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REVIEW ARTICLE

Possibility to Utilize Sorghum Flour in a Modern Bread Making Industry

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Abstract

The origins of Sorghum Grain, its morphological structure, chemical composition, flour production and possible usage as bread component were addressed in this review article. A substantial character to stand against the severe environmental conditions was made. Sorghum Grain, an important cereal crop for the maintenance of food security in many regions around the globe whereas it's considered as the fifth most essential cereal crop worldwide. It is not just nutritionally important; it appears to have a unique functional characteristic and is potentially the source of high value products. Incorporation of sorghum flour into bread formula can reduce the caloric intake of developed populations (overconsumption of refined foods) where, protein deficiency is not an issue. Additionally, the use of sorghum flour in gluten free or composite bread can give us functional breads containing antioxidants and therefore helpful to relief celiac and tumour sufferers. Moreover, sorghum based bread making industry has great socio-economic potential for the populations in tropical areas. However, production of high quality bread from sorghum requires the solute molecules in the dough mainly starch to have a suitable characteristic for the gas-holding and visco-elastic properties likely to those of wheat gluten molecules. Specifically, the solute molecules have interaction with each other and with the water molecules to hold the gas produced by yeast activity, give dough with the required expansion capacity during fermentation and to set into a firm cellular structure during baking. To achieve that and to produce sorghum bread with enhanced nutritional and functional properties; much more research efforts are still needed.

Keywords: Sorghum grain, cereal crop, food security, functional breads, visco-elastic properties.

Introduction

Sorghum (*Sorghum bicolor* (L. Moench) is a cultivated tropical cereal grass. It is the only species which is cultivated for food and feeds among other 28 species and it is generally, although not universally, considered to have first been domesticated in North Africa, possibly in the Nile, Sub-Saharan and/or east Africa regions as recently as 1000 BC (Kimber, 2000). The cultivation of sorghum played a crucial role in the spread of the Bantu group of people across Sub-Saharan Africa (Taylor, 2003). Today, sorghum is cultivated in the warmer climatic areas across the world. It is quantitatively the world's 5th largest most important cereal grain, after wheat, maize, rice and barley. It is called by a variety of names in different regions, among them; Great millet and Guinea corn in West Africa, Kafir corn in South Africa, Dura in North Africa, Mesego/Haruur in Somalia and Djibouti, Jowar in India, gaoliang in China and milo or milo-maize in USA. It is described as a very tolerate crop, which can resist the limiting conditions of water shortage and alkaline soils (Doggett, 1988). Sorghum is cultivated for different purposes, USA which is a major producer of sorghum; the grain is used mainly as animal fodder, while in Africa and India, the grain is considered as a major food source and forms the staple diet for large populations living in the semi-arid regions in Asia and Africa where, sorghum is produced for human consumption and it is almost the only source of energy and protein in those regions (Taylor *et al.*, 2011). Lack of gluten in sorghum gives a significant importance to tackle the present day scenario of Celiac Disease (CD) occurrence (Kasarda 2001). Previous study revealed that Grain sorghum contains phenolic compounds like flavonoids (Shahidi and Naczk, 1995) which have been found to inhibit tumour development (Huang and Ferraro, 1992). The starches and sugars in sorghum are released more slowly than in other cereals (Klopfenstein and Hoseney, 1995) and that could be beneficial to diabetic patients. Sorghum, like the other cereals, is a good source of the B vitamins and minerals such as potassium and phosphorus, while its calcium content is low (Khalil *et al.*, 1984). Sorghum is consumed into a wide variety of foods, such as baked products, tortillas, couscous, gruel, steam-cooked products semi-leavened breads, popped form, fermented or non-fermented porridges and alcoholic or non-alcoholic beverages (Anglani, 1998). Moreover, grain sorghum has great potential to be used in different industrial applications and processed into starch, flour, grits and flakes as well as malted products. In this review article, we will try to recap the possible sorghum potentiality to use it in a modern bread making industry.

