Food Science and Engineering
http://ojs.wiserpub.com/index.php/FSE/

Review

A Comparison Between Wheat and Sorghum Flour in Biscuits Application: A Review

Rawan Al Majzoub, Sandra Abou hamdan, Sanaa Khaled, Sami El Khatib, Maha Krayem*

Lebanese International University, Department of food sciences and technology, Bekaa Campus, Al Khyara-West Bekaa, Lebanon
Email: maha.krayem@liu.edu.lb

Received: 7 November 2022; **Revised:** 5 January 2023; **Accepted:** 14 January 2023

Abstract: Production of biscuits from composite flour (wheat/sorghum) was investigated. The use of this composite flour is increasing due to its nutritional properties that make the product highly desirable and acceptable. Sorghum is the 5th most important cereal worldwide. Sorghum is malted to increase its hydrolytic enzymes through steeping, germination, kilning and roasting. The concentration of sorghum flour added to wheat flour is a concern. In order to better understand the functional properties of sorghum-wheat composite flour, this review was carried out. Sorghum grain was ground into flour and substituted for wheat flour in a variety of amounts. Biscuits produced from 30% sorghum flour is shown to be the best concentration in terms of quality, acceptability and sensory properties. The maximum sensory overall acceptability scores were found for biscuits prepared from substitution levels (20-40%). Consumption of these biscuits will enhance the nutrient intake of people, especially children and enhance the utilization of sorghum in developing countries.

***Keywords*:** composite flour, sorghum malt, wheat, biscuits, substitution, gluten

1. Introduction

Biscuits made from wheat flour or other ingredients are consumed by many people all over the world. Recently, consumers are becoming more interested in consuming foods that are both nutritious and healthy [1]. It's a crispy pastry product made from wheat flour, shortening, sugar and baking powder. The main ingredient for biscuit production is wheat flour which contains gluten as key protein that distinguishes it from other cereal flours [2]. The use of composite flour (a mixture of other flours with wheat) increased due to its nutritional benefits that make the product highly desirable and acceptable [2]. Since sorghum flour is gluten-free, it could be combined to wheat flour to produce high quality biscuits that could be consumed by celiac disease patients [3]. Sorghum is the world's fifth most important cereal crop, but it also has a variety of other uses that are being investigated in light of the global interest in renewable resources. It is commonly used as flour, paste, or snack [4]. Malting of sorghum is a technological technique that aimed to enhance hydrolytic enzymes, throughout several stages including steeping, germination, kilning and roasting [4]. Sorghum has wide health benefits including anti-obesity, anti-hypertension, anti-cancer, anti-diabetic effects, and celiac disease prevention [5]. Identifying the best concentration of sorghum flour's addition to wheat flour is the main concern. If sorghum flour is added alone without wheat the obtained mixture would be very thick and sticky to the hands, and this would give a low-consistency baked product [5]. Thus, Sorghum's historical background, its health benefits, utilization

DOI: https://doi.org/10.37256/fse.4120232140

and malting procedure were investigated in this review. In addition, wheat flour for biscuit production, its health benefits and milling techniques were highlighted. Finally, the effect of the addition of sorghum flour in biscuits production was investigated.

2. Sorghum historical background

Sorghum (*Sorghum bicolar* L. Moench) is a member of the subfamily *Panicoideae* in the family *Gramineae* [6]. Sorghum is a gluten-free cereal that is widely grown throughout African countries and the main staple composed of many nutrients and anti-nutrients as well [6]. It is ranked 5th most ideal worldwide grain to other cereals like maize, rice, wheat and barley. It has wide applications in food technology [7-8] consisting of 24 diverse species [6]. Globally, sorghum is an essential part of millions of people's diets due to its high productivity and adaptability. Sorghum belongs to the family "Poaceae", tribe "Andropogoneae", subtribe "Sorghinae", genus "Sorghum" [6]. It thrives in hot, arid and semi-arid tropical climates with minimal rainfall [2]. It is considered as a multipurpose crop used in fuels, bioethanol, alcoholic beverages, building material, animal feed and it has a positive effect on human's health [6].

2.1 *Origin and production of sorghum*

Sorghum originates from the north East part of Africa in Ethiopia about 6,000 years ago [9]. It has been shown that sorghum was early domesticated among Neolithic Sudanese populations [6].

Then, from Africa sorghum crossed the globe by trading. From Africa to India first until it became the key role in India's agriculture [6, 9]. Then, from India sorghum crossed China followed by USA and Australia. Now it is considered as the major summer crop in Australia [6].

The largest producers are the USA, accounting for 17% of global output, followed by other countries like India, Nigeria, China, Mexico, Sudan, Argentina, Ethiopia, Burkina Faso, Brazil and Australia [8-9].

2.2 *Structure of the sorghum grain*

Sorghum plant is 1-3 meters tall, it is a solid sphere like structure [8]. It has deep roots with stem, its leaves are long and flat, its grain is covered by glumes (it holds the grains after pollination). The grain color is the main indicator of the sorghum quality [9].

Sorghum consists of several parts: pericarp, testa, germ, endosperm and Aleurone layer [4, 9]. Sorghum grain comes in a variety of colors, including white, orange, red, and brown, but the white, red and black varieties are the most common [2].

2.2.1 *Pericarp*

The pericarp contributes to 4.3-8.7% of the sorghum grain. Epicarp, mesocarp and endocarp are the three layers of the pericarp. The epicarp is waxy whereas the mesocarp is starchy which gives sorghum an individual characteristic. The pericarp contributes to 5-8% of the grain protein [4].

2.2.2 *Testa and aluerene layer*

Testa is located between the pericarp and endosperm [4]. The major constituent of this layer is tannins (6%) which protect the grain from insects, birds and fungi that may affect the overall quality of sorghum [4, 8]. Aluerene layer is an outer layer rich in oil, protein and ash [4].

