EFFECTS OF MALTING AND FERMENTATION ON THE COMPOSITION AND FUNCTIONALITY OF SORGHUM FLOURS

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Organization

Background

Production and utilization of sorghum:

- Globally
- Africa
- Tanzania

Literature review

- Composition and functionality
- Health and nutritional benefits
- Starch and protein digestibility
- Processing methods (malting and fermentation)

Materials and methods

Results

Global level

- **Sorghum is number five after wheat, rice, maize and barley in terms of production** (FAO, 2005)
- **It feeds approximately 300 million people mainly in Africa and Asia** (Leder, 2004)
- **US is the number one producer, followed by Nigeria, Sudan, Mexico, China, India, Ethiopia, Argentina, Burkina Faso, Brazil and Australia** (Dicko et al, 2005)
- **Used as animal feed and ethanol production in US and other developed countries** (Godwin and Gray, 2000)
- **Used both for human food and animal feed in Africa, Asia and Latino America** (Anglan,1998; Mahgoub et al,1999;Yetneberk et al, 2004)

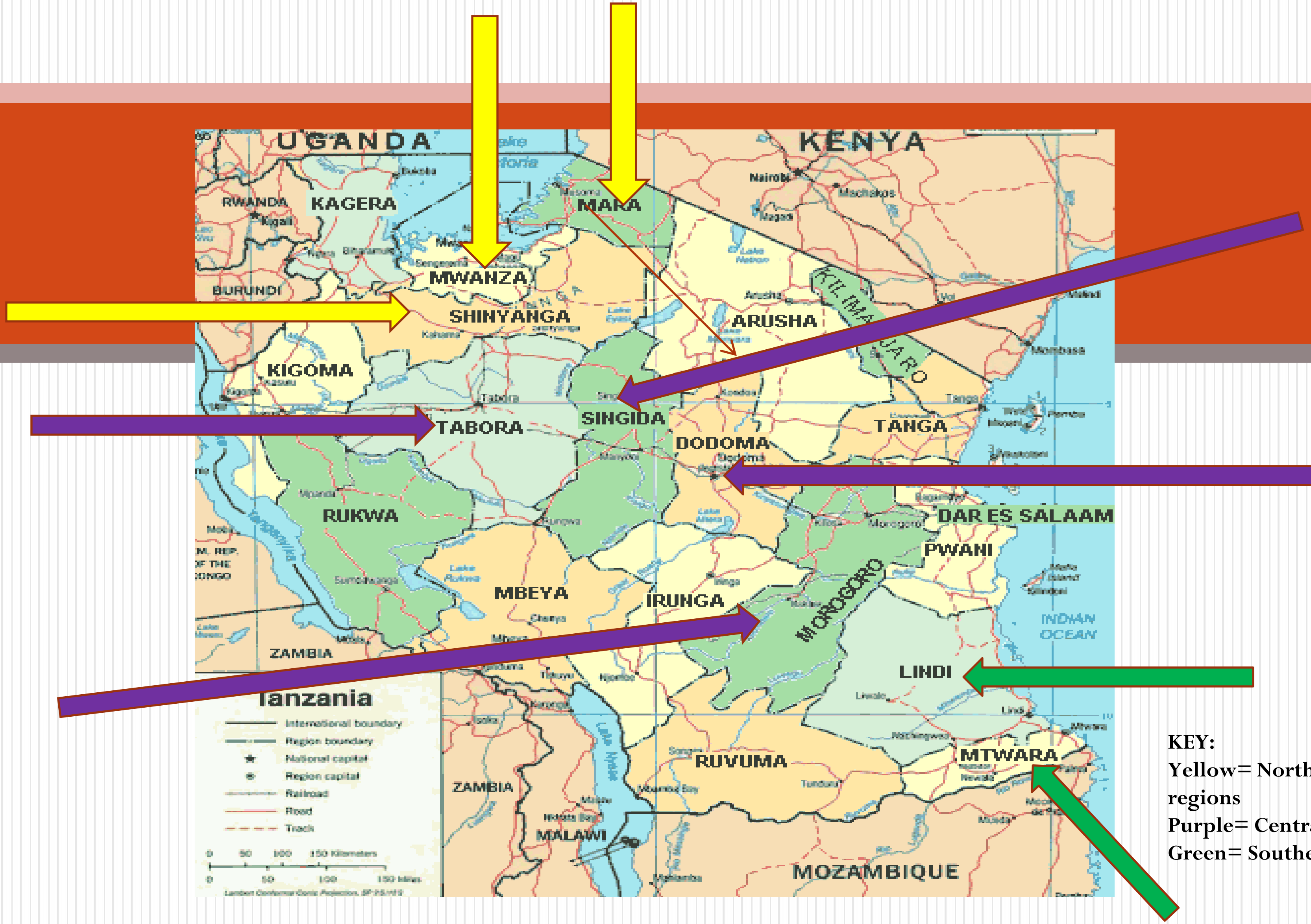
In Africa

- **Produced mainly as human food** (Godwin and Gray, 2000)
- **Nigeria is the major producer followed by Sudan, Ethiopia, Somalia, Burkina Faso and Ghana** (Murty and Kumar,1995
- **Burkina Faso is the main consuming country in the World per person** (Murty and Kumar,1995)
- **Foods products prepared with sorghum include porridges (thin and stiff), pancakes, couscous, injera, kisra, unleavened breads, also alcoholic and non-alcoholic beverages** (ICRISAT,1992; Murty and Kumar,1995)