Description and distribution of sorghum grain

Grain sorghum is approx. 4 mm in length and it is more or less spherical in shape but somewhat flattened at the germ end (Serna-Saldivar and Rooney, 1995). The 1000 kernel weight ranges from approx. 25 to 35 g. Sorghum grain color varies from almost white to almost black, with shades of red and brown being common (Taylor and Emmambux, 2010). Sorghum excels and uniquely adapted to arid and semi-arid conditions due to its drought tolerance (Anglani, 1998), it can also survive periods of water logging and floods. Historically, the timing and place of sorghum domestication are not fully known although it is known to have initiated with early settled human life. According to Vavilov (1926), the old Abyssinian (today's Ethiopian ancestors) area is believed to be the centre of origin of sorghum while other authors have suggested a more broad area (De Wet and Harlan, 1971) or separate centres of origin for different species (Snowden, 1935). However, it is generally agreed that *S. bicolor* originated and was domesticated, in the Sub-Saharan Africa and spread to other regions of the globe in a very unevenly manner with Africa (Sudan and Nigeria) and Asia (India) having the largest areas harvested. Sorghum is also widely grown as a staple food crop in the drier parts of Central and South America (Colombia, Venezuela and North-Eastern Brazil). In the developed countries, led by the USA, where sorghum is primarily used as a feed grain, an intensive breeding programme, the application of large quantities of fertilizer and the advancement of agricultural practices (e.g. pest control, seed bed preparation) have maximized the attainable yield that reached 4.5 tonnes/ha in 2010. This is five times that for developing countries such as sorghum producers in Africa (0.84 tonnes/ha in 2010) where this grain is almost entirely used as a staple food. Notwithstanding its poor yield, sorghum plays a fundamental role in rural food security in the semi-arid tropical areas that represent home for billions of people. According to the latest estimations presented by index mundi Network; the top 15 sorghum-producing countries in a year 2014 (in decreasing order) were: United States, Mexico, Nigeria, Sudan, India, Ethiopia, Argentina, China, Australia, Brazil, Burkina Faso, Mali, Cameroon, Niger and Chat. The importance of sorghum is illustrated by the fact that it represents more than 70% of total cereal production in some states of Africa (Arendt *et al*., 2013) and in many parts of Africa, Asia, Central America and the Middle Eastern Arab countries; sorghum is the staple food and in some countries also it is the main source of beverages.

Morphological structure of the sorghum grain

Sorghum grains are generally spherical or spindle shaped and may be colored white, red, yellow or brown. The terms 'soft' and 'hard' have been used to designate vitreous and opaque areas of sorghum endosperm, respectively. Grain hardness plays an important role when dry milling sorghum. The sorghum kernel is a naked caryopsis and it consists of three anatomically distinctive regions; the pericarp (outer layer), the endosperm (starch storage) and the germ (embryo) (Dendy, 1994). The endosperm may be further sub-divided into the sub-aleurone layer, corneous or glassy endosperm, and the floury endosperm. The pericarp contains a cuticle comprising layers of waxy materials and is divided into three histological tissues: the epicarp, mesocarp and endocarp (Earp *et al*., 1983). The epicarp is two or three cells thick and consists of rectangular cells often containing pigmented material. Unlike other cereals, the sorghum mesocarp may contain starch granules. The endocarp is mainly composed of cross and tube cells. Some sorghum varieties have a layer of pigmented cells under the pericarp called the testa or undercoat that can cause problems in processing. However, the undercoat can be lost through breeding procedures (Hoseney *et al*., 1974). The endosperm tissue is composed of the aleurone layer, peripheral, corneous and floury areas. The aleurone layer is the outer cover and it consists of single layer of rectangular cells adjacent to the testa or tube cells (Serna-Saldivar and Rooney, 1995). The cell possesses a thick cell wall, large amounts of protein, ash and oil. The peripheral endosperm tissue is composed of several layers of dense cells containing large amounts of protein and small starch granules (Sullins and Rooney, 1975). The corneous and floury endosperm is composed of starch granules, a protein matrix, protein bodies and cell walls rich in β-glucan and hemicelluloses. In the corneous endosperm, the protein matrix has a continuous interphase with the starch granules and protein bodies embedded in the matrix (Seckinge and Wolf, 1973; Hoseney *et al*., 1974). The centre of the endosperm is floury, here the packing of the starch and proteins is less tight and there are air spaces present that result in diffraction of the incoming light, giving an unclear or chalky appearance under scanning electron microscopy (Dendy, 1994). According to Rooney and Sullins (1969); the embryo is embedded in the sorghum kernel rendering it difficult to remove. It consists of two major parts: the scutellum and the embryonic axis. The scutellum represents the reserve tissue containing high amounts of oil, protein, enzymes and minerals which represents a connecting bridge between the endosperm and germ.