2.2.3 *Endosperm*

The endosperm is the largest component of the sorghum grain which contributes to 82-87% of sorghum. It is rich in proteins and the main tissue dedicated for the its storage. Its texture is believed to be the main indicator of the food making properties of sorghum [4].

2.2.4 *Germ*

It is known as the sorghum grain's live section. It consists of the embryonic axis and scutellum [4]. The cotyledon, or scutellum connects the endosperm with the germ consisting of protein, oil, minerals and enzymes. The embryonic axis is the new seed during germination and development. The germ is rich in albumin, globulins and essential aminoacids [4, 9].

2.3 *Chemical composition of sorghum*

Sorghum, as all cereals, has a great amount of starch and protein. The sorghum grain is highly rich in starch followed by proteins, non-starchy carbohydrates and fat (Table 1) [9-10]. As mentioned above the endosperm is the richest part in protein and starch, the germ is rich in oil and vitamins and the bran is affluent in fibers [11].

Table 1. Chemical and Biological data of sorghum on dry weight basis [10]

Parameter	Dry weight
Protein %	9.6
Fat %	4.5
Available Carbohydrates %	67.4
Crude Fiber %	4.8
Ash %	3
Calories per 100g	447
Protein Digestibility %	84.8
Net protein Utilization %	50
Utilizable Protein %	4.8
Digestible energy %	79.9

2.3.1 *Carbohydrates*

Each serving of sorghum (1 cup) accounts for 143 g of carbohydrates (CHO) [10]. Carbohydrates are stored in the sorghum in the form of starch which accounts for about 70% present mainly in the endosperm [12]. Sorghum starch contains amylose (40-50%) and amylopectin (45-54%) [11]. There is a correlation between the levels of starch component and the sorghum utilization in many foods. For example to obtain a thick paste, high amylose is needed, while to obtain low viscous weaning food a low amylose and high amylase is needed [9]. Low amylose sorghum varieties gives the food higher functional properties in terms of solubility and is mainly used for the preparation of infant porridge [9].

2.3.2 *Proteins*

Proteins are the sorghum grains' second most important component, but genetic and environmental variables influence these protein levels [10-12]. It accounts for 15% of the sorghum grain as shown in Table 1 [10]. Proteins in sorghum could be seperated into fractions of albumins, kafirins, globulins, prolamines and glutelins [10].

Prolamine is predominant in the endosperm while albumins and globulins are predominant in the aleurone layer. During germination, starch and protein are hydrolysed into soluble sugars and aminoacids respectively. This degradation allows the storage of starch and protein by amylase and protease [4]. The main aminoacids found in sorghum grain are threonine, methionine, phenylalanine, lysine and tryptophan [10].

2.3.3 *Lipids*

Sorghum is higher in fat content (3%) stored mainly in the form of triglycerides [11-12], compared to wheat and rice which content mainly found in the endosperm, the germ and the bran knowing that the germ accounts for 80% of the total fat [4, 11]. Oleic and linoleic acids make up 76% of the total fat, which is devided into free and bound forms [4]. The lipid profile of sorghum is unique in its high potential to lower the risk factors of heart disease [12]. Sorghum also contains plant sterols which reduce the absorption of cholesterol in the plasma and the liver. Antiploriferation characteristics on human colon carcinoma cells may also be found in sorghum lipids [12].

2.3.4 *Vitamins and minerals*

Sorghum is a good source of B-complex vitamins: vitamin B1, B2 and B3. Other forms of fat-soluble vitamins are also present in the sorghum grain. Its content in vitamin A is very low although the germ contains β-carotene [4, 11].

The major minerals found in the grain are potassium, phosphorous but calcium and zinc levels tend to be low [4]. Sorghum fortification is being used around the world to boost the amount and bioavailability of iron and zinc in the grain [9].

2.3.5 *Polyphenols*

Sorghum has a unique polyphenolic profile which acts against environmental stresses and plays the role of antioxidants by scavenging free radicals. Flavonoids, tannins and lignins are the major phenolic compounds of the grains. Those phenols are mainly present in the bran layer but differs according to the genotype [13]. Xiong et al. [13] investigated the antioxidant activity of sorghum and proposed that brown and black bran colored species has the greatest potential as natural antioxidant and prone to nutraceutical applications [13]. Concerning tannins, red and brown sorghum grains has the highest amount of tannins which has a beneficial effect on human health and food industry applications. Tannins promote different health benefits as preventing inflammation and thrombosis and preventing cancer [12]. Concerning flavonoids, anthocyanins, flavones and flavanones are the major components mainly found in the bran layers which protect sorghum against fungus and mold growth [13] and may protect against high low-density lipoprotein (LDL) [12].

2.4 *Sorghum utilization*

Globally, the total sorghum consumption is around 60 million tons used in the food industry or as feed. Sorghum is consumed in many ways as snacks, bread, flour, alcoholic beverages and pasta. The grits obtained from the endosperm can be used in brewing or fermentation due to its high quantity in oil. The germ's oil can be used as salad oil and the starch of the grain can be used in food industry or for papers and fabrics [4].

2.4.1 *Human food*

Sorghum is mainly consumed in countries whose income is low like: Ethiopia, Somalia, Botswana, India and China. Sorghum consumption is the highest in Africa and Asia [4]. This consumption was reduced after 1990s due to change in consumer's preference, rapid urbanization, the improvement of food security, nutrition levels and the absence of processing technologies to yield high shelf-life sorghum flour, but still sorghum is highly consumed depending on the region and the climate of the concerned region [4]. In USA and Japan sorghum has gained substantial interest to be used as snacks and cookies [9]. Sorghum is a gluten-free product that can be consumed in a variety of ways as flat bread, fermented or unfermented porridge, boiled products and deep-fried in oil [9]. Sorghum is consumed in different ways depending on the region, it is mainly consumed as whole grain or flour. Sorghum alone is insufficient for biscuit making

since it is gluten-free energy source so by adding some sorghum flour to wheat flour, a great biscuit will be formed especially for the gluten allergic people [9].