Production and use of sorghum in Tanzania

- Over 500,000 t are produced per year (Rohrbach & Kiriwaggulu, 2007)
- Is second after maize as a major source of energy, protein, vitamins, and minerals (MAC,1998)
- Less than 2% of the harvest enters the formal market and the remainder is consumed on the farm (Rohrbach &Kiriwaggulu, 2007)
- Production is concentrated in semi-arid parts of the country (Dodoma, Singida, Shinyanga, Tabora, Mwanza, Mara, Morogoro, Lindi and Mtwara) on account of its drought-tolerance (MAC, 1998)

Areas where sorghum is most produced



KEY:
Yellow= Northern regions
Purple= Central regions
Green= Southern regions

Uses of sorghum in Tanzania

- Sorghum/wheat composite flour is used to make snacks like flat breads/pancakes and buns

- Used to make stiff and thin porridges
- Used to make alcohol and non-alcoholic beverages

Factors affecting use of sorghum in Tanzania

- **Poor protein and starch digestibility - a major constraint to infants and young children nutrition**
- **Negative attitude towards sorghum (considered as food for the poor and of inferior quality**
- **Under-researched especially its composition and functionality** (FSTA, 2007)
- **Less scientific evidence on the health and nutritional benefits has been published** (Taylor and Emmabux, 2000)
- **Limited utilization options due to lack of product development expertise** (Laswai et al, 2000)

Grain composition and functionality

Starch (60-80%)

- with two large molecules (linear-amylose and branched-amylopectin) held together by hydrogen bonding (Duoduet al, 2003)
- high amylopectin-good for brewing, extrusion cooking, and preparation of weaning foods (Dicko et al, 2005)

Protein (7-15%)

- divided into albumin, globulins, kafirins and glutelins
- kafirins comprise about 50-70% of the protein (Hamaker et al 1995; Oria et al,1995; Duodu et al , 2003)
- kafirins are sub-divided into α, β and γ, with the α-kafirins (80%) being the principal storage protein

Non-starch polysaccharide (2-7%)

- **located mainly in the bran and constitute about of the kernel** (Hoseney,1994)
- **contribute to insolubility and resistant nature of sorghum starch**
- **important NSPs are arabinoxylans and β-glucans**
- **arabinoxylans are important in the processing of sorghum for baking and brewing** (Serna-Saldivar and Rooney,1995)

Lipids (3%)

- **mainly present in the germ and more unsaturated than in corn**
- **fatty acid composition is similar to corn, with linoleic (49%), oleic (31%), and palmitic acid (14%)** (Glew et al,1997)

Vitamins

- **contains significant amount of β-carotene, B-vitamins (thiamin, riboflavin and pyridoxine) and lipid-soluble vitamins A, D, E and K** (Anglan,1998)

Minerals

- **good source of magnesium, iron, zinc, cooper, calcium, phosphorus and potassium** (Glew et al,1997 and Anglan,1998)

Health and nutritional benefits

Health benefits

Sorghum has:

- **Phenolic compounds which can decrease the risk of cardiovascular** (Carr et al, 2005)
- Antioxidant activity (Dykes et al, 2005)
- **Cholesterol lowering properties** **(Klopfenstein et al, 1981)**
- **Anti-inflammatory properties** **(Ziyan et al, 2007)**
- **Anti-cancer and anti-allergic properties** **(Yang et al, 2009)**
- **Phytochemicals (phenolic compounds, plant sterols and policosanols) important lipids for human health**

Nutritional benefits

Sorghum is:

- **Similar to maize in nutritional value** (FAO,1995)
- **Rich in β-carotene the pro-vitamin of vitamin A**
- **A gluten free -good for people with celiac disease**
- **A rich source of vitamin B-complex and tocopherols** (Dykes and Rooney, 2006)
- **Relative high potassium, magnesium, fiber, copper, iron, zinc,calcium and phosphorus** (Glew et al,1997; Anglan,1998)
- **Rich in polyunsaturated fatty acids** (Glew et al, 1997)

Starch and protein digestibility

Low sorghum starch and protein digestibility is the major factor contributing to low nutritional quality

