A REVIEW ON: CHARACTERISTICS AND CLASSIFICATION OF SOURDOUGH AND ITS IMPACT ON THE BREAD PROPERTIES, CHEMICAL COMPOSITION AND FERMENTATION OF SORGHUM

Emad Mohamed Ali Karrar

Abstract

Today, consumers desire to have a large range of foods that are nutritious, healthy and have a long shelf life without added preservatives. The Sourdough fermented by lactic acid bacteria and, along with yeast; they play a key role in the fermentation of bread dough. Influences that impact the quality of sourdough are dough yield, temperature, type of starter culture, pH and acidity, and the type of flour. Sourdough is classified into 3 types (Types I, II, and III); the most widely used for commercial production is Type III. The addition of sourdough previously served to improve flavour, texture, shelf life and nutritional properties of bread. Sourdough also improves general properties such as loaf volume, evenness of baking, color, aroma, taste, and texture of breads. Sorghum is the fifth most important cereal crop after wheat, maize, rice and barley. The carbohydrate and protein contents of sorghum are considerably high compared with other cereals such as maize, wheat and rice and important source of antioxidant phenolic compounds. The addition of phenolic-rich materials to wheat bread improves the antioxidant potential of the final product. Fermentation plays a major role in sorghum food preparation as it provides an improvement of nutritional quality.

Key words: Characteristics, Classification, Sourdough, Sorghum, chemical composition Lactic acid Fermentation.

1The State Key Laboratory of Food Science and Technology, School of Food Science and Technology, International Exchange and Cooperation Program, Jiangnan University, Wuxi, Jiangsu 214122, PR China
2Department of Food Science and Technology, Faculty of Engineering and Technology, University of Gezira, Wad Medani, P.O. Box 20, Sudan
INTRODUCTION

Sourdough is an intermediate product which has been used for the production of food, especially staple foods, all over the world for thousands of years (Vogelmann 2013). As soon as ground cereals or starchy raw materials come in contact with water, fermentation takes place over time (Vogelmann 2013). The ancient Egyptians knew both the brewing of beer and the process of baking leavened bread with use of sourdough, as proved by wall paintings and analyses of desiccated bread loves and beer remains (Rothe et al., 1973; Samuel, 1996). Nowadays, sourdoughs are used worldwide for a huge variety of products: leavened bread, fermented gruels, alcoholic and/or acid fermented drinks, vinegar and fermented rice (Hammes et al., 2005). Sourdough is an intermediate product between dough and traditional bread preparation, containing flour, water and metabolically active microorganisms, mainly lactic acid bacteria (LAB) and yeast. During the fermentation of the dough, the metabolic products of LAB improve the organoleptic and technological properties of bread as well as their shelf life, nutritional value and healthy aspect (G. Rollán et al 2010). Besides sourdough breads, examples are Sudanese kisra (sorghum), Ethiopian injera (teff), Mexican pozol, Ghanaian kenkey and Nigerian ogi (maize), Indian idli (rice, beans or chickpeas), Turkish bosa (wheat, maize, sorghum, millet and/or rice) or Nigerian gari or fufu (cassava) (Steinkraus, 1983).

Sourdough fermentation is one of the oldest biotechnological processes the production of bread. In a later stage, beer yeast was used for dough leavening (Spicher and Stephan 1999; Kulp and Lorenz 2003; Chavan and Chavan 2011; and Manuela Mariotti2014). In today’s scientist, the first fermentation step, the bulk proof, is reduced or even excluded during the mechanization of the bakery. To catch up with the loss of flavors, some bakeries have developed or adapted brew systems. A part of the dough is fermented for several hours to develop a pleasant aroma that is known as a sponge. Sponge is combined with the rest of the ingredients into the final dough. With the next step in the evolution, to simplify this complex processing in the bakery, specialized companies now supply dried sourdough to the bakery industry (Chavan and Chavan 2011). Sourdough fermentation is a traditional process for improving bread quality and producing different wheat and rye breads (Thiele and others 2002; Chavan and Chavan 2011). Today's, the sourdough is used in the industry of breads, cakes, and flakes. The typical advantage of sourdough is mainly due to its micro flora, basically represented by LAB and yeasts. Owing to its microbial life, such dough is metabolically active and can be reactivated. These microorganisms guarantee acid
production and leavening upon addition of flour and water. The mechanisms in sourdough are complex (Hammes and Ganzle 1998; Chavan and Chavan 2011; and Manuela Mariotti 2014). Distinct characteristics of flour and process parameters contribute to exercise very particular effects on the metabolic activity of the sourdough microflora. During fermentation, biochemical changes occur in the carbohydrate and protein components of the flour due to the action of microbial and enzymes.