By combining sorghum flour with wheat flour, sorghum can be used in pasta goods [9]. Sorghum can be incorporated to a variety of health products like noodles, bakery products and weaning supplementary foods [14].

2.4.2 *Animal Feed*

Sorghum grain products are used as feed for livestock. The quantity of sorghum used in feed depends on the rising income and the competition of sorghum with maize. This competition is due to the fact that maize and sorghum are similar in energy, protein and essential vitamins [15]. According to some industries, sorghum's price should be 10% cheaper than maize's for it to be highly competitive and accepted [4].

2.4.3 *Alcohol distillers*

Sorghum grain is believed to be the potential raw material for the production of alcoholic beverages categorized in two types: clear beer and opaque beer [4, 15]. Sorghum grain gained a high interest in alcohol industry as a raw material due to the changes in government policies that allowed using sorghum grains for producing potable alcohol [4]. For example, Dolo is a reddish-cloudy opaque beer obtained from red sorghum malt [9].

2.5 *Health benefits of sorghum*

Currently, consumers favor the consumption of healthy foods even at a high cost. Phenolic compounds have a positive health impact on colon microflora, dislypedemia, diabetes, cancer, oxidative stress and hypertension [13, 16].

2.5.1 *Anti-cancer effect*

Many studies revealed that phenolic compounds found in sorghum can prevent cancer development [16]. Many cancer cells including colon, hepatoma, leukemia, breast and stomach cancer cells are prevented by the action of 3-Deoxyanthocyanidins, found in darker colored sorghum [17]. This 3-DXA along with tannins can deactivate aromatase activity (an enzyme involved in breast cancer) [17]. As a result, little is known about which phenolic plays a key role in cancer's antiproliferative impact, therefore research is needed [16].

2.5.2 *Anti-obesity and anti-inflammatory effect*

Due to sorghum's endosperm which includes increased levels of resistance and limited starch digestion, sorghum is an ideal meal for obese people [13]. A recent study conducted by [12] found that healthy people who ate sorghum whole grain biscuits felt more satiety and less hunger than those who ate wheat biscuits. Another study [18] found that sorghum condensed tannins can modify starch by reacting strongly with amylose resulting in resistant starch. Because resistant starch can't be digested in the small intestine, it passes through the large intestine where it provides dietary fiber benefits [17]. Sorghum polymeric tannins also impede starch digestion by blocking the enzymes saccharase and amylase. This complexation of tannins with proteins along with other factors, may have contributed to limited weight gain [17].

The generation of pro-inflammatory chemicals has been shown to be inhibited by numerous phenolic compounds isolated from sorghum grain. Furthermore, sorghum extracts that are rich in 3-deoxyanthocyanidins were found to decrease the release of interleukin-1, tumor necrosis factor and other cytokines associated with inflammation [13]. The functional effects of whole sorghum and its derivatives in humans are unknown, however, they could be linked to enhanced adiponectin which reduces inflammation markers [17].

2.5.3 *Anti-diabetic effect*

Diabetes is one of the most complicated chronic diseases. Hyperglycemia and improper glucose metabolism develop from insulin resistance and pancreatic β-cell malfunction, leading to type 2 diabetes [16]. The phenolic extracts of sorghum have been proven to successfully control diabetes by lowering serum glucose, total cholesterol

and triglycerides [17]. In addition polyphenols and anthocyanins have been shown to block starch digestive enzymes including α-amylase and glucosidase, slowing starch digestion and reducing the glycemic index, all of which are thought to have anti-diabetic properties but more research is needed to prove the role of sorghum phenolics against diabetes [16].

2.5.4 *Anti-dyslipidemic and anti-CVD effect*

Phytochemicals are abundant in the sorghum grain and has a great ability to lower cholesterol levels by modulating its absorption, excretion and synthesis what leads to a reduced LDL concentration. Published data shows that sorghum grains are beneficial to be consumed as food ingredients or dietary supplements to help people control their cholesterol levels [13].

2.5.5 *Anti-hypertension effect*

Sorghum has recently been linked to a reduction in blood pressure [17]. Few investigations have ruled out that a sorghum-kafirin isolate decreased the activity of the angiotensin 1 enzyme which causes oxidative stress and narrower blood vessels [17].

2.5.6 *Celiac disease prevention*

Celiac disease is an autoimmune sensitivity to gluten grains like wheat, barley and rye that impacts the population globally. Sorghum has been assumed to be safe for celiac patients, but no clinical testing had been done except for a study by Italian experts [19]. They did reports on the safety of sorghum food items, finding that sorghum did not cause celiac disease toxicity and can be deemed safe for celiac disease patients [1, 19].

2.6 *Sorghum malting*

Malted barley, or "Malt" is a great bundle of starch, enzymes, protein, vitamins and minerals content, as well as many other minor ingredients, that serves as the primary raw material for brewers and distillers. It aims to enhance hydrolytic enzymes, throughout several stages including: steeping, germination, kilning and roasting as shown in the flow chart in Figure 1 [4]. Also, the final quality of malt could be dependent of the parameters of malting [4].

2.6.1 *Mechanism of malting*

The grains are sifted and steeped for 24 h in 600 mL water at room temperature (28 °C) containing 0.6 mL of formaldehyde solution (12 h steeping, 2 h air rest, other 10 h steeping). After soaking, the hydrated grains are spread on a sieve to remove any excess water and left to sprout for 5 days at 20 °C, the water is added every 12 h and the ones that didn't germinate are discarded. The germinated seeds are dried for 24 h at 50-55 °C in a hot air oven. The sorghum malt is obtained and its ready for milling to obtain malt flour [20-21]. Sorghum grains undergo significant metabolic changes as a result of malting. Soaking the grain softens it and enhance the water availability. Starch and protein are broken down by enzymes released during germination, resulting in the immediate release of sugar and aminoacids. Proteolytic enzymes improve the availability of aminoacids particularly lysine, methionine and tryptophan which are insufficient in the grain [20].