Low starch digestibility

Due to:

- **High levels of prolamine around the starch granule acts as barrier to starch gelatinization**
- **Starch to protein interactions and associations within the plant tissues** (FAO, 1995)
- **High proportion of peripheral endosperm tends to resist water penetration, enzyme digestion and mechanical disruptions** (Rooney & Sullin, 1973; FAO, 1995)

Low protein digestibility

Due to:

- **Exogenous factors e.g. grain organizational structure, polyphenols, phytic acids, starch and non-starch polysaccharides** (Rooney and Sullin,1973)
- **Endogenous factors e.g. disulfide and non disulfide cross linking, kafirins hydrophobicity and changes in protein secondary structure** (Rooney and Sullin,1973)
- **Tannin-protein interaction-prolamine (60%) binding strongly to tannins** (Butler et al, 1984)
- **High proportions of cross-linked kafirins to kafirins thus higher intermolecular disulfide-cross linking among kafirins** (Hamaker et al, 1986, 1987)

Processing methods to improve digestibility

Malting

- a controlled germination followed by the controlled drying of the kernels
- promotes development of hydrolytic enzymes with high activity
- modifies endosperm and produces characteristic flavor
- improves protein and starch digestibility, vitamin and mineral bioavailability and essential amino acid composition
- increases nutrient density while decreases anti-nutritional factors like phytate and tannins

Fermentation

- **a microbial metabolic process, usually anaerobic**
- **by yeast to produce alcohol beverages and by lactic acid bacteria to produce non-alcoholic foods and beverages**
- **prolongs shelf-life of the product**
- **provides optimal pH for phytases activity**
- **improves the *in vitro* protein digestibility**
- **increase nutrient density**
- **decrease anti-nutritional factors like phytate and tannins**

Study objectives

- **To investigate the effects of malting and fermentation processes on whole food grade and whole red tannin sorghum flour composition**
- **To investigate the effects of malting and fermentation processes on functionality in buns made from whole food grade and whole red tannin sorghum flour**

Study hypothesis

- **Composition and functionality of whole kernel sorghum flour will improve due to the malting and fermentation pre-treatments**
- **Composition and functionality of whole food grade Macia sorghum flour will differ from whole red tannin sorghum flour**

Experimental design

- Split-plot design
- Whole plots were the 2 sorghum varieties
- Subplots were the 4 treatment-variety combinations
- Experiment will be repeated 3 times
- There will be 3 replicates for each treatment
- Each replicate will be 1 block
- ANOVA will be performed using SAS (1999) Proc Mixed procedures for each sample

Grain quality

- **Grain quality test was performed for both sorghum cultivars**
- **Kernel hardness was determined using tangential abrasive decortication device (TADD), seed scarifer, Stenvert hardness hammer mill, and Wisconsin breakage tester**
- **Stress cracks was determined by visually counting on a light table**

Malting process

- **5.2 kg of sorghum kernels were weighed and divided into two equal halves**
- **First half (2.6 kg) of kernels were soaked in water maintained at 30˚C and 100% RH for 40 hr, then allowed to germinate at 25˚C and 100% RH for 72 hr before oven drying with various time and temperature intervals starting with 12 hr at 47˚C, 4 hr at 57˚C and 4 hr at 67˚C**