**CHARACTERISTICS OF SOURDOUGH**

Use of sourdough in wheat breads has acquired popularity as a mean to improve the quality, flavor and shelf life of wheat breads. A large collection of traditional products depend on the use of sourdough fermentation to yield baked goods with particular quality characteristics. San Francisco sourdough, French breads, and soda crackers are other examples of wheat products that rely on the process of souring. In dough, fermentation decreases elasticity and viscosity, whereas the addition of sourdough to final bread dough results in less elastic and softer dough. The level of rheological changes taking place in these dough and its influences on bread quality can be controlled by adjusting fermentation time and the ash content of flour during the prefermentation process (Clarke and others 2004; Chavan and Chavan 2011). The characteristics of sourdough rely on the metabolic activities of its resident LAB: lactic fermentation, proteolysis, and synthesis of volatile compounds, anti mould, and antiropiness production are among the most important activities during sourdough fermentation (Hammes and Ganzle 1998; Gobbetti and others 1999; and Chavan and Chavan 2011). Moreover, endogenous factors in cereal products (carbohydrates, nitrogen sources, minerals, lipids, and free fatty acids, and enzyme activities) and process parameters (temperature, dough yield [DY], oxygen, fermentation time, and number of sourdough propagation steps) markedly influence the microflora of sourdough and the features of leavened baked goods (Hammes and Ganzle 1998; and Chavan and Chavan 2011). The ratio between flour and water is called the DY and is defined as: Dough yield = (amount of flour + amount of water) ×100/amount of flour. The DY value of a sourdough will significantly affect the flavor profile of the sourdough. The firmer the sourdough (lower DY value), the more acetic acid is produced and the less lactic acid. The acidification rate is also affected by the DY of a sourdough. The higher the DY, the faster the acidification will occur, most probably due to the better diffusion of the produced organic acids into the environment (Spicher and Stephan 1999; Decock and Cappelle 2005; and Chavan and
Temperature is the important factor, as it influences DY more than acidification rate and also has an impact on the microbial composition of the sourdough (Spicher and Stephan 1999; and Chavan and Chavan 2011). Optimum temperatures for the growth of Lactobacilli are 30 to 40°C depending on strain and for yeasts 25 to 27°C. In general, a higher temperature, a higher water content of sourdough, and the utilization of whole meal flour enhance the production of acids in wheat sourdoughs (Brummer and Lorenz 1991; Decock and Cappelle 2005; and Chavan and Chavan 2011). The micro flora used for the fermentation. Two species famous: heterofermentative and homofermentative LAB. The flavor can easily be affected changing the fermentation temperature as explained above. A commercially available sourdough starter commonly consists of mixtures of different LAB groups to assure good acidification (Chavan and Chavan 2011). The titratable acidity and pH of the dough are important during sourdough fermentation. In the first phase, acidity and pH remain constant, while during the intermediate phase, titratable acidity increases due to the presence of yeast. During the longterm fermentation phase, the yeast presence becomes negative and titratable acidity, and pH of the dough depends mainly on the LAB introduced into the system. The yeasts present in sourdough are only slightly influenced by lactic acid, but much more affected by acetic acid (Decock and Cappelle 2005; Chavan and Chavan 2011). Flour is another parameter that significantly influenced the sourdough. Ash content is important to determine flour grain extraction rate (Matz 1996; Chavan and Chavan 2011). The ash also influences the buffering capacity of the sourdough system that makes possible to reach a higher total titratable activity. The falling number of the flour is an indicator for the enzymatic activity of the flour. The lower the value the more amylase activity is present in the flour. At that moment, more free sugars will be available for the micro flora to grow (Spicher and Stephan 1999; Chavan and Chavan 2011; and BonnoSekwati-Monang et al.2012).

**TYPES AND CLASSIFICATION OF SOURDOUGH**

More specifically, sourdoughs are grouped into three types, on the basis of the technology applied i.e. type I, type II and type III sourdough. The first type sourdoughs (Type I) are produced in traditional way. To keep the microorganisms in an active state, these are characterized by continuous, daily increments. Type II sourdoughs are used as dough-souring supplements during bread making. The prepared in long fermentation periods (from 2 to 5 days) and at elevated fermentation temperature often >30°C to speed up the activity. Type IIIsourdoughs are in dried form, having LAB resistant to the drying
process (Hammes and Ganzle, 1998; Bocker et al., 1995 and Decock and Cappelle 2005; and Chavan and Chavan 2011). The dough’s of types II and III require the addition of baker’s yeast (Saccharomyces cerevisiae) as leavening agent whereas type I sourdoughs does not require this addition. Sourdough LAB, consisting of obligate and facultative heterofermentative and obligate homo-fermentative species associated with type I, type II and type III sourdoughs. Bacterial isolates from sourdough or other natural environment are selected and tested for their suitability for being used as sourdough starters and their viability after drying. Lyophilized and weighed strains of Lactobacillus delbrueckii, Lactobacillus fructivorans, Lactobacillus plantarum, and Lactobacillus brevis have been established as sough dough LAB (Hammes and Ganzlle.1998; and Chavan and Chavan 2011). The type-1 sourdough starters, frequent inoculation of these strains is required as these are not well adapted to the cereal environment (Roecken and deVoysey, 1995). Due to the selective pressures that results from the environmental conditions of sourdough preparation, Lactobacillus sanfranciscensisdominates type I sourdough fermentations (Decock and Cappelle 2005; and Chavan and Chavan 2011).

