nutritional studies on traditional Sudanese sorghum staple food (kisra) supplemented with edible groundnut cake. Ph.D Thesis. University of Mysore, India.

Maynard, L.A.(1944).The Atwater system of calculating the caloric value of diets. Editorial Review. J. Nutr. 28:443.

Miranda, P.M and Horwitz, D.L .(1978) High fibre diets in the treatment of diabetes mellitus. Ann Internal Med. 88: 482, 87.

Mohammed, T.A: and Ahmed, A.E.(1987) Feeding and metabolic studies on the nutritive value of grain sorghum with reference to their tannin contents. Sudan J. Vet Sci. and Anim. Husb. 26:91-100.

Neucer, N.J., Jaks, T.J. and Sumrell, G. (1978). Interaction of globlular protein with simple polyphenol .J.Agri food Chem. 26: 214-216

Novellie, L. (1966). Kaffircorn malting and brewing studies. J. Sci. Food Agric. 17: 354-360.

Odunfa, A. and Adeyele, S. (1985). Microbilogical changes during the traditionl production of ogi baba, a west African fermented sorghum gruel. J. Cereal Sci, 3 : 173-180.

PAG compendium (1975). Plant breeding and genetics Vol. D. 3.3. 19, World Mark Press. Ltd. John Wiley, New York.

Painter, N.S. (1982).Diverticular disease of the colon. S.A. Med. J. 61:1016-1018.

Parada, M.L.; Simard, R.E. and Larrea-Reynoso, S.S.(1985).Influence of germination, nixatamalization and fermentation on the nutritional value of sorghum protein, Microbiologie-Aliments Nutrition. 3: 124-132.

Passmore, R. and Eastwood, M.A. (1986). Unavailable carbohydrates or dietary fibre. In Davidson and Passmore's Human Nutrition and Dietetics, PP. 34-38 Churchhill Livingstone, London.

Pearson, D (1976). The chemical Analysis of Foods. 7th Edn Churchhill Livingstone, London.

Pederson, C.S. (1971). Microbiology of food fermentation's (2nd Edition). The AvI Publishing Co. Inc., Westport, Connecticut.

Pomeranz,Y.; Shogren, M.D.: Finney, K.F. and Bechtel, D.B.(1977) Fibre in breadmaking : Effects on functional Properties. Cereal Chem. 54:25-41

Quinn, M.R. ; Beuchat, L.R.; Miller, J.; Young, G.T. and Worthington, R.E. (1975). Fungal fermentation of peanut flour: Effects on chemical composition and nutritive value J-Food Sci. 40: 470-474.

Ray, T.K. Mansell K.M.; Knight, L.C.; Malmud, L.S.; Owen, O.E. and Boden, G (1983). Long term effects of dietary fibre on glucose tolerance and gastric emptying INID diabetic patients. Am. J. Clin. Nutr. 37,(3); 376-381.

Reddy, N.R.; Pierson, M.D. and Salunkhe, D.K. (1986). Legume -based fermented foods, GRC Press Inc. Boca Raton, Flovida.

Rendleman, J. A. (1982).Cereal comlexes :Binding of calcium by bran and components of bran. Cereal Chem. 59 ,(4); 302-309.

Rinfel, J.; Ruzsa, C.; Mozsik, G. Javor, T (1990). Hormonal changes during administration of diatery fibres in patients with decreased glucose tolerance. Orv-Hetil 28: 131(4); 175-177.

Roth, H.P. and Mehlman, M.A. (1978) The role of diatery fibre in health . Am.J. Clin Nutr. 31:1-290.

Russel, A.E; Shuttleworth, S.G and Williams Wynn, D.A. (1968) .Cited by Reddy, N.R; Person, M.D., Sath, S.R . and Salunkh.e, D.K. (1985). Dry bean tannin. J. AOCS 62:541-49.

Saunders, R.M. (1978). Topics in dieatary fibre research pp43. In Wheat bran composition and digestibility. Editor G.A. Spiller, Plenum Press: New York.

Saxena, K.L., Chakrabarti, O.H. and Nath, M.C.(1968). J.Nutr. Diet. 5:125 Cited by Ahemd, A.R. (1987) Physicochemical and nutritional studies on tradtional Sudanese sorghum staple food (kisra)supplemented with edible groundnut cake. Ph.D. Thesis, University of Mysore, Indida.

Schaffert, R.E. (1972). Protein quantity, quality and availability in sorghum bicolor (L.) Moench Grain. Ph.D. Thesis, Purdue University, Lafayette, Indiana, USA..

Schneider, F.(1979). Sugar Analysis Oficial and Tentative Methods Recommended by the International Commission for Uniform Methods of Sugar Analysis (ICU MSA).

Shadad, M.E. (1989). Proximate composition, taninn content and protein digestibility of sorghum cultivars grown in Sudan. M.Sc. Thesis, Faculty of Agric. , U niversity of Khartoum, Sudan.