Cleaned red tannin and Macia sorghum kernels before germination

Sprouted red tannin and Macia sorghum kernels after a 72 hr germination period

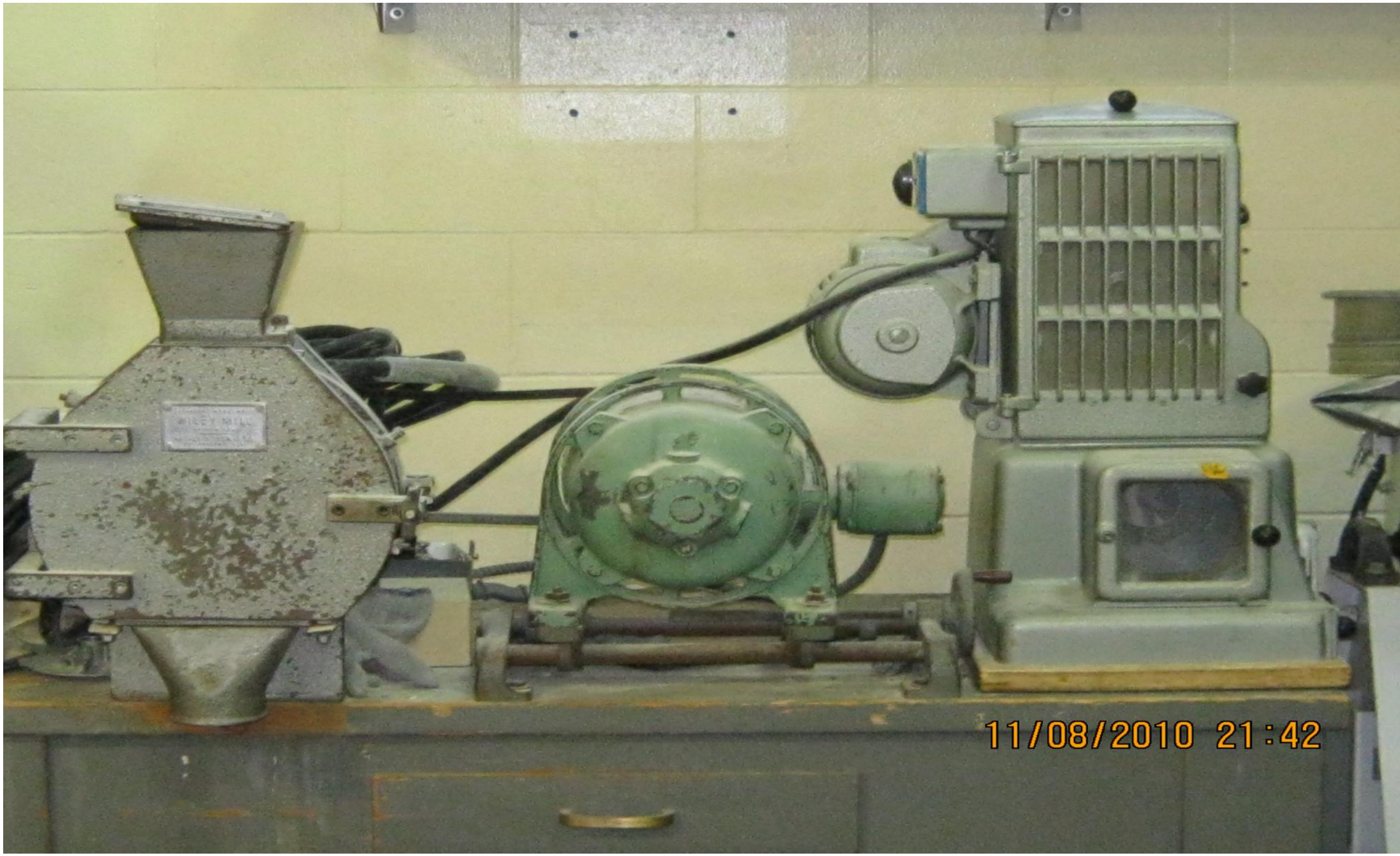
Fermentation process

- **Half (1.3 kg) of Regular (Rg) and half (1.3 kg) of malted (mal) flour were mixed with tap water (5:7w/w) and 15g of Dannon all natural plain nonfat yogurt into a slurry**
- **The slurry was then covered with aluminum foil and left to ferment at 25˚C for 72 hr**
- **Fermented slurry was oven dried at 65˚C for 24 hr**

Flour milling and treatments

- **Milling operations were done using a Quadramat Jr. laboratory mill**
- **The malted kernels from the first half (2.6 kg) were milled into malted flour (mal)**
- **The second half (unmalted) kernels (2.6 kg) were milled into regular flour (Rg)**
- **Dried cakes from Rg and mal fermented flour slurries (1.3kg) each, were re-milled into fermented (fe), and malted and fermented (malfe) flour respectively**