Sourdough process has been used as a form of leavening is the oldest biotechnological processes in food production (Roecken and Voysey, 1995; and Chavan and Chavan 2011). The use of sourdough in wheat breads has gained popularity as a mean to improve the quality and flavor of wheat breads (Brummer and Lorenz, 1991; Corsetti et al., 2001; Thiele et al., 2002; Chavan and Chavan 2011; and E. Torrieri 2014). To facilitate continuous production, one could save a portion of ripe sourdough to seed subsequent dough, a process that continued into the nineteenth century (Clarke and Arendt 2005; Chavan and Chavan 2011). A large array of traditional products relies on the use of sourdough fermentation to yield baked goods with particular quality characteristics. Some examples, San Francisco sourdough French breads (Kline et al.1871; E. Torrieri 2014) and soda crackers (Sugihara, 1978; E. Torrieri 2014) are other instances of wheat products that rely on the process of souring. The same process is also used in the production of a number of flat breads, a typical example of which is the Egyptian baladi bread (Qarooni, 1996; and E. Torrieri 2014).

SOURDOUGH FERMENTING MICROORGANISMS

Until now, a little less than 50 different species of LAB isolated from sourdough have been reported (Hammes et al., 2005). Many species of lactic acid bacteria occur naturally in wheat flour, including members of the genera Lactobacillus, Pediococcus, Enterococcus, Lactococcus, and Leuconostoc (Hammes and Vogel, 1998 and Paramithiotis, Choul iaras et al. 2005). Most of the species of lactic acid bacteria of the genus
Lactobacillus are isolated from sourdoughs (Corsetti et al., 2001; Paramithiotis, Chouliaras et al. 2005). Lactobacillus sanfranciscensis, Lb. brevis and Lb. plantarum is the most frequent lactobacilli isolated from sourdoughs (Gobbetti, 1998; Corsetti et al., 2001; Corsetti et al., 2003; and Corsetti et al. 2007). Homo-fermentative species do not produce any carbon dioxide; their function is acidification and flavor development. Although, homo-fermentative species of LAB may be used in the majority of fermented food applications but heterofermentative species play a major role in sourdough fermentation (Salovaara, 1998 and Paramithiotis, Chouliaras et al. 2005), especially when sourdoughs are prepared in a traditional manner (Corsetti et al., 2003; Corsetti et al., 2001). The hetero-fermentative LAB results in best taste and flavor of the sourdough breads, because only heterofermentative lactic acid bacteria can produce the large amount of acetic acid under anaerobic conditions which are required in sourdough (Paramithiotis, Chouliaras et al. 2005; Corsetti et al. 2007).

Fermentation with homofermentative lactic acid bacteria results in high concentration of lactic acid, relative to acetic acid, results in mild and flat sour taste in bread (Spicher and Rabe, 1981; and Gobbetti, 1998). Oura et al. (1982) prepared rye bread with pure culture of hetero-fermentative bacteria L. brevis; this provided the rye bread with desirable aroma but not an elastic crumb. They observed an opposite effect when they used homo-fermentative bacteria (L. plantarum). It was concluded that in order to get satisfactory aroma and crumb characteristics, both bacterial species must incorporate. Cossignani et al. (1996) used Lactobacillus sanfranciscensis, L. plantarum and Saccharomyces cerevisiae for leavening wheat sourdoughs. They found that the dough’s fermented with starters had more balanced microbiological and biochemical characteristics than dough’s started with Saccharomyces cerevisiae, in which alcoholic fermentation end products largely predominated. By using starters, the greatest lactic acid bacteria cell number and acetic acid production was achieved. The starters resulted in more complete profiles of volatile compounds and greater structural stability. Starting from glucose, homo-fermentative LAB mainly produce lactic acid through glycolysis (homolactic fermentation) while hetero-fermentative LAB produce, besides lactic acid, CO2, acetic acid and/or ethanol (depending on the presence of additional substrates acting as electron acceptors (Axelsson, 1993). The LAB, both homo-fermentative and hetero-fermentative species, contribute most to the process of dough acidification, while yeasts are primarily responsible for the leavening however, the hetero-fermentative LAB also contribute partly to the leavening process (Gobbetti et al., 1995a). Gobbetti (1998) reported Lb. sanfranciscensis and Lb. plantarum association in Italian wheat sourdough. Lb. plantarum may be superseded by another
facultative heterofermentative species, Lactobacillus alimentarius in its association with Lb. sanfranciscensis in sourdough made from durum wheat (Corsetti et al., 2001). Lactobacillus alimentarius is capable of fermenting all four flour soluble carbohydrates (maltose, sucrose, glucose and fructose) and it is possible that this reduces direct metabolic competition with Lb. sanfranciscensis. Lactobacillus brevis and Lb. plantarum have generally been found associated with Lactobacillus fermentum Russian sourdoughs (Kazanskaya, et al., 1983). Gobbetti et al. (1994a) reported that Lb. acidophilus is common in Umbrian (Italian region) sourdoughs, even though it is rarely isolated from sourdoughs of different origin. Corsetti et al. (2007) described a new sourdough associated species, Lb. rossiae. Lb. rossiae is often associated with the key sourdough Lb. sanfranciscensis. Lb. rossiae has been found in environments other than sourdough (De Angelis et al., 2006), while no other habitat is known for Lb. Sanfranciscensis (Hammes et al., 2005). However, occurrence of lactic acid bacteria and yeasts in sourdoughs and the association between acidification and bacterial metabolism was first demonstrated in 1894 (Hammes and Ganzle, 1998). Association of yeasts and lactic acid bacteria is often used in the production of beverages and fermented foods (Gobbetti, 1998).