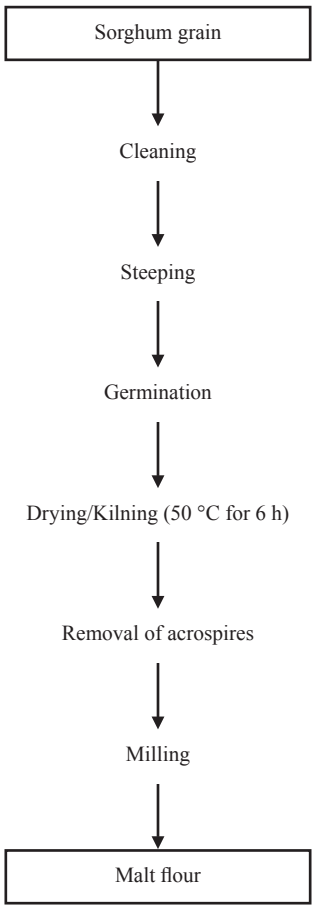

Figure 1. General flow chart of malting [4]

3. Wheat flour for biscuit making

The *Triticum* L. (wheat) genus is divided into the following categories: phylum: *Angiospermatophyta*, class: *Monocotyledonopsida*, order: *Poales (Glumiflorae)*, family: *Poaceae (Gramineae)*, subfamily: *Pooideae*, tribe: *Triticeae*, subtribe: *Triticinae*, genus; *Triticum L.* [22]. Wheat represents the most important grain all around the world. It has been used 10,000 years ago, then spread to all around the world. It is a special grain since it can adapt easily to any region, due to its wide genetic diversity [23]. Besides of being the primary source of starch and energy, it contains significant amounts of protein, vitamins, phytochemicals and dietary fiber, all of which are beneficial to human's health [24-25]. Wheat is being used primarily as whole and refined flour for the production of a wide range of bakery goods [23].

Wheat flour is the most common ingredient for biscuit production due to its high gluten forming ability. Wheat flour is extracted from the wheat grain by removing the seed coat and the embryo and grinding the endosperm only [26].

3.1 *Composition of wheat flour*

The endosperm, which consists of carbohydrates and proteins, the bran which consists of fiber and protein and the germ containing vitamins set up the wheat grain. The protein content of wheat flour varies depending on the type of wheat used by millers and the amount of gluten extracted from it. The higher the gluten, the higher the wheat flour protein, consequently the better the CO_2 trapping in biscuits [27]. Wheat flour has the ability to retain gas and form a cohesive dough with viscoelastic qualities, which are all necessary for the formation of a light texture biscuits [28]. Gluten protein is developed during mixing, fermentation and handling processes which has an impact on the rheological

properties of the dough [28]. Wheat flour can improve elasticity, viscosity and extensibility of the biscuits due to its high quality components [28].

The main components of the wheat flour are starch and protein accounting for 70% and 8% respectively [26]. The minor components are polysaccharides and lipids accounting for 3% and 2% respectively [29]. The starch content of wheat flour makes up three quarters of its total dry weight that's why it's considered the most abundant component in the flour [26] composed of amylose and amylopectin which soften the crumb [4]. Protein which is mostly found in the endosperm of the wheat grain is the second most abundant component in wheat flour [26]. Proteins in the flour are responsible for the formation of gluten, where its quality depends on the climate and agrarian practices [27]. During dough kneading, yeast will expand the dough, and form aminoacids and polypeptides which increase the flavor quality of the flour [26]. In addition to protein and starch, wheat flour contains a great amount of phytochemicals (phenolics and tarpenoids) produced by the cells of the wheat grain, which have a beneficial impact on our health [30]. Lipids in the wheat flour are classified as starch lipids and free and bound non-starch lipids consisting mainly of triglycerides [31] Non-starch polysaccharides (NSP) are also chemical components found in the wheat flour composed of arabinoxylans (AX), B-glucan, cellulose and arabinogalactan peptides, responsible for health promoting effects [31]. Also, wheat flour contains 2% of fiber mainly in the white flour [23].

Gluten is referred as the 'heart and soul' of baking products since it provides high processing qualities [3]. It is the main protein found in wheat flour, which was described first by Giacomo Beccari in 1,728. Beccari called the water-insoluble portion of wheat flour by "glutinis". Thomas Burr Osborne's studies of plant proteins between 1,886 and 1,928 led him to identify the gluten as being made up of prolamines and glutelins. Gliadin and glutenin, together make up to 85% of the total protein in wheat endosperm according to Osborne. The gluten matrix and the function it serves determine the qualities of wheat for the final use. Gliadins are mainly responsible for the dough's viscosity and extensibility, whereas glutenins are primarily responsible for the dough's strength and elasticity [20]. Gluten-induced/ sensitive entropy, or celiac disease is defined by intestinal mucosa damage caused by the wheat gliadin component. People with celiac disease can not consume products containing wheat or make from wheat flour [3].

3.2 *Health benefits of wheat flour*

The major health benefits of the wheat flour are due to the wheat grain that include beneficial components that may prevent cancer, obesity, CVD and gastrointestinal diseases [32]. Wheat grain contains fructans (present in the bran and endosperm) a fermentable carbohydrate termed as FODMAP (fermentable, oligo, di-monosaccharides, polyols). This component can reduce the fermentation in the colon and treat gastrointestinal diseases. It is also contributed to enhanced calcium and iron absorption [30].