Quadramat Jr. laboratory mill



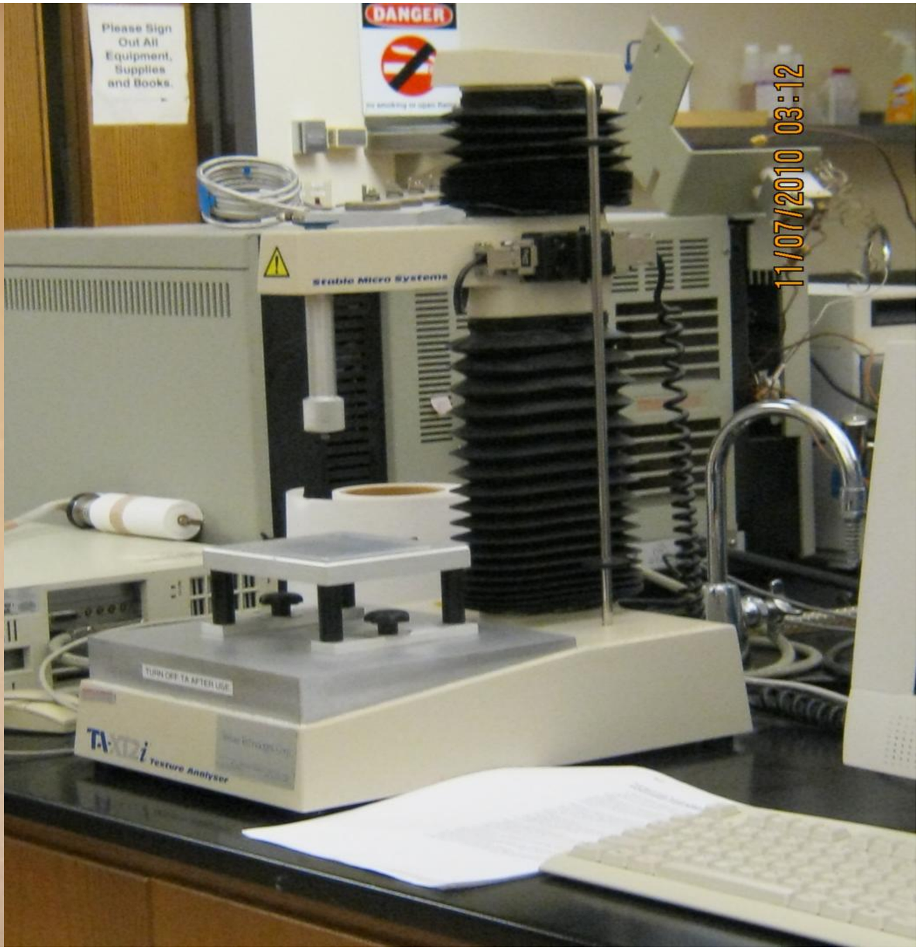
Flour composition and functionality

The 8 types of flours, 4 from each sorghum cultivar, will be assayed for:

- **reducing sugars** (Miller, 1959)
- **free amino acids and soluble protein** (Lowry et al, 1951)
- **pH**
- **titratible acidity** (AACC Methods 02-31, 2000)

Product development

- **Product - buns prepared using the eight types of flour** (Karegero & Mtebe, 1994)
- **Ingredients - flour (70-30% wheat-sorghum), water, salt, yeast, baking powder, sugar and oil**
- **Frying - 2/3 cup of batter dropped into corn oil at 375°F and fried until golden brown**
- **Property evaluations – textural profile analysis (TPA) for hardness and elasticity, surface color and oil uptake**