**IMPROVING NUTRITIONAL AND SENSORY QUALITY**

In dough, fermentation decreases elasticity and viscosity, whereas the addition of sourdough to final bread dough results in less elastic and softer dough (Clarke and others 2004 and Chavan and Chavan 2011) measured the rheology of dough by using experimental techniques and found a decrease in resistance to extension and an increase in both extensibility and degree of softening. During the sourdough fermentation, different organic acids are produced. These organic acids improve the flavor of bread, help the swelling of gluten, and increase gas retention, resulting in products with good texture and enormous volume and also functioning as natural dough conditioners (Park and others 2006). EPS produced by LAB during fermentation is one of the aspects of sourdough technology with the potential for the replacement by hydrocolloids (Korakli and others 2001). Acids produced during fermentation strongly impact the mixing behavior of dough, and dough with a lower pH value requires a slightly shorter mixing time (Hoseney 1994). The pH of sourdough varies with the nature of the process and starter culture used, but for wheat sourdoughs it ranges from 3.5 to 4.3. The nature of the flour, in particular its ash content, has a great influence on acidification (Collar and others 1994; Clarke and others 2002). The acid enhances the solubility of the glutenin fraction extracted from wheat flour and also affects the swelling power of gluten (Axford and others 1979). In comparison to bread
prepared with baker’s yeast, the sourdough breads are characterized by moist, dense grains, and a rather chewy texture (Qarooni 1996). The application of sourdough to wheat breads has a positive impact on bread volume, which is a primary quality characteristic and shelf life of bread (Collar and others 1994; Clarke and others 2004). Punctures of relatively small size (1 or 2 mm) are required in bakery products, whereas large voids or irregular crumb distributions are undesirable. An increase in the mean cell area has been shown by addition of 20% sourdough that increases the acceptability of the product (Crowley and others 2002).

**SHELF LIFE**

Bread staling indicates decreasing consumer acceptance that is attributable to changes in crumb other than those resulting from the action of spoilage organisms (Bechtel and others 1953). Contamination of bread occurs after baking, and airborne distribution of dust and mold spores is the main reason for bread spoilage (Legan 1993 and Chavan and Chavan 2011). In addition to economic losses, bread spoilage also represents a health hazard to consumers, especially when bread is contaminated with mycotoxigenic molds. The sourdough fermented by LAB has a positive impact on bread staling. One such effect is an improvement in the specific volume, which is linked to the reduction in the rate of stalling (Axford and others 1968). Breads containing sourdough increase the shelf life of bread (Corsetti and others 2001; Arendt et al. 2007; and Chavan and Chavan 2011). Sourdough associated LAB produce many antimicrobial substances, such as organic acids, CO2, ethanol, phenyllactic acid (Messens and De Vuyst 2002; Schnurer and Magnusson 2005 and Arendt et al. 2007; Chavan and Chavan 2011). Between the organic acids, acetic and propionic acid produced by heterofermentative LAB are more effective than lactic acid (Schnurer and Magnusson 2005; Arendt et al. 2007; and Chavan and Chavan 2011). Caproic acid produced by L. Sanfranciscens is CB1, together with a mixture of acetic, formic, propionic, butyric, and n-valeric acids, play a key role in inhibiting Fusarium, Penicillium, Aspergillus, and Moniliagrowth in bread (Corsetti and others 1996; and Chavan and Chavan 2011). Also, L. plantarum shows antimicrobial activity, especially phenyllactic acids have been identified as responsible for fungal inhibition (Lavermicocca and others 2000; Dal Bello and others 2007; Ryan and others 2009; and Chavan and Chavan 2011). A synergistic impact was found when sourdough fermented with antifungal L. plantarum strains was used in combination with calcium propionate for production of wheat bread (Ryan and others 2008; and Chavan and Chavan 2011). Lactobacillus reuteri strains have been shown to produce reuterin, an antimicrobial substance active against bacteria, yeasts, and fungi (Ganzle and others 2000; Ganzle 2004; and Chavan and Chavan 2011). Sourdough-
associated LAB are also effective versus rope spoilage of bread induced by Bacillus spp., probably due to production of organic acids and antibacterial substances (Katina and others 2002; Valerio and others 2008; and Chavan and Chavan 2011). In general, LAB plays a key role in the preservation and microbial safety of fermented food, thus promoting the microbial stability of the final products of fermentation (Chavan and Chavan 2011).