Alberts et al. [33] reported that a wheat bran cereal (13.5 g/day) supplemented diet, decreased stool bile acid content knowing that bile acids contribute to the development of colorectal cancer [32-33]. Also, Waliszewski et al. [34] suggested that the phytochemicals' content in the wheat bran may reduce colon cancer risk [32, 34]. Wholegrains contain large amounts of fiber, so this adds a cardiovascular advantage to our health. Costabile et al. [35] found a substantial reduction in total serum cholesterol after the consumption of wheat-bran cereal for 3 weeks [32, 35]. Also, Jensen et al. [36] found that people who added wheat grain in their diet had less risk of coronary heart disease (CHD) [32, 36].

Wheat grain is linked also to obesity, according to Freeland et al. [37], after the consumption of a wheat meal, less food intake were reported due to the fiber content that increased their satiety [32, 37]. Wheat bran can provide beneficial improvements in digestive health, where it can delay gastric emptying and improve fecal bulking [32].

In October 2010, the EFSA panel approved two health claims concerning the benefits of the wheat bran: the first "the consumption of wheat bran may increase fecal bulk which improves intestinal health", the second "the consumption of 10 g/day of wheat bran reduces intestinal transit time which improves gut health" [32, 38].

3.3 *Place of wheat flour in food industry*

Bread consumption is increasing in developed countries, particularly bread made with whole wheat flour since its rich in complex carbohydrates, fibers and proteins. In Europe, Asia and Africa, durum wheat flour is the common ingredient for pasta, bread and couscous [23, 32]. Durum wheat flour may be mixed with other flours to produce bread

especially in Mediterranean regions and to produce ready-to-eat breakfast cereal in Germany. Besides, wheat flour may be used in cookies, cakes and flat breads like Arab bread, tortilla and Indian chapatti [23].

Waxy wheat flour is a typical ingredient to enhance the stability and shelf-life of baked wheat dishes. The addition of 40% waxy flour to Chinese noodles increased the quality of the noodles and reducd the cooking time. Waxy wheat flour is the ideal choice for freezing items since it has a low rate of retrogradation [23]. Nowadays, old wheat is mixed with modern wheat to compensate the missing components in each. Since the demand for a wide range of product's variety is increasing, old wheat flours are being mixed with modern ones (different in nutritional composition of phytochemicals, antioxidants and carotenoids which give great health benefits) to respond to these demands. For example, compared to modern wheat, the emmer grain contains a relatively high amount of protein and the einkorn wheat contains a higher amount of lysine. So the production of bread by mixing these flours will give a healthier product, since the high lysine can supplement the missing health components in modern wheat flours, resulting in a better nutritional balance. Emmer flour is being utilized globally to produce bread and pasta mainly in Italy and Switzerland [23].

3.4 *Whole wheat flour milling*

The milling process breaks up wheat grains into flour, bran and pollard (a dusty material resulting from grinding). The wholemeal flour is a combination of flour, bran and pollard present in the grains. The miller's goal is to extract as much flour as possible from the wheat grain, but caution is needed here to avoid contamination by bran and pollard which give undesirable color of the flour, and by germ which decreases the wheat's quality. Wheat grain protein content ranges from 7-17% affected by temperature, weather conditions and wheat variety. High protein wheat called "hard wheat", create an ideal flour for bread, while those with low protein called "soft wheat" are better for biscuits and cakes [39]. Before milling, wheat must be screened and checked for any impurities, conditioned by adding or removing water then prepared for milling procedure. Bran color of the kernel has a significant effect on whole wheat flour, it can be white, black, red or blue [39]. The milling procedure is the most significant factor when making whole grain flour since it may have a great effect on the quality of the end product. Stone and roller mills are the most common methods for grinding whole grain flours [39]. The purpose of milling is to separate the endosperm from the germ and bran to obtain a higher shelf-life flour with a good color and to finely grind as much endosperm as possible in order to extract the maximum white flour from the wheat [40].

3.4.1 *Stone milling*

Stone milling is the oldest mill for producing whole grain wheat flour by grinding wheat kernels between two stones using shear force but it has a disadvantage that it may damage starch, protein and unsaturated fats due to the heat generated [39].

3.4.2 *Roller milling*

This process involves separating the endosperm from the bran and germ, then gradually reducing the endosperm's size by pushing the wheat through smooth rollers [41]. First, wheat grains are separated into different portions by crushing and sifting, next the grain is soaked to toughen the bran, then the starch is conditioned. The grain is run through rollers to crush the kernels into coarse pieces after being tampered for six hours [40]. Some of the endosperms becomes powdered at each crushing, so those left behind and called "middlings". Purification aims at removing those too small particles that are unable to pass through middlings. Middlings can be packaged and sold as farina "used to make creamed cereal porridge", or as semolina "used to make macaroni". Then the middlings used for flour making are passed through smooth rollers to reduce them. The flour is then bleached to increase the flour quality [40].

4. Biscuits manufacturing and production

Biscuits are a type of baked food that contain flour, shortenings, sugar with a low moisture content [42]. It is traditionally served as a morning side dish with molasses, honey or jam [43]. They are widely consumed in many

countries all around the world due to their high appeal, long stability and low cost [42]. Adeyeye [41] stated that wheat flour is believed to be the standard flour for biscuits production based on consumer appeal, but celiac disease as well as the high market price and processing costs of wheat, has prompted the use of gluten-free flours in the production of cookies and biscuits [42]. Since sorghum flour, is rich in energy, proteins, vitamins, carbohydrates and fiber, it is the best choice to be used in the production of biscuits to develop product with smooth texture and higher overall quality [42].

4.1 *Processing of biscuits with composite flour (sorghum and wheat)*

Margarine and sugar are combined to form the desired consistency, then blended with whole milk powder, flour (sorghum plus wheat), salt and baking powder. The dough is prepared by creaming of fat and sugar, then kneaded, cutted into slices and baked. Finally, cooling the biscuits at room temperature is conducted before being stored and packed [43]. The flow chart for biscuits production is shown in (Figure 2) [20].

