TECHNOLOGICAL AND SENSORIAL EFFECTS OF SORGHUM ADDITION AT WHEAT BREAD

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Abstract

Sorghum is a versatile plant with high potential, an excellent source of phytochemicals. Fine and coarse whole sorghum flour was added in 10 to 40% proportion to bread. The dough stability and development time increased with sorghum proportion. Bread's characteristics depreciated with sorghum addition. The specific volume decreased with 20 to 40.8% for flour replacement from 10 to 40%. Crumb porosity decreased with 3.1, 3.8, 8.4 and 14.7 for replacement of wheat flour with 10, 20, 30 and 40% coarse whole sorghum flour. Greater depreciation was observed when fine sorghum flour was used. The bread crumb with sorghum added was darker, greyish-brown, with visible particle of sorghum bran. The taste, smell and odour weren't affected very much. The taste wasn't bitter at all. These results proved that the sorghum could be added in bread.

Key words: *sorghum, wheat bread, rheology, baking, whole*

1. INTRODUCTION

Sorghum is an ancient grain which is largely consumed in semiarid region of world. Sorghum is surpassed in human alimentation only by wheat, maize, rice and potatoes (Henley, 2010). Despite of that in Western world is consumed by human only in small quantities; the largest part is used for animal feed (Waniska, et al., 2004). In the semi-arid countries from Africa and Asia sorghum represent an important part of dietary intake (Ndjeunga & Nelson, 2001).

Sorghum is a very useful and resistant plant which can grow in adverse condition of aridity, drought, on poor soils and could be used almost all part of plant for human consumption or animal feed (Obilana, 2004) (Taylor, et al., 2006).

Sorghum could be used for baking, mixed with wheat flour in different ratio or could be used alone, for the preparation of gluten free bread or other product (Wolter, et al., 2013) because sorghum does not contain gluten and is suitable for the consumption by persons with celiac disease. Nutritionally, sorghum is very similar to corn (Léder, 2004) but it has a slightly lower rate of digestibility due the higher content of kafirins, protein which are crossed linked. In contrast with other grains like wheat, maize or rice sorghum contain a high amount of tannin in bran. Tannins reduce the feed efficiency but are potent sources for antioxidants. Brans of sorghum with high content of tannins are among the vegetal with highest oxygen radical absorbance capacity - 1008-3100 units ORAC, depending of species (Waniska, et al., 2004). Not all species of sorghum contain tannin but contains a wide variety of polyphenols as phenolic acids, flavanoids, 3-deoxyanthocyanins. The total phenolic content of sorghum varied between 3 and 43 mg / 100g (Taylor, et al., 2014). Tannins are not present in common species of sorghum (Henley, 2010) (Léder, 2004). Other nutritional aspects could be important. Gluten free breads prepared from sorghum and oat showed the highest level of total available carbohydrates, compared with buckwheat, quinoa, and teff and lowest glycaemic index (Wolter, et al., 2013). Policosanols present in waxes from the surfaces of kernel could improve the balance between high density lipids and low density lipids from blood by reducing the amount of low density lipoprotein. The product rich in non-digestible carbohydrates, as bran or dried distillers grains, contain higher amount of these. Dried distillers grains contain approximately 2500 ppm policosanols (Taylor, et al., 2006). Various components present in sorghum could be useful in improving the health of population. Taylor et al. present some positive effects of sorghum in reducing and/or prevention of oxidative

stress; anti-cancer, anti-inflammatory and anti-diabetic properties; cardiovascular disease prevention and anti-hypertensive properties (Taylor, et al., 2014).

Usually sorghum is consumed by humans as flat brad, fermented or unfermented porridges and fermented beverages (Mugula, et al., 2011) or even popped (Khatir, et al., 2013). The aim of this study is to investigate the potential of sorghum for baking. Sorghum, as other cereals are milled and transformed in flour and flour is used in food. In other experiments flour of decorticated sorghum were used (Schobe, et al., 2005) (Angioloni & Collar, 2012). Other researcher studied the production of breads from composite flours composed from wheat and sorghum flours. In these studies sorghum flour was used, the bran was removed and remained mainly the endosperm. The parts reach in nutrients as polyphenols, fibres and waxes was not incorporated. Bran, a valuable source of fibres and antioxidants, was used for other purposes than human nutrition. In this study we are interested about the possibility to use whole sorghum in bread formulation, to obtain functional food.