Chemical constituents of the sorghum grain

Table 1 compares the significant chemical characteristics of sorghum grain with that of the other major cereals. In detail, the major constituents of sorghum grain are:

Starch: Starch content represents approx. 71% of sorghum grain (Serna-Saldivar and Rooney, 1995). Sorghum starch gelatinization temperature (66 to 81°C) is high compared to that of wheat and possibly higher than that of maize (Taylor and Emmambux, 2010). Starch gelatinization temperature also seems to be quite variable among the sorghum cultivars.

Table 1. Sorghum grain chemistry compared to other cereals (Wheat, Rice Maize and Barley).

Sorghum	Other cereals
Some varieties contain condensed tannins	Not present in wheat, rice and maize, perhaps very low levels in barley
All varieties contain greater or lesser amounts of polyphenols	Present in wheat, rice, maize and barley, but generally in lower amounts
Many varieties highly pigmented	Some varieties of wheat, rice, maize and barley also highly pigmented
High starch gelatinization temperature	Rice starch the same temp, maize starch slightly lower, wheat and barley starch considerably lower
Endosperm non-starch polysaccharides are predominantly insoluble	Rice and maize are the same, barley is rich in soluble non-starch polysaccharides while wheat contains both insoluble and soluble types
Endosperm protein rather inert	Maize protein similar, rice and barley protein somewhat less inert while Wheat protein will form visco-elastic dough
Protein quality poor, deficient in lysine	Maize, barley and wheat similar, rice protein quality is better
Protein digestibility reduced after wet cooking	Wheat, maize and barley protein digestibility reduced to a lesser extent
Fat content is quite high	Maize is even higher, wheat and barley are low while rice is very low
Malt contains low levels of ß-amylase	Maize similar, rice higher wheat and barley high levels

Source: Taylor (2003).

Generally, sorghum has lower starch digestibility than maize (Taylor and Emmambux, 2010). On the basis of this, it has been suggested that sorghum may be a particularly suitable food for diabetic and obese people (Dicko *et al*., 2006). However, there is little, if any direct evidence to support this contention. It appears that the lower starch digestibility is not an intrinsic property of sorghum starch but primarily as a result of the endosperm protein matrix, cell wall material and tannins (if present) inhibiting enzymatic hydrolysis of the starch (Taylor and Emmambux, 2010). Protein disulfide bond cross-linking involving the kafirin proteins in the protein matrix around the starch granules seems to be of major importance in reducing starch digestibility (Ezeogu *et al*., 2008). The endosperm cell wall, non-starch polysaccharides of sorghum are rich in the water-unextractable 'water-insoluble' glucuronoarabinoxylans (Verbruggen, 1996). In contrast to the cell walls of barley, which are mainly of the "water-soluble" β-glucan type and those of wheat, which are "water-soluble and insoluble" arabinoxylans. These differences may have importance consequences when sorghum is used in brewing (Verbruggen,. 1996) or bread making (Hugo *et al*, 2003).