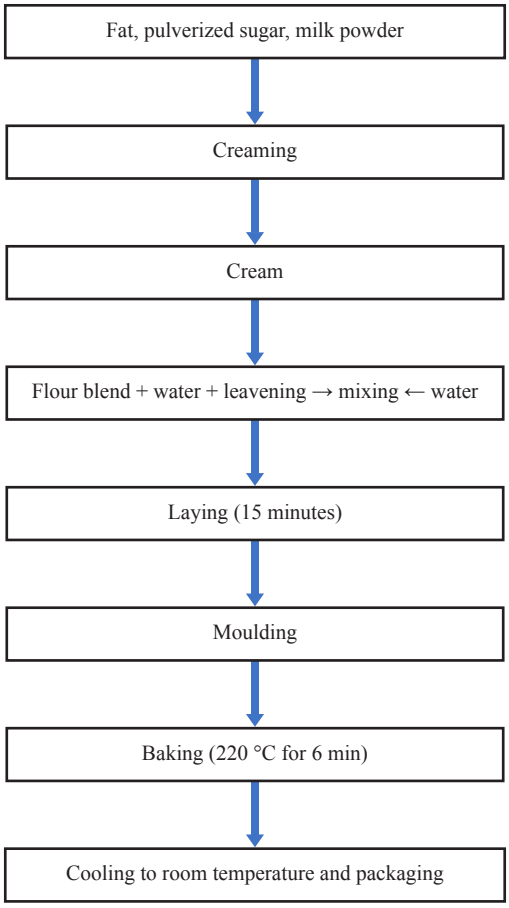

Figure 2. Flow Chart for Biscuit Production [20]

4.2 *Reasons for the introduction of sorghum flour in biscuit industry*

Sorghum flour has a great nutritional profile (Table 2) as well as a potential health impact on humans. Due to its richness in nutrients it is often added to biscuit industry [42]. In addition, sorghum flour produces a smoother texture biscuit when added to wheat flour in biscuits making [42]. Since celiac disease is the abnormal production of gluten in the body, resulting in inflammation of the small intestine and reduction in the absorption of fat soluble vitamins and iron,

the addition of sorghum flour into biscuits will offer an advantage since it's a gluten-free flour and can be consumed safely by celiac disease patients [42-43].

Table 2. Nutritional Composition of Sorghum [10, 44]

Constituents (%)	
Protein	4-21
Water soluble protein	0.3-0.9
Lysine	1-3
Starch	55-75
Amylose	20-30
Soluble sugar	1-4
Reducing sugar	0.05-0.5
Fibers	1-3
Fat	2-7
Ash	1-3
Minerals (%)	
Calcium	0.011-0.58
Phosphorous	0.16-0.75
Iron	0.001-0.02
Vitamins (%)	
Niacin	0.003-0.006
Thiamin	0.0002-0.0005
Riboflavin	0.00015

4.3 *Effects of the addition of sorghum flour on product attributes*

Attention should be taken here concerning the addition of sorghum flour into biscuits. Sorghum flour has a poor hydration property. Therefore, if sorghum flour is added alone without wheat the obtained mixture will be very thick and sticky to the hands, and this will give a low consistency baked product. The poor hydration property of sorghum flour is not the only reason to obtain a poor quality of biscuits. Gluten is responsible for the taste, texture and appearance of biscuits. Combinations of gluten-free flours can be used to create biscuits of acceptable sensory qualities that could be consumed by people who suffer from gluten intolerance [3]. Sorghum flour is gluten-free so no viscoelastic network will be formed in the dough, which is responsible for the volume of the biscuits. Sorghum flour has a very low gelatinization property since its poorly hydrated favouring the rapid degradation of starch and resulting in a very hard dough [5]. So

the production of biscuits from only sorghum flour is impossible, since it will result in a poor quality final product which is unacceptable and undesirable [5]. When 30-40% of sorghum flour is added to biscuits, an increase in biscuit hardness and toughness were observed [45]. The sensory properties for texture, flavor, taste and appearance were all decreased when high amount of sorghum flour is added [45] *Nankatai* prepared biscuits from different rates of sorghum flour, he used 10, 20 and 30% of sorghum flour. He concluded that rates of 10, 20 and 30% of sorghum flour incorporated were not significantly different in terms of color, texture, flavor and overall acceptability from the control one [46]. Ragaee and Abdel-Aal [47] also reported that biscuits made from 30% sorghum flour substitution levels had no negative effects on the quality of biscuits produced. Consumers couldn't distinguish between wheat flour biscuits and those from composite flour, because it was highly acceptable. Biscuits with 20% substitution sorghum flour was highly acceptable in terms of taste, color and appearance [41].

The best choice is to produce biscuits from composite flour by substituting few amount of wheat by sorghum flour. Wheat flour has a better hydration characteristic compared to sorghum, so its existence in the dough matrix will make a great difference on the overall quality of biscuits [42-43]. Because sorghum flour has a greater bulk density than wheat flour, composite flour of 20-40% sorghum flour substitution levels had greater bulk densities than wheat flour alone. The high bulk density of sorghum-wheat composite flour makes it favourable thickener in the production of biscuits and cookies [42]. Also, sorghum flour has a high water absorption property, so during this substitution, more hydrophilic elements will be absorbed in the dough resulting in a high consistent baked product. In addition, higher swelling property is achieved when sorghum flour is added which is the principle for the volume of the biscuits [42]. More fiber content in biscuits is achieved when sorghum flour is added to wheat four due to the fact that sorghum flour is richer in fiber than wheat flour [43]. Finally, substituting 30% of wheat flour by sorghum flour, produced a highly acceptable biscuits without altering the sensory properties, as well as biscuits with better texture, taste, aroma and crispeness [42-43].