Zaroug et al., in a study on two different sorghum cultivar showed that the antioxidant properties off sorghum are preserved during fermentation and heating and even increase (Zaroug, et al., 2014). Flat breads prepared with 40% sorghum flour had significant higher antioxidant capacity than flat breads prepared from wheat flour (Yousif, et al., 2012). These proved that sorghum have a great potential in tailoring food products with high antioxidant levels.

The use of sorghum for bread production have great inconvenient due the absence of gluten to form a viscous, elastic and yet plastic dough, able to retain gases during fermentation and baking. Modern application of biotechnology where used to improve baking properties, as transglutaminase. Transglutaminase addition did not have effects in gluten free bread production (Renzettia, et al., 2008). The use of gums (hydrocolloids) had a better effect on breads properties than addition of enzymes (Taylor, et al., 2006). Some minor improvements were observed when sourdough was included in recipe. (Wolter, et al., 2014)

Sorghum could contribute to a sustainable development of agriculture and food sector or biotechnology, for bio-films and bioethanol production (Taylor, et al., 2006). Nutraceuticals present in sorghum could improve population's health and life quality (Taylor, et al., 2006). Sorghum is associated with the food of poor people, from rural zones (Léder, 2004) (Mugula, et al., 2011), but is a valuable grain which could promote health providing complex carbohydrates, fibres, minerals and antioxidants. Inclusion of sorghum in the diet promotes people's dietary diversity and maintains food plant biodiversity (Taylor, et al., 2014). The selection of sorghum cultivars (Goodall, et al., 2012) and careful cultivation and supplementation (Ahmed, et al., 2014) could improve the nutritional and technological properties and ensure a future of sorghum in human's nutrition.

2. MATERIALS AND METHODS

Wheat flour was replaced with whole sorghum flour in 10, 20, 30 and 40%. The rheological characteristics of dough were measured with a Farinograph and baking tests were performed too. The breads were evaluated.

For the experiment we used untreated wheat white flour, kindly provided by a local mill, Cibin Mill from Sibiu. Flour's characteristics were: 0.64% (d.w. basis) ash content; 24.9% wet gluten; 316 s Falling Number, 69 mm H_2O P; 102 mm L; 22.5 G; $227 \cdot 10^{-4}$ J W; 0.68 P/L; 55.2% Ie. Sorghum (*Sorghum bicolorum*) was provided by a Romanian cereal trader, with 12.2% moisture. Fresh yeast Pakmaya was purchased from a local store.

Sorghum was milled with a lab mill (Laboratory Disk Mill DLFU, Buhler) in three granulation: 0.1, 1 and 3 on mill's scale. The whole sorghum flour replaced wheat flour in formulation in 10, 20, 30 and 40% (14% wet equivalent). Farinographic test was performed in accordance with ICC No. 115/1 method. Baking test were performed using lab equipment, Sadkiewicz planetary mixer and oven with tempered fermentation chamber. The formula and working protocol for baking test is presented in table no. 1

Table 1. Formula for baking test

Ingredients	
Flour (wheat and sorghum), %	100
Water	determined hydration capacity
Yeast, %	3
Salt, %	1.5
Bakint test parameters	
Mixing	2 min at speed 3, vessel cleaning, 3 min at speed 5; final temperature 30±1°C
Fermentation	60 min, 30±1°C
Dividing	2 pieces of 500g
Moulding	manual, round, 2 times with 10 hand movements with resting 5 min
Proofing	35 min, 30±1°C
Baking	22 min, 230°C

The specific volume of bread was measured by rape seed displacement. The elasticity of bread crumb was measured by height recovery of a crumb cylinder after his compression at half of height for 1 minute followed by 1 minute recovery. The porosity of crumb was measured by differences between the volume of a bread crumb cylinder and the volume of compressed crumb cylinder, measured by oil displacement with a graduated cylinder.