Non-starch polysaccharides

Sorghum contains approximately 6-11% non-starch polysaccharides (NSPs; dietary fiber) which probably a slightly lower level than that in wheat. The major NSPs of the sorghum endosperm are water-unextractable (insoluble) glucuronoarabinoxylans (GAX) (Taylor *et al*., 2006; Taylor and Emmambux, 2010). Because they are water-insoluble, the sorghum GAX are probably not functional in bread making, unlike the wheat arabinoxylans. Concerning their nutritional attributes; they probably have good laxation properties but do not have the cholesterol lowering effects associated with soluble dietary fiber (Taylor *et al*., 2011).

Protein: Protein content and composition varies due to genotype, water availability, temperature, soil fertility and environmental conditions during grain development period. According to David (1995), it is usually 11-13% but sometimes higher than that and ranges from approx. 7 to 16% with an average of approx. 11% (Serna-Saldivar and Rooney, 1995). The major sorghum grain proteins are prolamin storage proteins, as in virtually all other cereal grains and are known as kafirins (Belton *et al*., 2006). Kafirins are classified into four major groups (α, β, γ and δ) based on differences in molecular weight, solubility, structure and amino acid composition and sequence. With regard to amino acids, sorghum kafirin is usually high in glutamic acid, leucine, alanine, proline and aspartic acid (Hoseney *et al*., 1981). From a nutritional point of view, lysine and threonine represent the first and second most limiting amino acids in sorghum proteins, from a human nutrition perspective. Sorghum lysine meets 40% of the recommended daily/portion level for infants (Waniska *et al*., 2004). They are poorly digestible, especially when cooked in water, as occurs during most food preparation processes, unlike wheat proteins; sorghum proteins are not highly functional. Concentration and/or modification of sorghum proteins (alkaline extraction, reducing agents, enzymatic hydrolysis, deamidation, irradiation and extrusion) could be one way to address this challenge (Duodu *et al*., 2003). However, an important positive health issue with respect to the kafirins is that because, they are so different in structure from the wheat gliadin and glutenin storage proteins. It has been conclusively shown that sorghum does not elicit morphometric or immunomediated alteration of duodenal explants from patients suffering from celiac disease (Ciacci *et al*., 2007). Celiac disease which is a syndrome characterized by damage to the mucosa of the small intestine and caused by ingestion of wheat gluten and similar proteins (Catassi and Fasano, 2008). It is becoming recognized that celiac disease is a major health problem in Western countries, affecting at least 1 in 150 people. The only treatment is lifelong avoidance of foods containing wheat and similar cereals such as rye, triticale and barley. Hence, sorghum is an important alternative for making baked products such as bread. However, a major challenge in using sorghum in bread baking is the very poor visco-elastic properties of kafirin dough compared to that made from wheat gluten (glutenins and gliadins). When mixed with water, gluten proteins become hydrated and form a three-dimensional network, which is responsible for the unique visco-elastic property of wheat dough (Belton, 1999; Oom *et al*., 2008). Due to their higher hydrophobic character which is related to their higher leucine content compared to the gluten proteins; kafirins are difficult to hydrate. Belton *et al*. (2006) suggested that the poor hydration of kafirins may also be linked to their α-helical structure mainly, in contrast to high-molecular-weight (HMW) glutenin subunits of wheat, which have a high level of β-sheet and β-turn structure. Moreover, the kafirins are much smaller proteins than the HMW glutenins and this probably also has a bearing on their lack of elasticity. In addition, because kafirins are encapsulated in protein bodies (Duodu *et al*., 2003); they are probably unavailable for participation in dough fibril formation, unlike gluten proteins which are present in the continuous matrix after seed desiccation (Shewry, 1999)**.**

Lipids: Sorghum contains approx. 3.4% lipids, rather more than wheat and rice but less than maize, the majority of which are neutral triglycerides (triacylglycerols). The triglycerides of sorghum are rich in unsaturated fatty acids. The predominant fatty acids are linoleic (38-49%), oleic (31-38%) (Serna-Saldivar and Rooney, 1995) and palmitic acids (14%) (Arendt *et al*., 2013), therefore this grain provides a higher amount of energy.