5. Conclusion

As a conclusion, to obtain biscuits with a high quality, caution is needed for the concentration of sorghum flour added. Adding only sorghum flour instead of wheat flour, will result in a unacceptable and undesirable biscuits since sorghum has a poor hydration quality. The best solution is to produce biscuits from composite flour by substituting few amount of wheat by sorghum flour. Composite flour of 20-40% sorghum flour substitution levels was capable of of increasing consumer acceptability of sorghum-wheat flour biscuit, without affecting sensory attributes. Consequently, this is an indication of viable alternative raw material in confectionery industries.

Authors contributions

All authors have contributed equally in writing this manuscript.

Conflict of interest

The authors declare no competing financial interest.

References

[1] Dahlberg J, Berenji J, Sikora V, Latković D. Assessing sorghum [Sorghum bicolor (L) Moench] germplasm for new traits: Food, fuels & unique uses. *Maydica*. 2011; 56-1750: 85-92.

[2] Adebo OA. African sorghum-based fermented foods: Past, current and future prospects. *Nutrients*. 2020; 12(4): 1111.

[3] Rai S, Kaur A, Singh B. Quality characteristics of gluten free cookies prepared from different flour combinations. *J Food Sci Technol*. 2014; 51(4): 785-789.

[4] Acharya D. *Preparation and quality evaluation of malted sorghum incorporatd bread* [PhD Thesis]. Department of Food Technology Central Campus of Technology Institute of Science and Technology Tribhuvan University, Nepal; 2021.
[5] Djoulde DR, Sidoine MB, Lendzemo VW. Development of sorghum-based shortbread biscuits from "muskwari" flour. *Food Sci Nutr*. 2020; 8(7): 3181-3189.
[6] Ananda GKS, Myrans H, Norton SL, Gleadow R, Furtado A, Henry RJ. Wild sorghum as a promising resource for crop improvement. *Frontiers in Plant Science*. 2020; 11: 1108. Available from: https://doi.org/10.3389/fpls.2020.01108.
[7] Enyew M, Feyissa T, Carlsson AS, Tesfaye K, Hammenhag C, Geleta M. Genetic diversity and population structure of sorghum [Sorghum Bicolor (L.) Moench] accessions as revealed by single nucleotide polymorphism markers. *Frontiers in Plant Science*. 2022; 12: 799482. Available from: https://doi.org/10.3389/fpls.2021.799482.
[8] Ramatoulaye F, Mady C, Fallou S, Amadou K, Cyril D, Massamba D. Production and use sorghum: A literature review. *Journal of Nutritional Health & Food Science*. 2016; 4(1): 1-4. Available from: http://dx.doi.org/10.15226/jnhfs.2016.00157.
[9] Dicko MH, Gruppen H, Traoré AS, Voragen, van Berkel WJH. Sorghum grain as human food in Africa: Relevance of content of starch and amylase activities. *African Journal of Biotechnology*. 2006; 5: 384-395.
[10] Jacob A, Fidelis A, Salaudeen K, Queen R, Salaudeen K. Sorghum: Most under-utilized grain of the semi-arid Africa. *Scholarly Journal of Agricultural Science*. 2013; 3(4): 147-153.
[11] Kulamarva AG, Sosle VR, Raghavan GSV. Nutritional and rheological properties of sorghum. *International Journal of Food Properties*. 2009; 12(1): 55-69.
[12] Stefoska-Needham A, Beck EJ, Johnson SK, Tapsell LC. Sorghum: An underutilized cereal whole grain with the potential to assist in the prevention of chronic disease. *Food Reviews International*. 2015; 31(4): 401-437.
[13] Kumari P, Kumar V, Kumar R, Pahuja SK. Retracted article: Sorghum polyphenols: plant stress, human health benefits, and industrial applications. *Planta*. 2021; 254(3): 47.
[14] Ratnavathi CV, Patil JV. Sorghum utilization as food. *Journal of Nutrition & Food Sciences*. 2014; 4(1): 2155-9600. Available from: https://doi.org/10.4172/2155-9600.1000247.
[15] International Crops Research Institute for the Semi-arid Tropics, Food and Agriculture Organization of the United Nations. *The world sorghum and millet economies: facts, trends, and outlook*. Patancheru, Andhra Pradesh, India: Rome, Italy: International Crops Research Institute for the Semi-Arid Tropics; Food and Agriculture Organization of the United Nations; 1996. p.68.
[16] Xu J, Wang W, Zhao Y. Phenolic Compounds in Whole Grain Sorghum and Their Health Benefits. *Foods*. 2021; 10(8): 1921.
[17] Birhanu S. Potential benefits of sorghum [Sorghum Bicolor (L.) Moench] on human health: A review. *International Journal of Food Engineering and Technology*. 2021; 5(1): 8-18.
[18] Barros F, Awika J, Rooney LW. Effect of molecular weight profile of sorghum proanthocyanidins on resistant starch formation: Effect of sorghum proanthocyanidins on resist starch formation. *J Sci Food Agric*. 2014; 94(6): 1212-1217.
[19] Ciacci C, Maiuri L, Caporaso N, Bucci C, Del Giudice L, Rita Massardo D, et al. Celiac disease: In vitro and in vivo safety and palatability of wheat-free sorghum food products. *Clinical Nutrition*. 2007; 26(6): 799-805.
[20] Adhikari N, Acharya DR. Effect of incorporation of malted sorghum flour on quality of biscuit. *Sunsari Technical College Journal*. 2015; 2(1): 33-37.
[21] Mridula D, Gupta RK, Manikantan MR. Effect of incorporation of sorghum flour to wheat flour on quality of biscuits fortified with defatted soy flour. *American Journal of Food Technology*. 2007; 2: 428-434. Available from: https://doi.org/10.3923/ajft.2007.428.434.
[22] Bálint AF, Kovács G, Sutka J. Origin and taxonomy of wheat in the light of recent research. *Acta Agronomica Hungarica*. 2000; 48(3): 301-313.
[23] de Sousa T, Ribeiro M, Sabença C, Igrejas G. The 10,000-year success story of wheat! *Foods*. 2021; 10(9): 2124.
[24] Shewry PR, Hey SJ. The contribution of wheat to human diet and health. *Food Energy Secur*. 2015; 4(3): 178-202.
[25] Stevenson L, Phillips F, O'Sullivan K, Walton J. Wheat bran: Its composition and benefits to health, a European perspective. *Int J Food Sci Nutr*. 2012; 63(8): 1001-1013.
[26] Zhang A. Effect of wheat flour with different quality in the process of making flour products. *Int J Metrol Qual Eng*. 2020; 11: 6.
[27] Ahmad S, Ahmed M. A review on biscuit, a largest consumed processed product in India, its fortification and nutritional improvement. *International Journal of Science Inventions Today*. 2014; 3(2): 169-186.
[28] Hrušková M, Bednářová M, Novotný F. Wheat flour dough rheological characteristics predicted by NIRSystems