Sorghum-wheat buns

TA-XT2i Texture analyzer machine

Results and Discussion

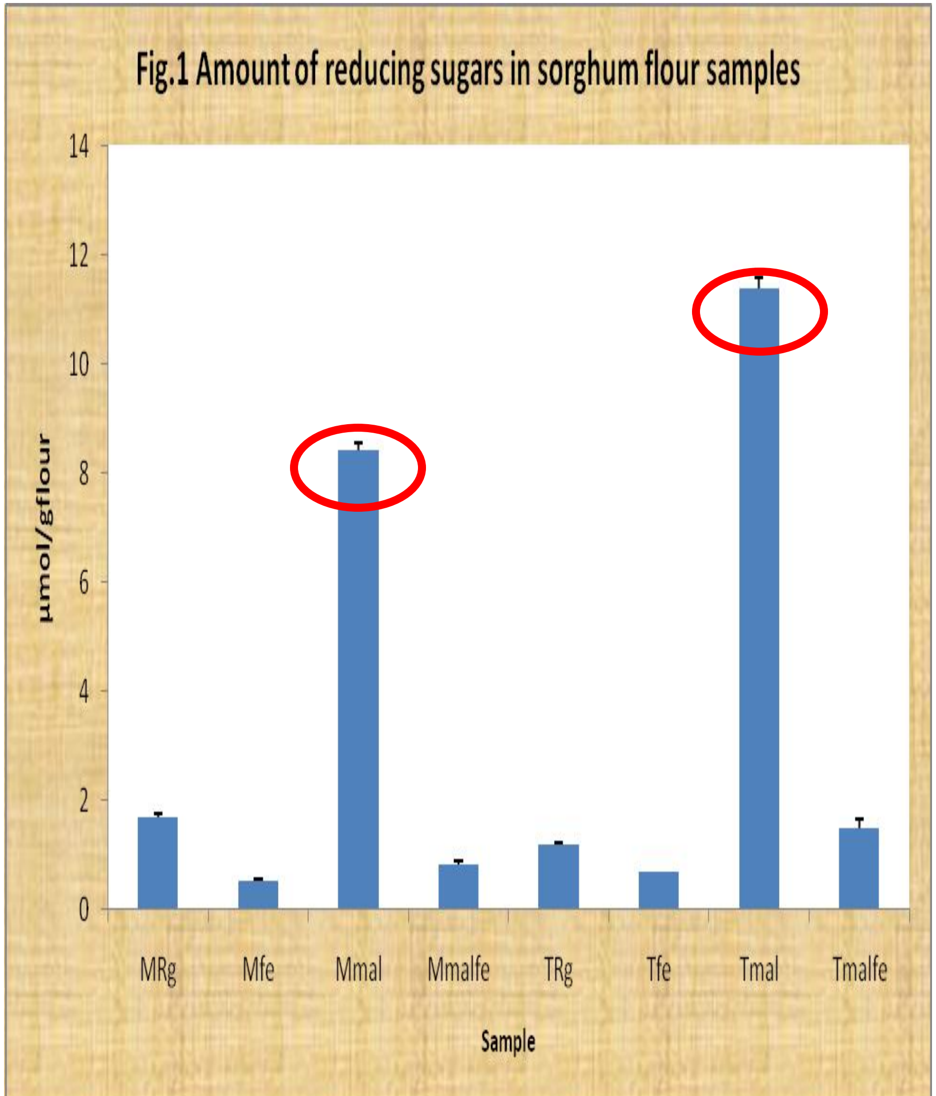


Fig.1

- **An increase in the amount of reducing sugars in malted flour and a decrease in the fermented flour.**
- **An increase during malting could be due to starch hydrolysis by α-amylases**
- **A decrease during fermentation could be due to sugars being utilized as a source of energy by microorganisms presumably lactic acid bacteria**

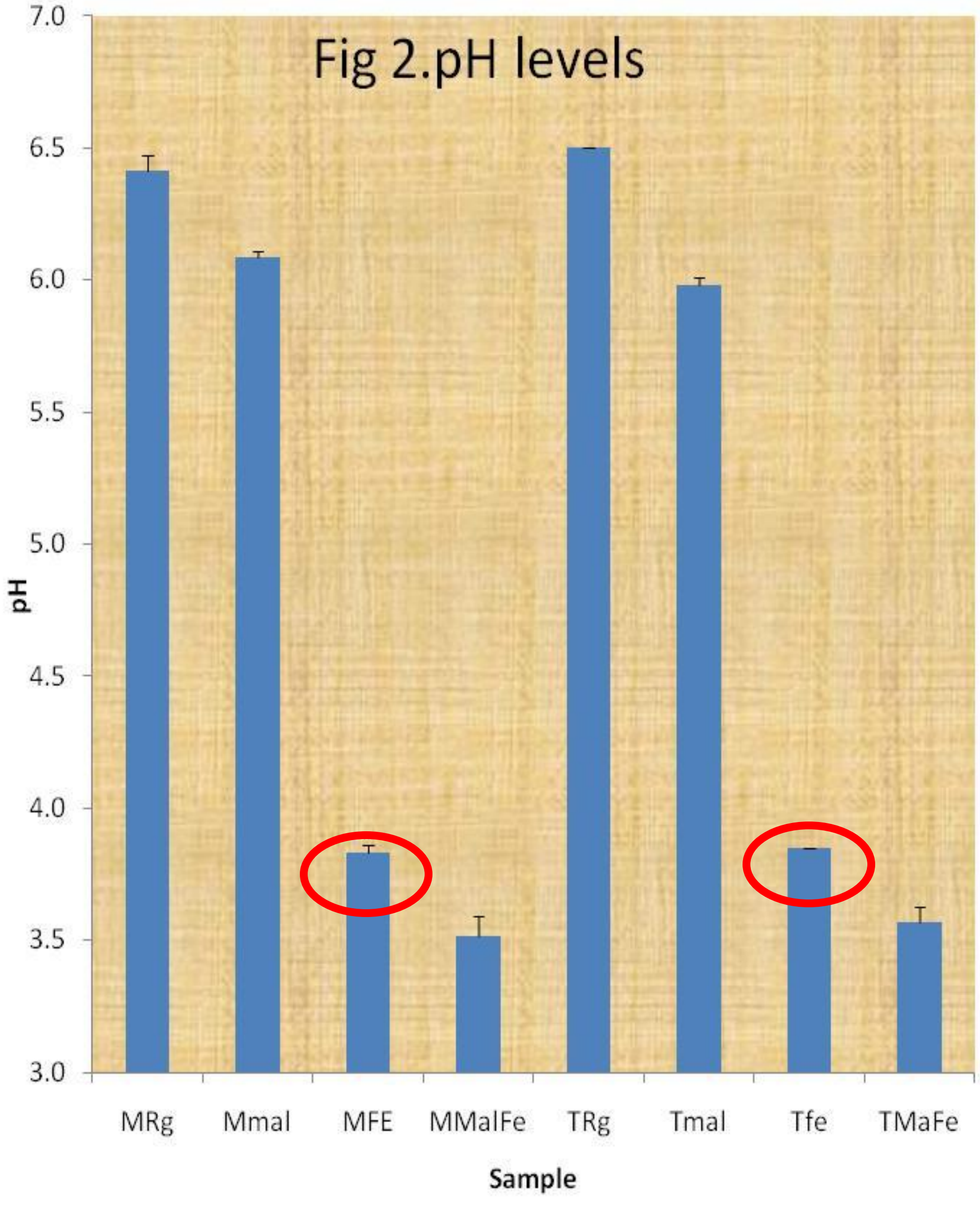


Fig 2.