Minerals and vitamins: Sorghum grain is an important source of minerals and amongst them; P is the most abundant (Kent and Evers, 1994). However, its bioavailability is negatively related to the proportion which exists bound of phytates. Minerals are located in the pericarp, aleurone layer and germ; therefore, refined sorghum products lose part of these important nutrients, as in all other refined cereal fractions. Sorghum is an important source of fat-soluble and B-complex vitamins (Waniska *et al*., 2004) except vitamin B12 (Gazzaz *et al*., 1989). Amongst the B vitamins, concentrations of thiamine, riboflavin and niacin in sorghum were comparable to those in maize. Some yellow-endosperm sorghum varieties contain β-carotene which can be converted to vitamin A by the human body (Dendy, 1994). Detectable amounts of other fat soluble vitamins, namely D, E and K have also been found in the sorghum germ. Sorghum, in its typical form of consumption, is not considered as source of vitamin C.

Tannins, phenolic compounds and phytochemicals: Sorghum tannins are almost exclusively of the ‘condensed’ type, also known as proanthocyanidins or procyanidins (Serna-Saldivar and Rooney, 1995) and are only present in cultivars with a pigmented testa (referred to as brown sorghum but now classified as tannin sorghums). However, all sorghums contain phenolic acids, which are located in the pericarp, testa, aleurone layer and endosperm (Hahn *et al*., 1984). Tannins are mainly polymerized products of flavan-3, 4-diols. Previous studies (Jambunat and Mertz, 1973; Steadman *et al*., 2001) revealed that the tannin levels vary amongst sorghum genotypes and range from 10.0 to 68.0 mg/g (dry wt.). They primarily reside in the pigmented testa, which is only a portion of the outer covering layer, comprising approximately 5-6% (dry weight) of the kernel. Tannins protect the grain against attack by pests, such as birds, insects, moulds and bacteria, pre-harvest germination and environmental effects (Waniska *et al*., 1989). The agronomic advantages of the protective tannins are conversely accompanied by a nutritional inconvenience and reduction in food quality. In fact, condensed tannins bind to proteins, carbohydrates and minerals, thus reducing their digestibility and decreasing the feed efficiency by 5-15% (depending on the livestock species and processing of the rations) (Waniska *et al*., 2004). To reduce these negative effects, various processing mechanisms, such as decortication, fermentation, germination (malting) and chemical treatments (e.g. chloric acid, formaldehyde and alkali) are used (Beta *et al*., 2000). Among them; malting effectively lowers (up to 43%) the assayable levels of sorghum tannins (Osuntogun *et al*., 1989). However, during malting, tannins affect malt amylase activity, but alkaline or formaldehyde treatments effectively counteract this phenomenon, thus allowing brewers to avoid the associated problems (Beta *et al*., 2000).

The tannin sorghums are a potent source of antioxidants (Riedl and Hagerman, 2001), which is mainly attributed to their chemical structure containing many aromatic rings and hydroxyl groups and additionally tannins are not able to act as pro-oxidants (Hagerman *et al*., 1998). The phenolic acids of sorghum are derivatives of benzoic or cinnamic acid. As in other cereals grains, phenolic acids in sorghum are mainly concentrated in the pericarp and occur mostly in a bound form (esterified to cell wall polymers). The most abundant phenolic acids identified in sorghum include syringic, protocatechuic, caffeic, p-coumaric (70–230 μg/g dry wt.) (Hahn *et al*., 1983), ferulic (1400–2170 μg/g dry wt.) (Hahn *et al*., 1984) and sinapic (100–630 μg/g dry wt.) acid (Hahn *et al*., 1984; Waniska *et al*., 1989). The phenolic acids are thought to play a role in plant defence against pests and pathogens. Their content in sorghum correlates most strongly with *in vitro* antioxidant activity and thus may contribute to health benefits associated with consumption of whole-grain sorghum (Awika and Rooney, 2004).