3. RESULTS AND DISCUSSIONS

From wheat white flour and whole sorghum flour were prepared mixtures and theirs rheological properties were evaluated with a Farinograph. A control was prepared, only with wheat flour. The samples were codified according with the dimensions of milled sorghum (0.1 very fine grist, 1 fine grist and 3 coarser grist) and with the proportion of wheat flour replacement (P10, P20, P30 and P40 for 10%, 20%, 30% and, respective 40% replacement). In figure 1 were presented the calculated values of water absorption. The water absorption decreased with the amount of wheat flour replaced with sorghum flour. The water absorption decreased from 58.5% for the control to 49% for the higher amount of wheat flour replaced with the finest sorghum flour. The sorghum flour with a coarser particles bind higher amount of water despite that a coarser particle have a smaller specific surface. Usually finest wheat flour bind higher amount of water due the higher starch granule damage (Shelton & Lee, 2000). Dough development time was affected by the proportion of sorghum in mixture (Figure 2). Wheat flour used had dough development time, 2 min, and this increased to 7 min when coarsest sorghum flour was added in higher percentage. The coarser particle needed a longer time to adsorb water.



Figure 1. Water absorption of wheat-sorghum mixtures

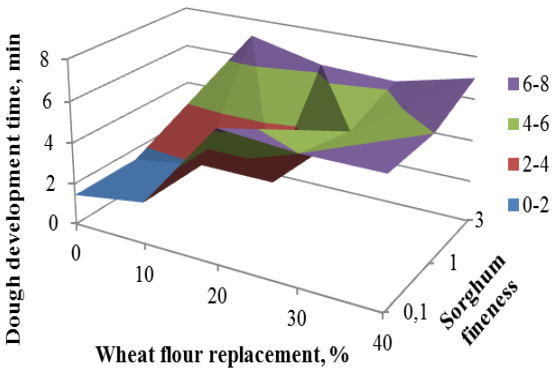

Figure 2. Dough development time of wheat-sorghum mixtures

The doughs prepared with sorghum flour were more stable during mixing. The consistency decreased with 65 unit during the 5 minutes after the peak was reached, for 100% wheat flour, and for the dough prepared with sorghum in 40% percentage addition decreased with only 25 units for the coarser sorghum flour (Figure 3). The finest sorghum flour showed an inconstant behaviour while the coarser sorghum flour was the most consequent.

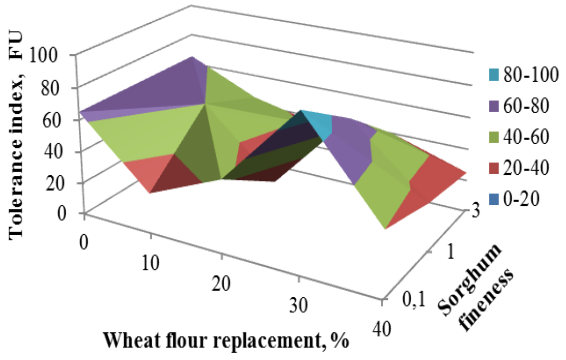

Figure 3. Mixing tolerance index of wheat-sorghum mixtures

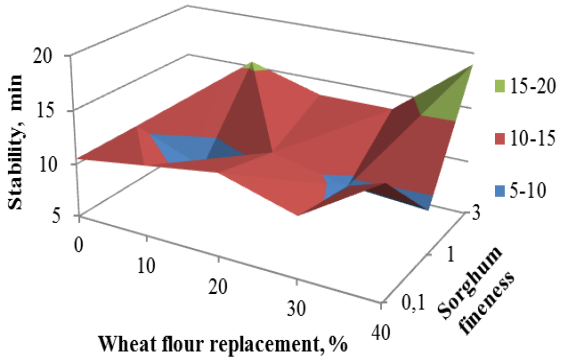

Figure 4. Stability of wheat-sorghum mixtures

In figure 4 were presented the results for the dough stability. Dough stability increased with the percentage of wheat flour replacement. The lowest values were observed for medium coarse sorghum flour and the best results for coarsest flour. Dough stability increased from 10.5 min, in the case of wheat flour, to 19 minutes for 40% replacement. Similar behaviour was observed in the case of dough softening (Figure 5) and time to break down (Figure 6).