**SORGHUM**

Sorghum is fifth most important food crop of the world. It is mostly cultivated in South Asia, Central America and Africa because of climate friendly natures of these countries. Sorghum belongs to the family of cereals which grown to be used as nutritious food because it has proteins, fibers, carbohydrates, fats, calcium, sugar, iron, magnesium, phosphorous, potassium, sodium, zinc, copper, it consists of 70% starch.

It is one of the main staples for the world’s poorest and most insecure people. It is a key staple in many parts of the developing world, especially in the drier and more marginal areas of the semi-tropics. Various processing methods are used for preparation of foods from sorghum; among them, fermentation is a unique method for food preparation in Sudan and in Africa in general (AbdElmoneim et al 2004). It is the most important cereal crop in Sudan (Elkhalifa and El-Tinay, 2002). Where it is consumed in fermented forms, mainly as nasha (thin porridge), aceda (thick porridge) and Kisra (local thin bread), (Hamid A.Dirar, 1993). Interest is increasing in potential new food applications of sorghum, particularly due to sorghums resilience against the high temperature and drought conditions that may arise due to climate change (Taylor, Schober, & Bean, 2006). It has been reported that Sorghum flour has the potential to be used in composite bread (Hugo et al. 2003). Bread is an important stable food, the consumption of which is steady and increasing in Sudan. It is however, relatively expensive, being made from imported wheat that is not cultivated in the tropics for climatic reasons (Edema et al., 2005). Efforts have been made to promote the use of composite flours in which flour from locally grown crops replace a portion of wheat flour for use in bread, thereby decreasing the demand for imported wheat (Giami et al., 2004). For instance, sorghum is gaining increasing attention as a food crop that can be used in baking to reduce the cost of wheat in the semi-arid tropic countries. However, when sorghum flour is included in composite flour it gives a drier, grittier and a faster firming crumb. These adverse effects have been attributed to the higher starch gelatinization temperature and low water holding capacity of sorghum flour (Hugo et al. 2003 and Hamid A. Dirar, 1993).

**SORGHUM GRAIN DESCRIPTION**
The grain is approximately 4 mm in length, and it is more or less spherical in shape but somewhat flattened at the germend (Serna-Saldivar and Rooney, 1995). The 1000 kernel weight ranges from approximately 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). Grain color strongly affects flour color. Sorghum is uniquely adapted to arid and semi-arid conditions, and it can also survive periods of water logging. The 10 leading sorghum-producing countries in decreasing order are the United States, Nigeria, India, Mexico, Sudan, Argentina, China, Ethiopia, Burkina Faso, and Egypt. In the United States, Mexico, and Argentina, sorghum is mainly used for animal feed. However, in the other countries, particularly in Africa and India, it is mostly used for human food and for brewing beer. Sorghum is a gluten-free cereal (Ciacci et al., 2007), and it contains various phenolic compounds that appear to have health benefits (Dykes and Rooney, 2006), which makes the grain suitable for developing functional foods and nutraceuticals.

**Grain structure with respect to milling**

The sorghum consists of three distinct parts: the pericarp (outer layer), endosperm (storage tissue), and germ (embryo). Note that the aim of milling is generally not simply to reduce the grain into small particles. Usually, the aim is to also separate the pericarp and germ from the endosperm, with the resulting flour being endosperm of varying purity. The pericarp and germ are removed because most people find the color, texture, and taste imparted by them to food products to adversely affect their acceptability.

**Pericarp**

The pericarp, which is rich in insoluble dietary fiber, accounts for 4.3 - 8.7% of sorghum grain (Waniska and Rooney, 2000). It is subdivided into three tissues, namely (from the outer side) the epicarp, mesocarp, and endocarp. The epicarp is covered with a thin layer of wax and contains most of the sorghum grain pigments; hence, it has a major influence on grain color. The mesocarp contains starch granules, which is a feature unique to sorghum and pearl millet (Serna Saldivar and Rooney, 1995). It has been suggested that the presence of starch granules in the mesocarp may account for the high friability of the sorghum pericarp (Taylor2003). Friability is a negative attribute of the pericarp for dry milling because it causes fragmentation into fine pieces, thus escaping separation and thereby contaminating the flour. Some sorghum cultivars have a pigmented subcoat (testa) between the pericarp and the endosperm. The pigmented testa contains condensed tannins (Waniska and Rooney, 2000). Tannins protect these tannin sorghums...
against insects, birds, and fungal attack. Until recently, sorghum tannins have been viewed as undesirable due to their antinutritive properties. They complex with food macromolecules such as proteins, thereby reducing the digestibility of the macromolecules. However, current research indicates that tannins have health benefits, which are discussed later.