Sharafetdinov, Kh, Kh.; Plotnikova, D.A; Tsagikian, T.A.(1993). Comparetive efficiency of various food fibres in correction of carbohydrate and lipid metabolism in patients with type II diabetes mellitus 3 : 9-13

Shepered, A.D.; Wood head, A.H. and Okorio, J.F (1970). Sorghum Processing. In : Annual Reprot, East Africa Industrial Research Organization.pp 36-58.

Shutler, S.M.; Walker, A..F.and low, A.G. (1987).The cholesterol lowering effects of legumes. I. Effect of major nutrient. Nutr. 4 : 71-86.

Singh, U.; Kherdekar, M.S. and Jambunathan, R.(1982).Studies on Desi and kabuli chickpeas (Cicer arieinum L) cultivars.The levels of amylase inhibitors. Levels of oligosaccharides and in vitro digestibility . J.Food Sci. 47:510-412.

Singleton, V.L and Kratzer; F.H. (1973) Plant Phenolics In : Toxicants occuring nutrually in foods . Nat.L. Acad. Sci (2nd ed.). Natl. Res. Council. Washington, D.C. pp309-345.

Sommer, H.; Kasper, H. (1980). The effect of dietary fibre on the pancreatic exretory function. Hepato-Gastroenterology 27: 477-83.

Spiller, G.A.; Wong, L.G.; Whittam, J.H.; and Scala, J. (1982). Correlation of gastrointestinal transit time to fecal weight in adult humans at 2 levels of fibre intake. Nutr. Rep. Int. 25:23-

Springsteen, E.; Zabik, M.E. and Shafer. M.A.M (1977) Notes on layer cakers containing 30 to 70% wheat bran. Cereal Chem. 54 (1): 193-198.

Stanyon, P. and Costello,C (1990). Effect of Wheat bran and polydextrose on the sensory characteristics of biscuits. Cereal Chem. 67,(6): 11-12.

Strumeryer, D.H.and Malin, M.J. (1975) Condensed Tannins in grain sorghum: Isolation, Fractionation, and Characterization J.Agric. Food chem. 23,(5); 909-914.

Sukkar, M.Y. (1985) Human Nutrition for Medical Studies and Allied Health Science. Ist. Edn. Ithaca Press 13.

Sur, G.; Swaminathan, M. and subramanian, V.(1955) Bull. Central Food Technoligcal Research Institute, Mysore, 4:133.

Swain, T.(1965). The tannins. In Plant Biochmistry . Bonner, J and Verner. J.E.eds. Acad. Press, New York. PP. 552-580.

Taur, A..T.; Pawar, V.D. and Ingle, U.M. (1984). Effect of fermentation on nutritional improvement of grain sorghum [sorghum bicolor (L.) Moench]. The Ind. J. Nutr .Dieter. 21:129-136.

Thompson. S.A and Weber, C.W (1979). Influence of pH on the binding of copper, zin and iron in 6 fibre sources. J.Food Sci. 44:752-754.

Trowell, H.C. (1978). Diabetes mellitus and dietary fibre of starchy foods. Am.J. Clin Nutr. 31:553-57,

Trowell, H.C. (1986). Development of the dietary fibre hypothesis of diabetes mellitus.In: Hand Book of Dietary Fibre in Hum Nutr., Editor Spillar G.A. CRC Pres, New York, PP 345-347.

Vaaler, S.; Hanssen, K.F; Dahl-Jorgensen, K., Frolich, W.; Aaseth, J.Odegaard, B. Aagenaes, D (1986). Diabetic control is improved by guar gum and wheat bran supplementation. Diabetic-Medicine 3 (3); 230-233.

Vahoung, G.V;Kritchevsky;D.(1980). Dietary fibre in health and disease Plenum Press:New York.

Van-Holdt, M.M; and Brand, J.C.(1960).Kaffircorn malting and brewing studies-VII.J.Sci Food. Agric, 11:467-472.

Van-Veen, A.G.and Steinkraus, K.H.(1970). Nutritive value and wholesomeness of fermented foods .J.Agric. Food Chem.18, (3); 568-73.

Wall, J.S. and Ross, W.M. (1970) Sorghum Production and Utilization Ist ed. The AVI Publishing Co. Westport, Connecticut, USA.

Wang, H.L; Ruttle, D.I. and Hesseltine, C.W (1968). Protein quality of wheat and soybeans after rhizopus oligosporus fermentation J.Nutr., 96: 109-114.

Waston, T.G. (1975). Inhibition of microbial fermentation by sorghum grain and malt. J. Appl. Bact. 38: 133-142.

Yousif, B.Y. and Magboul, B.I. (1972). Nutritive value of Sudan food stuffs, Part (1) Sorghum Vulgare (Dura). Sudan J. Food Sci. Tech.4: 39-40.