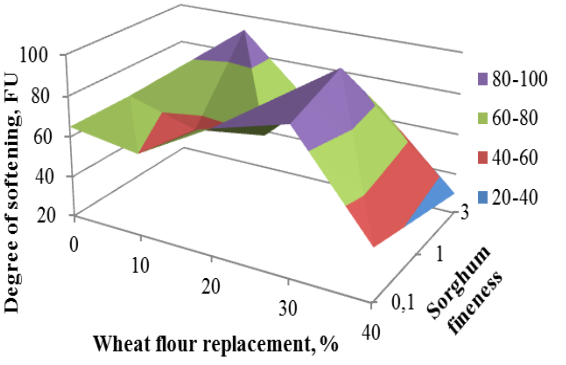

Figure 5. Degree of softening of wheat-sorghum mixtures

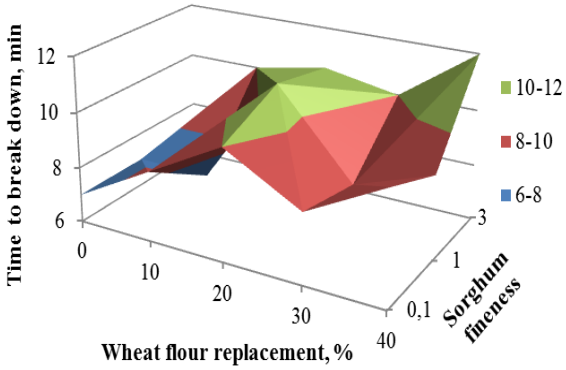

Figure 6. Time to break down of wheat-sorghum mixtures

The dough with sorghum needed a longer time to drop the consistency and the softening effects were lower than dough with wheat flour only. . The higher proportions of coarser sorghum flour the better were the results. The doughs were more stable. The degree of softening decreased from 65 to 30. The tendency of softening was difficult to predict for these dough because the time to reach the peak of consistency increased too and during kneading the gluten structure was altered.

The dough rheology is very complex and antagonist processes overlap and complicate the dough development. For a better evaluation baking tests are recommended to confirm these results. The results of baking test are presented in figures 7 to 9.

Despite the dough rheology show some improvement of stability, the quality of breads prepared with addition of sorghum flour suffer depreciations. The specific volume of breads decreased when the percentage of wheat flour with sorghum flour increased – data are presented in figure1. The specific volume of bread without sorghum was 378 cm^3/100g but decreased with 20% when the finest sorghum flour replace wheat flour with 10%. At 40% replacement specific volume of bread decreased with 41%. The impact of coarse flour was not so dramatic at low level of replacement. At 10% replacement of wheat flour the specific volume decreased with only 4% and decreased with 23% only at 30% wheat flour replacement. At higher level of replacement the specific volume decreased with 37%, similar with the effect of finest sorghum flour.

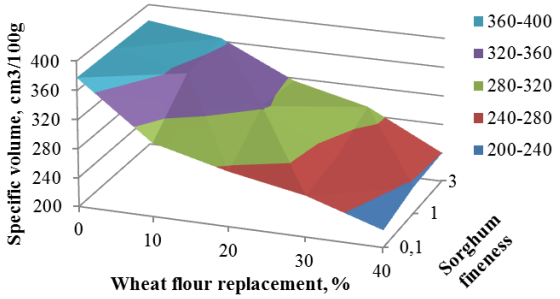

Figure 7. Specific volume of bread from wheat-sorghum mixtures

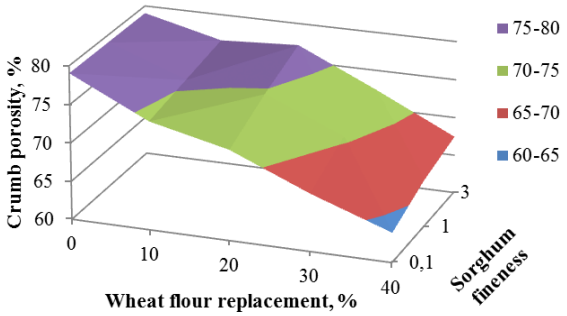

Figure 8. Crumb porosity of bread from wheat-sorghum mixtures

Crumb porosity is related with specific volume of bread, represent the ratio between the volume of gas cell and the volume of total crumb probe. In figure 8 is presented the variation of crumb porosity with the percentage of wheat flour replacement. The pattern of variation was very similar with the variation pattern for specific volume. The smallest porosity was observed at the breads prepared with 40% replacement of wheat flour with the finest sorghum whole flour, with 19% lower than the porosity of control bread. The coarser sorghum flour had a smaller effects on porosity but still the porosity of bread with 40% coarsest sorghum flour was with 14,6% smaller than control.