**Endosperm**

The endosperm is the largest part, constituting 82 - 87% of the sorghum grain (Waniska and Rooney, 2000), and it contains mainly starch and protein. It is made up of the aleurone layer the peripheral area, and the corneous (hard) and floury (soft) areas. The latter two account for the largest portion of the endosperm. In sorghum, the aleurone layer is only one cell layer thick. It contains protein bodies, phytin bodies, and oil bodies (spherosomes). The peripheral endosperm region comprises several layers of dense cells containing essentially just protein bodies. The corneous endosperm cells contain a continuous matrix of kafirin protein-containing protein bodies, glutelin matrix protein, and starch granules. In the floury endosperm, starch granules, matrix protein, and protein bodies are discontinuous with airspaces in the cells. The proportion of starch relative to protein is also higher. The relative proportion of corneous and floury endosperm is largely genetically controlled. When milled, sorghums with a higher proportion of corneous endosperm yield a more gritty flour due to stronger adhesion between the starch granules and surrounding protein. The tannin sorghums invariably have a high proportion of the softer, floury endosperm.

**Germ**

The germ is the living part of the sorghum grain, and it consists of two main parts: the embryonic axis and scutellum (Serna-Saldivar and Rooney, 1995). The germ is very rich in lipids, approximately 28% by weight or 76% of total grain lipids. It is also relatively protein rich, approximately 18% by weight or 15% of total grain proteins. The germ proteins are mainly albumins and globulins, which are rich in lysine and other essential amino acids.

**GRAIN CHEMICAL COMPONENTS: FUNCTIONAL AND NUTRITIONAL ATTRIBUTES**

**Starch**

Starch constitutes approximately 71% of sorghum grain (Serna-Saldivar and Rooney, 1995). Sorghum starch gelatinization temperature, which ranges from 66 to 81°C, is high compared to that of wheat and possibly slightly higher than that of maize (Taylor
and Emmambux, 2010). Starch gelatinization temperature also seems to be quite variable between sorghum cultivars. 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, rather, primarily 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).

**Proteins**

Sorghum grain protein content is quite variable, ranging from approximately 7 to 16% with an average of approximately 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 species based on differences in molecular weight, solubility, structure, and amino acid composition and sequence. The sorghum kafirins can be categorized into three main classes α, β and γ—based on molecular weight and solubility. Kafirins have low nutritional quality because they are poor in essential amino acids, particularly lysine. They are poorly digestible, especially when cooked in water, as occurs during most food preparation processes (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 immunemediated alteration of duodenal explants from patients suffering from celiac disease (Ciacci et al., 2007). Celiac disease, a syndrome characterized by damage to the mucosa of the small intestine, is 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 a viable and important alternative for making baked products such as bread. However, a major challenge in using sorghum in bread baking is the very poor viscoelastic properties of kafirin dough compared to that made from wheat gluten (glutenins plus gliadins). When
mixed with water, gluten proteins become hydrated and form a three-dimensional network, which is responsible for the unique viscoelastic property of wheat dough (Belton, 1999; Oom et al., 2008). Because kafrins are more hydrophobic than the gluten proteins, related to the high levels of leucine, kafrins are difficult to hydrate. (Belton et al., 2006) suggested that the poor hydration of kafrins may also be linked to their mainly a-helical structure, in contrast to high-molecular-weight (HMW) glutenin subunits of wheat, which have a high level of b-sheet and b-turn structure. The kafrins are much smaller proteins than the HMW glutenins, which probably also has a bearing on their lack of elasticity. In addition, because kafrins 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 approximately 3.4% lipids, rather more than wheat 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 (C18:2; 38-49% of the total) and oleic (C18:1; 31-38% of the total) (Serna-Saldivar and Rooney, 1995). Sorghum is also rich in tocopherols (vitamin E; approximately 1.2 mg/100 g).

**Non-starch polysaccharides**

Sorghum contains approximately 6-11% non-starch polysaccharides (NSPs; dietary fiber), probably a slightly lower level than that in wheat. The major NSPs of the sorghum endosperm are water-unextractable (insoluble) glucuronoxarabinoolxylans (GAX) (Taylor and Emmambux, 2010; Taylor et al., 2006). 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. Phytochemicals 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, antiarrhythmic 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 (Taylor et al., 2006).

**Phenolic Compounds**
The quantity of phenolic compounds in sorghum grain can be substantial, particularly in red pigmented, tannin-type sorghums. The main groups of phenolic compounds in sorghum grain are phenolic acids, flavonoid-type compounds, and tannins (proanthocyanidins) (Dykes and Rooney, 2006). Sorghum phenolic acids are mainly derivatives of benzoic acid and cinnamic acid. They are concentrated in the pericarp and occur mostly in bound form (esterified to cell wall polymers). Ferulic acid is the most abundant bound phenolic acid in sorghum. Other phenolic acids abundant in sorghum include syringic, procatechuic, caffeic, p-coumaric, and sinapic.