- **A decrease in pH levels in sorghum flour samples.**
- **Malting caused little or no change in pH levels**
- **Fermentation caused a tremendous decrease in pH levels in sorghum flour from both sorghum cultivars**
- **A decease is supposed to be due to the production of acids most likely lactic, acetic, or formic acids by the micro-organisms particularly lactic bacteria.**

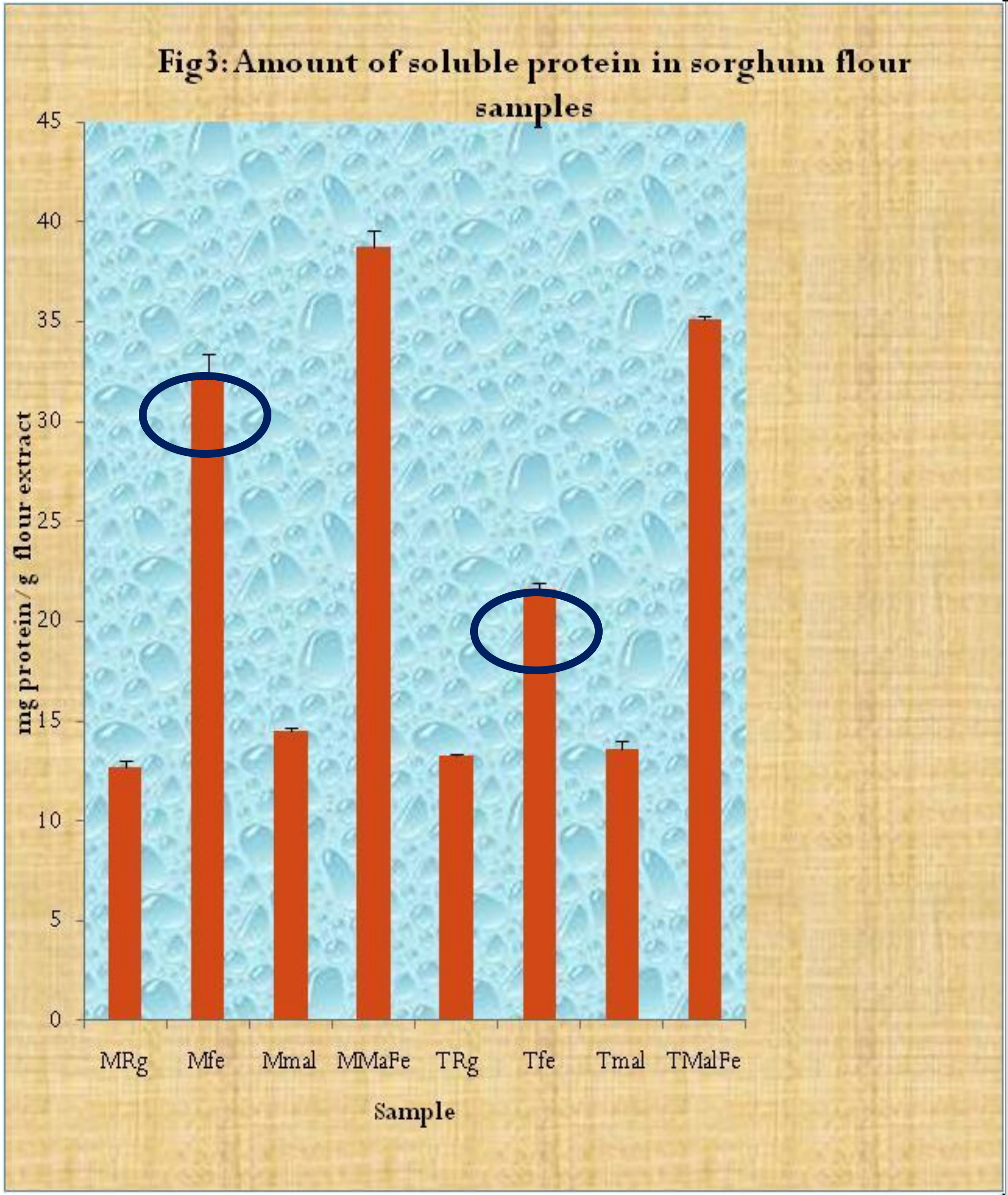


Fig 3.