Elasticity represents the recovery of bread crumb after a compression for 1 minute at the half of initial height and 1 min decompression. Crumb elasticity was affected through sorghum flour addition. The elasticity of control sample was 96.7% and decreased with 5% at 10% wheat flour replacement and with 10% for a level of wheat flour substitution of 20%. At higher level of substitution the crumb elasticity decreased with 20%. When coarser sorghum flours were used the elasticity was not so affected at 10 and 20% level of substitution but at maximum substitution was similar to the elasticity of bread crumbs with finest sorghum flour addition.

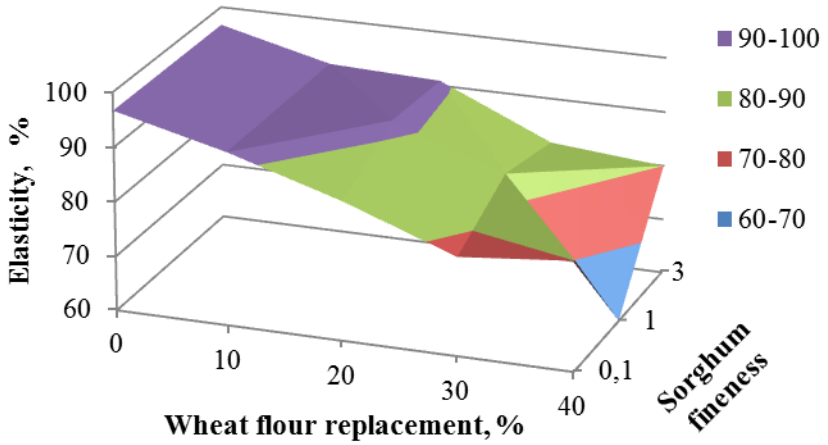

Figure 9. Crumb elasticity of bread from wheat-sorghum mixtures

Breads prepared with sorghum flour are presented in Figure 10. The crumb became more brown-greyish as the substitution of wheat flour with sorghum flour increased. Small black particles were more visible but overall aspect was not affected very much. The crumb became denser but the porosity remained uniform in section, did not appeared holes. When coarser sorghum flour was used the crumb became harsher but acceptable. The top crust of control bread was dark and shiny. The samples with high sorghum content had top crust paler, dull and with a harsh aspect, with visible particles of sorghum bran, similar to wheat bread prepared with wheat bran.