**Flavonoids**

Flavonoids form the largest group of phenolic compounds in sorghum. They are made up of a benzopyran nucleus with aromatic substituent at carbon 2 of the C ring. Many sorghum flavonoids have been isolated and identified, with anthocyanins being the major class found in sorghum (Dykes and Rooney, 2006). The anthocyanins contribute most of the color of sorghum. Sorghum anthocyanins are unique because they do not contain the hydroxyl group in the 3-position of the C ring and thus are called 3-deoxyanthocyanins. The two common sorghum 3-deoxyanthocyanidins are the yellow, apigeninidin, and the orange, luteolinidin. In sorghum, the 3-deoxyanthocyanins are concentrated in the pericarp, and the highest levels are found in sorghums with black pericarp.

**Tannins**

Sorghum tannins are probably exclusively of the “condensed” type (proanthocyanidins), which are HMW polyphenols that consist of polymerized polymers of flavonoid subunits, mainly flavan-3-ols and/or flavan-3,4-diols. The proanthocyanidins in tannin sorghums are mainly the B type because they are linked mostly by C4→C8 interflavan bonds with (−)-epicatechins as extension units and catechins as terminal units (Dykes and Rooney, 2006). Of the phenolics, the tannins have the highest antioxidant activity when considered on a molar basis.

**FERMENTED SORGHUM**

Sorghum bicolor (L.) Moench plays the most important role. Sorghum is deficient in lysine and sulphur containing amino acids. Fermentation of sorghum increases its nutritive quality, especially the contents of lysine and methionine (Au and Fields, 1981). Throughout Africa, the major sorghum food product is porridge. This is prepared by cooking sorghum flour with water. Porridges range in solids content from approximately 10% for a thin gruel to 30% for a stiff porridge of mashed potato-like consistency.
Depending on regional tastes, the sorghum porridges may be cooked at neutral pH, acidified to pH < 4.0 by lactic acid fermentation or acidification with fruit juice, or alkaline (pH 8.2) due to cooking with wood ash. These treatments affect the nutritional value of sorghum porridge. As stated previously, wet cooking in general substantially reduces the protein digestibility of sorghum foods (Duodu et al., 2003 and Hamid A. Dirar, 1993). This adverse effect is alleviated by lactic acid fermentation (Taylor and Taylor, 2002). Other nutritional benefits of lactic acid fermentation can include improved starch digestibility, increased levels of B vitamins, reduced antinutrients such as tannins and phytic acid, and, most important, the rendering of the porridge product microbiologically safe (Taylor and Dewar, 2000). Alkaline cooking adversely affects sorghum protein quality and availability (Klopfenstein and Hoseney, 1995). In North Africa and India, sorghum flour is widely used to make flatbreads. In the production of the major African flatbreads, which are kisra produced in Sudan and injera produced in Ethiopia and Eritrea, a slurry of flour undergoes lactic acid fermentation. In injera making, a part of the cooked flour in then added back. The fermented flour is then diluted into a batter, which is poured onto a circular hot plate. The resulting flat breads are moist and flexible and have a cellular structure formed by the fermentation gases. Kisra is approximately 3 mm thick, and injera is thicker (approximately 6 mm) probably because of the precooking of part of the flour. In contrast, the major Indian sorghum flatbread, known as roti or chapatti, is a thin, dry, crisp product with a puffed texture due to steam production during baking. These traditional products from sorghum flour are almost exclusively made in the home, and generally the sorghum used to produce the flour is homegrown. Hence, the options for flour fortification are limited. An exception is instant acidified sorghum porridge powder, called “Morvite,” which is commercially manufactured in South Africa. To make porridge, one simply mixes boiling water or milk with the powder. The porridge powder is made by pre-gelatinizing the starch using technologies such as extrusion cooking or gun puffing. The product is fortified with a range of minerals and vitamins so that a 100-g flour serving generally meets 15-25% of an adult’s micronutrient Recommended Dietary Allowance (RDA). Other similar vitamin- and mineral fortified sorghum powder porridge products are available. These are variously enriched with soya to provide 40% of an adult’s protein RDA and also with fruit, which when made with milk can provide 50 and 25% of a 2- or 3-year-old’s protein and energy RDAs, respectively.

MALTING
Malting (sprouting) is a widely applied traditional technology in Africa. Malting of sorghum is done throughout sub-Saharan Africa for the production of traditional African (opaque) beer and to a lesser extent for use as an ingredient in porridge making. Malting partially degrades the endosperm starch granules and protein bodies and protein matrix (Hamid A. Dirar, 1993) and in so doing results in an increase in free amino acids and sugars. Malting, however, appears to have little effect on the endosperm non-starch polysaccharide containing cell walls. We have found that malting sorghum decreased the pasting temperature of sorghum flour to values approaching that of wheat (Hugo et al. 2003; Taylor et al. 2005). The use of malted boiled and dried sorghum in sorghum-wheat composite bread at a ratio of 30:70 improved bread qualities in comparison to the unmalted sorghum and wheat composite. Crumb structure, water-holding and softness were improved and the rate of staling was decreased. Inactivation of the malt amylases and a higher content of gelatinised starch appeared to be the primary reasons for the improvement in bread quality.

