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

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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 \cite{GodwinGray2000}.
• Nigeria is the major producer followed by Sudan, Ethiopia, Somalia, Burkina Faso, and Ghana \cite{MurtyKumar1995}.
• Burkina Faso is the main consuming country in the World per person \cite{MurtyKumar1995}.
• Foods products prepared with sorghum include porridges (thin and stiff), pancakes, couscous, injera, kisra, unleavened breads, also alcoholic and non-alcoholic beverages \cite{ICRISAT1992,MurtyKumar1995}.
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

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

- Sorghum/wheat composite flour is used to make snacks like flat breads/pancakes and buns
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
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 scarifier, 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 (1.3 kg) 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
- titratable 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 decrease 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
- 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.
Thanks

To:
- Dr. C. Weller
- Dr. D. Rose
- Dr. D. Jackson
- Dr. R. Wehling
- Dr. S. Cuppett

&

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FOR THE FUNDING