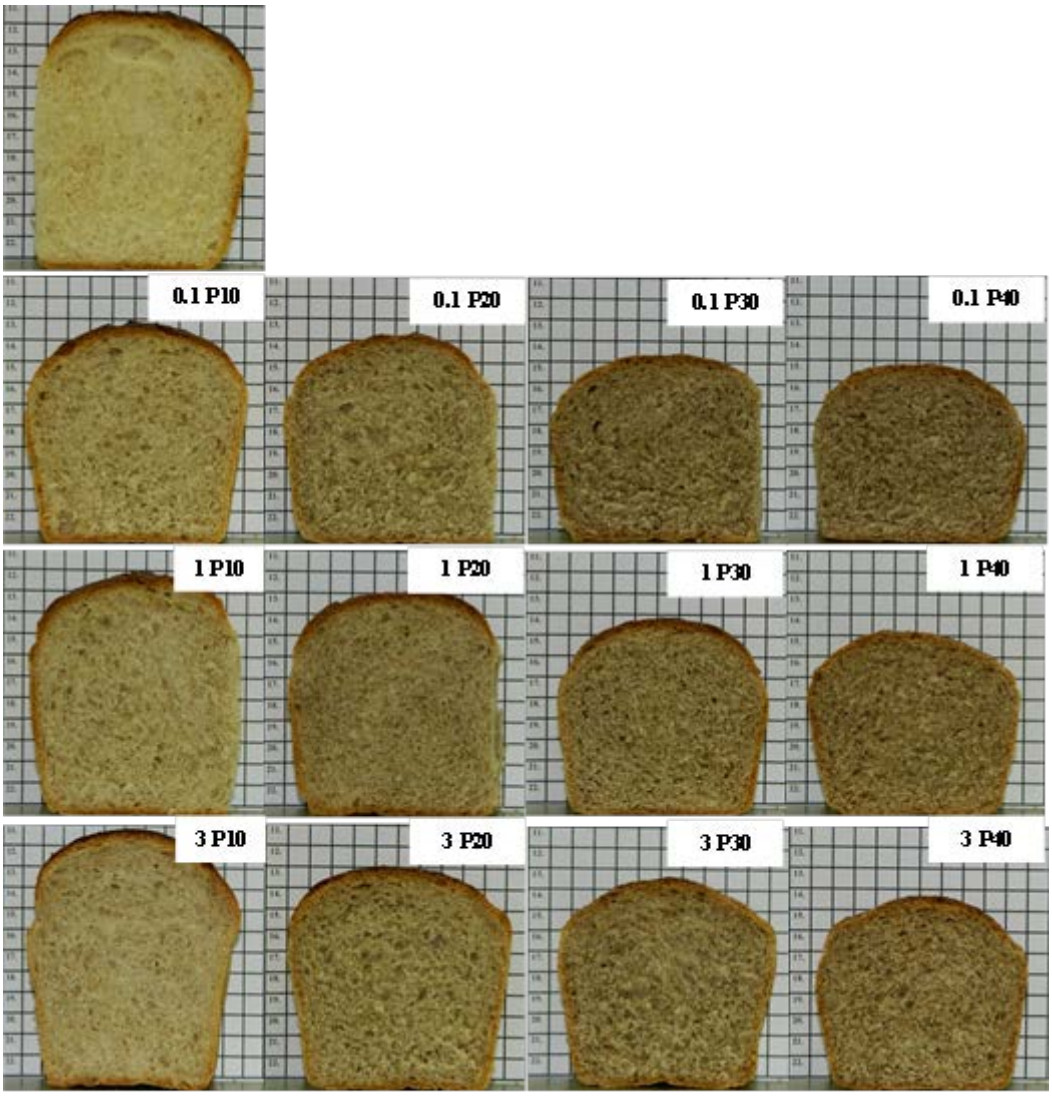

Figure 10. Overall aspect of breads prepared with 10 to 40% substitution of wheat flour with whole sorghum flour, different grinding level

The smell and taste of breads with sorghum did not changed very much, remained pleasant, specific for wheat flour bread. The taste and smell remain more than acceptable, even at 40% replacement of wheat flour.

4. CONCLUSIONS

Whole sorghum flour addition in the formula of bread to improve the nutritional and functional properties of breads had some difficulties due the presence of sorghum bran, lack of gluten and dilution of gluten from wheat flour. The rheological properties of dough showed some improvements through sorghum flour incorporation. The dough stability increased, dough softening decreased and increased mixing tolerance index. The water binding decreased. The coarser flour had better effects on dough rheology than finer sorghum flour.

The breads prepared with sorghum flour decreased in volume, porosity and elasticity. At 10 and 20% replacement of wheat flour the bread properties were affected little. At 30% the differences between samples with sorghum and control became obvious but breads remained acceptable. At 40% replacement specific volume decreased with approx. 40%. The bread's properties were heavy affected

by sorghum incorporation in high proportions. Breads prepared with coarser sorghum flour, as suggested by farinographic tests, were superior to breads prepared with finer flour. The smallest particles of sorghum flour were more rapidly hydrated and interact more quickly and intimate with wheat flour component and destabilised dough's strength.

Sensorial properties of breads as small and taste are very important for acceptance or rejection of product and were little affected by sorghum incorporation, even at 40%. Similar results were observed by other researchers which, also, incorporate sorghum flour in products from wheat flour, flat bread. At 40% level of wheat flour replacement the flat bread wasn't rejected by panellist during sensory analysis and was found acceptable (Yousif, et al., 2012). These results suggested that it is possible to produce bread with sorghum added in proportion of 40% but it is necessary to find the methods to improve the specific volume, crumb porosity and elasticity.

Sorghum utilisation in bakery is a real and valuable method to improve the nutritional and functional properties of breads and to contribute to human's food diversification and promote sustenability.

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REFERENCES

Ahmed, SO et al. 2014, 'Nutritional quality of grains of sorghum cultivar grown under different levels of micronutrients fertilization' *Food Chemistry*, Volume 159 , pp. 374–380.