**LACTIC ACID FERMENTATION**

Lactic acid fermentation (souring) is also a widely applied traditional technology. Souring, primarily because it reduces the pH due to lactic acid production, is a method of food preservation and prevents the growth of pathogens. Sorghum is soured in porridge and flatbread making and in opaque beer brewing (Taylor and Belton, 2002). Souring modifies the starch, proteins, increases vitamin and mineral availability and reduces the levels of antinutrients we have found that the addition of soured and dried sorghum flour decreased dough pH from 5.8 to 4.9. The compositing of this flour at a ratio of 30:70 sorghum: wheat increased bread loaf volume by about 4% compared to the unfermented sorghum: wheat composite control. Fermented flour also improved crumb structure and slightly decreased the crumb firmness. Mixing wet fermented sorghum flour directly with wheat flour (sourdough-type process) in the same ratio further increased loaf volume (Hugo et al. 2003). The sourdough process also reduced crumb finness, and simplified the bread making process. It appears that the low pH of fermented sorghum flour inactivates amylases and increases the viscosity of sorghum flour, thus improving the gas-holding capacity of sorghum and wheat composite dough (Taylor et al. 2005).

**MICROBIAL CULTURES**

As described in the section on the use of sourdough fermentation above, this traditional technology improves the quality of non-wheat breads. It has also been shown that similar improvements result with the use of defined cultures of a single lactic acid
bacteria species. Schober et al. (2007) made breads with sorghum flour (70%) fermented with Lactobacillus plantarum and potato starch (30%). The breads made with the L. plantarum were about 20% higher in loaf height with a corresponding higher specific volume than their controls (a regular sorghum flour formulation with HPMC and a chemically acidified flour formulation). Traditional flatbreads such as injera, kisra because they rely on a natural mixed fermentation with a fermentation time of up to two days, do not lend themselves to largescale commercial manufacture. However, there is evidence that the efficiency of injera and kisra fermentations can be improved by the use of identified microbial cultures. For example, recently, it has been shown that Lactobacillus and Saccharomyces cultures can be used to reduce kisra fermentation time from 19 to 4 hours (Hamid A. Dirar 1993). Injera of acceptable quality can be produced using baker’s yeast with one-hour fermentation (authors’ personal observation).

CONCLUSIONS

Sourdough could yield healthier products for consumers. Sourdough helps to improve texture, loaf volume, and shelf life to breads. Sourdough has also been shown to be useful in the production of breads with slow starch digestibility and hence low glycolic responses. The use of sourdough is useful for making bread products with an increased level of flavor compounds and improve crumb and crust and customer satisfaction. Sourdough technology can also be useful to reduce or eliminate the level of preservatives often used in baked products, as sourdough has shown antibacterial and antimold activity. Use of sourdough can also be extended to other products such as biscuits, pizza, and snack foods. Thus, sourdough could be useful in help mankind with healthy, tasty, and suitable foods.

Sorghum is the fifth most important cereal crop after wheat, maize, rice, and barley and, from a growth and survival perspective, out performs other cereals under various environmental stresses, in particular in the warmer temperatures and tropical regions of the world. Sorghum is widely utilized around the world as feed and food. It is also a potentially important source of nutraceuticals, such as antioxidant phenolics. The nutritive value of sorghum is lower than that of other cereals because of a low content of some essential amino acids, especially lysine, tryptophan and threonine and, additionally, due to the presence of condensed tannins and phytic acid. However, its nutritional value can be significantly improved through fermentation. Addition of sorghum sourdough useful to improve bread making with lower cost in wheat bread process and healthy.
REFERENCES

• Ciacci C, Maiuri L, Caporaso N, Bucci C, Del Giudice L, Massardo DR, Pontieri P,


• Gobbetti, M., Corsetti, A., Rossi, J., La Rosa, F and De Vincenzi, S., Identification and clustering of lactic acid bacteria and yeasts from wheat sourdoughs of central Italy. Ital J. Food Sci., 1994a., 85–94.


• Kazanskaya, L.N., Afanasyeva, O.V. and Patt, V.A., Microflora of rye sours and
some specific features of its accumulation in bread baking plants of the USSR. Developments in food science., 1983.


- Park YH, Jung LH, Jeon ER., Quality characteristics of bread using sourdough. J


Vogelmann, Stephanie Anke., Impact of process parameters on the sourdough microbiota, selection of suitable starter strains, and description of the novel yeast
Cryptococcus thermophilus sp. nov., 2013.