Sorghum grain contains several types of potentially health-promoting phytochemicals, including various phenolic compounds, plant sterols and policosanols. Examples of the health benefits that have been indicated for sorghum phytochemicals include antioxidant, anti-inflammatory, cancer-preventive, anti-arrhythmic activities associated with the phenolics; satiety-promoting activities specifically associated with the tannin-type phenolics (Dykes and Rooney, 2006) and cholesterol lowering activity associated with the policosanols (Leder, 2004; Taylor *et al*., 2006).

Sorghum flour production

The technology of milling sorghum grain into flour is not as well developed compared to that of wheat (Taylor and Dewar, 2001) and different traditional milling methods are still widely used in many countries. Generally, the first step of milling is decortication, a process aiming to remove the bran layers (pericarp and germ), thus reducing tannin and phytic acid contents. Decortication is generally performed using dehulling equipment employing the dry abrasion principle. These technologies are not particularly efficient and the quality of the flour can be variable. It results a low milling yield and high protein loss due to the softness of the endosperm which is a characteristic feature of some high-tannin sorghums (Reichert *et al*., 1988). Small roller mills with simple versions of those types used for wheat milling are a recent development for sorghum flour production. These small roller mills combine both decortication and reduction in particle size. Research by Kebakile *et al*. (2007) indicates that small roller mills are advantageous over other sorghum milling technologies due their capability to produce flour with higher extraction rate (flour yield) and much higher output. An important issue with respect to milling sorghum is that its endosperm consists of two main components; a hard outer part, the corneous (also referred to as vitreous) endosperm and a softer inner part the floury endosperm. The hard corneous endosperm resists reduction to fine particle size (Chandrashekar and Mazhar, 1999). Hence, milling the corneous endosperm to flour size can result in high levels of starch damage, which can adversely affect the bread making quality of the flour. The incorporation of the reduction rolls permits the production of fine sorghum flour which is suitable to use in baking. In general, 5-20% of the initial weight is removed, depending on the degree of refinement desired (Rooney and Waniska, 2000). Removal of the bran remarkably affects the flour composition. There is an increase in protein content due to removal of the dietary fiber-rich pericarp. However, there is a strong reduction in protein quality due to the removal of at least a part of the lysine-rich germ which is the primary essential amino acid in sorghum (Taylor and Schussler, 1986). Germ removal also substantially reduces the lipids (including tocopherols), vitamin (especially the B group) and mineral contents. However, mineral bioavailability may be improved when the bran is removed since it is rich in anti-nutrient phytic acid which binds and renders divalent minerals, such as zinc, iron and calcium, useless (Klopfenstein and Hoseney, 1995). Antioxidant activity of the flour is also reduced when the bran is removed. This is because phenolics are primarily responsible for antioxidant activity in sorghum and the non-tannin anthocyanis pigments are concentrated in the pericarp while the condensed tannins (proanthocyanidins), if present, are concentrated in the testa layer, which is directly above the aleurone layer of the endosperm.