Angioloni, A & Collar, C 2012, 'Effects of pressure treatment of hydrated oat, finger millet and sorghum flours on the quality and nutritional properties of composite wheat breads' *Journal of Cereal Science*, Volume 56, pp. 713-719.

Goodall, MA, Campanella, OH, Ejeta, G & Hamaker, BR 2012, 'Grain of high digestible, high lysine (HDHL) sorghum contains kafirins which enhance the protein network of composite dough and bread' *Journal of Cereal Science*, Volume 56 , pp. 352-357.

Henley, EC 2010, *Sorghum: An Ancient, Healthy and Nutritious Old World Cereal.* s.l.:United Sorghum Checkoff Program.

Khatir, AMM et al., 2013, 'Chemical Composition of New Phenotype Sorghum (Sorghum bicolor L) (Locally named Barbarei) Grains and Stover in South and West Darfur States, (Sudan)'*ARPN Journal of Science and Technology*, 3(7), pp. 683-686.

Léder, I 2004, 'Sorghum and Millets' In: *Cultivated Plants Primarily as Food Sources, in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO,*. Oxford, U.K.: Eolss Publishers.

Mugula, J, Byaruhanga, Y & Abegaz, K 2011, *Use of Biosciences for Value Addition and Diversification to Enhance Commercialization of Sorghum and Millet Products*, Nairobi, Kenya: ILRI.

Ndjeunga, J & Nelson, CH 2001, 'Prospects for a Pearl Millet and Sorghum Food Processing Industry in West Africa Semi-Arid Tropics' In: *Toward sustainable sorghum production, utilization and commercialization in West and Central Africa*, Bamako: WCASRN/ROCARS, pp. 178-216.

Obilana, AB, 2004, Breeding and Agronomy (of Sorghum)' In: *Encyclopedia of Grain Science, vol. III.* s.l.:Elsevier Academic Press, pp. 108-126.

Renzettia, S, Belloa, FD & Arendt, EK 2008, 'Microstructure, fundamental rheology and baking characteristics of batters and breads from different gluten-free flours treated with a microbial transglutaminase' *Journal of Cereal Science*, Volume 48, pp. 33–45.

Schobe, TJ et al. 2005, 'Gluten-Free Bread from Sorghum: Quality Differences Among Hybrids' *Cereal Chem.,* 82(4), pp. 394–404.

Shelton, DR & Lee, WJ, 2000, 'Cereal Carbohydrates' In: K. Kulp & J. G. Ponte, eds. *Handbook of Cereal Science and Technology, Second Edition, Revised and Expanded.* s.l.:CRC Press, pp. 385-416.

Taylor, JRN, Belton, PS, Beta, T & Duodu, KG, 2014, 'Increasing the utilisation of sorghum, millets and pseudocereals: Developments in the science of their phenolic phytochemicals, biofortification and protein functionality, ' *Journal of Cereal Science,* Volume 59, pp. 257-275.

Taylor, JR, Schober, TJ & Bean, SR, 2006, 'Novel food and non-food uses for sorghum and millets. *Journal of Cereal Science,* Volume 44, pp. 252–271.

Waniska, RD, Rooney, LW & McDonough, CM 2004, 'Utilisation (of Sorghum)' In: *Encyclopedia of Grain Science.* s.l.:Elsevier Academic Press, pp. 126-136.

Wolter, A, Hager, A-S, Zannini, E & Arendt, EK 2013, 'In vitro starch digestibility and predicted glycaemic indexes of buckwheat, oat, quinoa, sorghum, teff and commercial gluten-free bread' *Journal of Cereal Science,* Volume 58, pp. 431-436.

Wolter, A et al., 2014, 'Influence of dextran-producing Weissella cibaria on baking properties and sensory profile of gluten-free and wheat breads' *International Journal of Food Microbiology,* Volume 172 , pp. 83–91.

Yousif, A, Nhepera, D & Johnson, S 2012, 'Influence of sorghum flour addition on flat bread in vitro starch digestibility, antioxidant capacity and consumer acceptability' *Food Chemistry,* Volume 134 , p. 880–887.

Zaroug, M, Orhan, IE, Senol, FS & Yagi, S 2014, 'Comparative antioxidant activity appraisal of traditional Sudanese kisra prepared from two sorghum cultivars' *Food Chemistry,* Volume 156 , p. 110–116.