- **An increase in the amount of soluble protein in fermented flour (fe) and no change in the malted flour (mal) for both sorghum cultivars**
- **An increase in protein could be due to solubilization of sorghum flour as a result of fermentation and also to structural changes in storage protein (prolamines and glutelins) making them available to enzymatic attack**

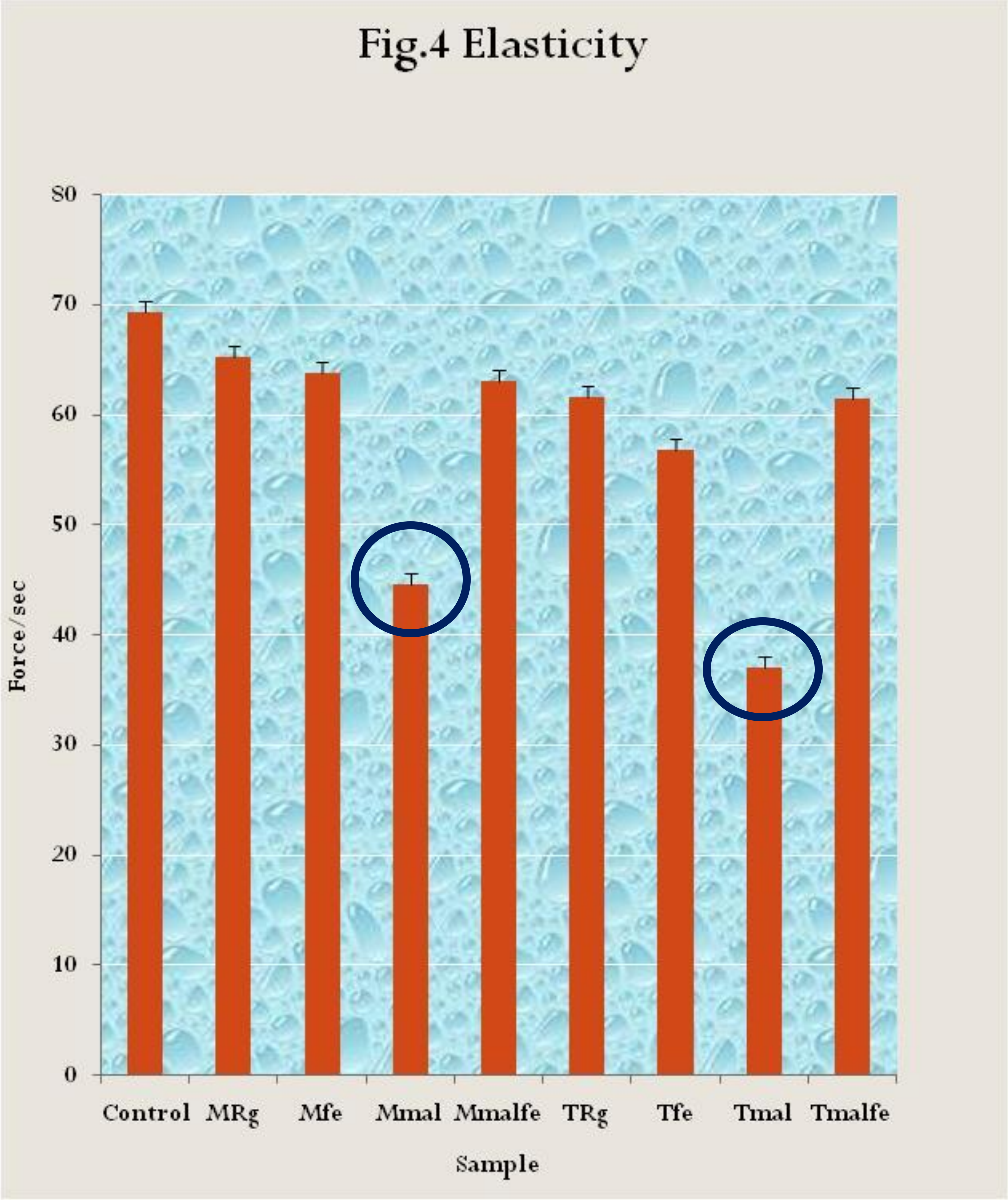


Fig 4.

- **Low elasticity in buns made from malted flour (mal)**
- **High elasticity in buns made from the regular flour (Rg), fermented flour (fe), malted/fermented flour (malfe) and 100% wheat flour (control)**
- **Low elasticity could be due to reduced levels of protein matrix, high levels of simple sugars and also high amounts of water**

Conclusion

- **Malting process caused an increased in the amount of reducing sugars**
- **Fermentation process caused an increase in the amount of soluble protein**
- **Malting caused a decrease in bun elasticity**
- **Fermentation caused a decrease of pH in flour**

Implications

Malted and fermented sorghum flour may be used:

- **In the preparation of nutritious foods for use by pregnant women, lactating mothers and the elderly,**
- **In the formulation of weaning foods for infants and young children, and**
- **In communities where people are malnourished especially in rural areas.**

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