Utilization of sorghum flour in a modern bread making industry

The most popular traditional breads from sorghum are roti in India, injera in Ethiopia, kisra in Sudan, lahooh in Somalia and tortillas in Central America. To make roti; a kind of dry pancake, finely milled sorghum flour is mixed with warm water and kneaded together to make cohesive dough, which is shaped into a circular disc 12-25 cm in dia and 1.3-3.0 mm thick and subsequently baked in a hot griddle. For the production of injera, sorghum flour is mixed with water and a yeast starter from a previous batch of injera. After fermentation for 24-48 h, the batter is poured onto a greased pan for baking. The resulting product is flexible, and its surface has essentially evenly spaced gas holes, that make up a honeycomb-like structure which has been formed through gas production during the prolonged fermentation and baking. The bottom surface of injera is smooth and shiny. A good injera is soft, fluffy and able to be rolled without cracking (Anglani, 1998). It should retain these textural properties after two to three days of storage, which is traditionally in a straw basket. A slight sourness is a characteristic taste of injera. For kisra production which mainly consumed in Sudan; Sorghum flour is mixed with water in a ratio of about 1: 2 (w/v), usually a starter is added by a back-slopping using mother dough from a previous fermentation incorporated at a level of about 10%. Fermentation is completed in about 12-19 h by which time the pH drops from about 6.0 to less than 4.0 (Asmahan and Muna, 2009). The fermented dough is then baked into thin sheets and is eaten with certain types of stew prepared from vegetables and meat (Mahgoub *et al*., 1999). Same formula is used to produce lahooh in Somalia with the inclusion of wheat flour and/or sometimes corn flour in their recipe and the main difference between these three lays in their thickness; whereas lahooh is more bulky than injera and kisra is considered the thinnest among them. The limited accessibility of wheat flour into some areas of the globe and occurrence of wheat protein related health illnesses motivated the researcher to undertake enormous studies to investigate the possibility to tackle these problems. As mentioned above sorghum is often recommended as a safe food for celiac patients because it is more closely related to maize than to wheat, rye, and barley (Kasarda, 2001). Sorghum might therefore provide a good basis for gluten-free bread. In 1964; The Food and Agriculture Organization (FAO) initiated the "Composite Flour

Program" to find new uses for raw materials other than wheat for the production of bread, cookies, pasta, and other flour based foods (Taylor and Dewar, 2001). Most of the research was carried out for the benefit of developing countries that were facing difficulties of importing wheat due to the high cost. Number of studies dealing with leavened breads containing sorghum has focused on composite breads from wheat and sorghum. Breads made from sorghum without adding wheat as all gluten free breads require a different technology. Gluten-free dough is more fluid than wheat dough and closer in viscosity to cake batters (Cauvain, 1998) due to the lack of a gluten network. This batter-type dough has to be handled similarly to cake batters rather than typical wheat dough. Gas holding is more difficult and the use of gums, stabilizers, and pregelatinized starch has been suggested as a means to provide gas occlusion and stabilizing mechanisms (Cauvain1998; Satin 1988). Furthermore, gluten-free and composite sorghum-wheat breads were shown poor characteristics as sorghum flour amount increased in their formulas, in which a maximum of only 30% low-tannin sorghum are regarded as acceptable (Munck, 1995). While such breads have been found acceptable by consumers (Carson *et al*., 2000); they are inappropriate for celiac patients. However, possible way to improve the quality of sorghum containing dough and its corresponding bread was the main interest of researchers in recent years. Since, the kafirin proteins are not functional in terms of providing the required visco-elastic characteristics to the dough; researchers used many additives to improve the gas holding capacity of sorghum containing dough systems.

According to Oom *et al*. (2008), if kafirin or zeins-the very similar prolamin protein of maize-mixed with solvent at elevated temperature (75°C); the resulting dough has visco-elastic properties. This is due to the fact that the temperature of 75°C is higher than the glass transition temperature of the kafirin and zein proteins. This finding could be offering a possible way-out to develop a good-quality breads from sorghum flour without using expensive additives. Several other ingredients (e.g. hydrocolloids, emulsifiers, soy flour, pre-gelatinised starch, egg powder, and skim milk powder) to enhance the functionality, achieve a higher rheological performance of dough and therefore to produce a high quality gluten free or composite breads from sorghum by improving bread volume, hardness, porosity and elasticity of the crumb, sensorial and overall acceptability.

Conclusion

In summary, it is clear that grain sorghum could be the crop of the twenty first century to tackle many problematic issues which some regard to economic aspects of the globe and other related to human health and wellbeing. Regardless the greater potential of sorghum grain, some serious technical problems remain unsolved.

More research and development are needed for better milling technologies which can insure to produce high quality flour from sorghum. For bread-making, further research could focus on attempts to create a visco-elastic protein network in order to improve the texture and shelf-life of the gluten free or composite sorghum-wheat bread.

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