6500. *Czech Journal of Food Sciences*. 2013; 19(6): 213-218. Available from: https://doi.org/10.17221/6610-CJFS.
[29] Lin J, Gu Y, Bian K. Bulk and surface chemical composition of wheat flour particles of different sizes. *Journal of Chemistry*. 2019; 2019: 1-11. Available from: https://doi.org/10.1155/2019/5101684.
[30] Shewry PR, Hey SJ. The contribution of wheat to human diet and health. *Food Energy Secur*. 2015; 4(3): 178-202.
[31] Goesaert H, Brijs K, Veraverbeke WS, Courtin CM, Gebruers K, Delcour JA. Wheat flour constituents: How they impact bread quality, and how to impact their functionality. *Trends in Food Science & Technology*. 2005; 16(1-3): 12-30.
[32] Stevenson L, Phillips F, O'sullivan K, Walton J. Wheat bran: Its composition and benefits to health, a European perspective. *Int J Food Sci Nutr*. 2012; 63(8): 1001-1013.
[33] Alberts DS, Ritenbaugh C, Story JA, Aickin M, Rees-McGee S, Buller MK, et al. Randomized, double-blinded, placebo-controlled study of effect of wheat bran fiber and calcium on fecal bile acids in patients with resected adenomatous colon polyps. *JNCI Journal of the National Cancer Institute*. 1996; 88(2): 81-92.
[34] Waliszewski P, Blaszczyk M, Wolinska-Witort E, Drews M, Snochowski M, Hurst RE. Molecular study of sex steroid receptor gene expression in human colon and in colorectal carcinomas. *J Surg Oncol*. 1997; 64(1): 3-11.
[35] Costabile A, Klinder A, Fava F, Napolitano A, Fogliano V, Leonard C, et al. Whole-grain wheat breakfast cereal has a prebiotic effect on the human gut microbiota: a double-blind, placebo-controlled, crossover study. *British Journal of Nutrition*. 2008; 99(1): 110-120.
[36] Jensen MK, Koh-Banerjee P, Hu FB, Franz M, Sampson L, Grønbæk M, et al. Intakes of whole grains, bran, and germ and the risk of coronary heart disease in men. *The American Journal of Clinical Nutrition*. 2004; 80(6): 1492-1499.
[37] Freeland KR, Anderson GH, Wolever TMS. Acute effects of dietary fibre and glycaemic carbohydrate on appetite and food intake in healthy males. *Appetite*. 2009; 52(1): 58-64.
[38] EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA). Scientific opinion on the substantiation of health claims related to wheat bran fibre and increase in faecal bulk (ID 3066), reduction in intestinal transit time (ID 828, 839, 3067, 4699) and contribution to the maintenance or achievement of a normal body weight (ID 829) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. *EFSA Journal*. 2010; 8(10): 1817.
[39] Doblado-Maldonado AF. New technologies for whole wheat processing: Addressing milling and storage issues. *Dissertations, Theses, & Student Research in Food Science and Technology*. 2012; 129: 31.
[40] Mahmoud IAA, Bureng PL, Mustafa AI. *Biscuits from composite flour of wheat and sorghum*. Khartoum: University of Khartoum; 2003. p.241.
[41] Adeyeye SAO. Assessment of quality and sensory properties of sorghum-wheat flour cookies. *Cogent Food & Agriculture*. 2016; 2(1): 1245059.
[42] Olurin T, Ogunmoyela O, Dudu O, Adubi T. Cookies-making potentials of sorghum-wheat flour blends. *Anchor University Journal of Science and Technology*. 2020; 1(2): 8.
[43] Folake OB, Abiodun AJ, Oluwatomiwo IR. Evaluation of proximate composition of biscuits produced from wheat (Triticum aestivum l.) and sorghum (Sorghum Bicolor [L.] Moench) composite flour. *Elixir Food Science*. 2018; 122: 51652-51656.
[44] Abah CR, Ishiwu CN, Obiegbuna JE, Oladejo AA. Sorghum grains: Nutritional composition, functional properties and its food applications. *European Journal of Nutrition & Food Safety*. 2020; 12(5): 101-111. Available from: https://doi.org/10.9734/ejnfs/2020/v12i530232.
[45] Mridula D, Gupta RK, Manikantan MR. Effect of incorporation of sorghum flour to wheat flour on quality of biscuits fortified with defatted soy flour. *American Journal of Food Technology*. 2007; 2(5): 428-434.
[46] Chavan U, Yewale K, Rao B. Preparation of bread and cookies from sorghum flour. *International Journal of Recent Scientific Research*. 2016; 7: 11145-11153.
[47] Ragaee S, Abdel-Aal ESM. Pasting properties of starch and protein in selected cereals and quality of their food products. *Food Chemistry*. 2006; 95(1): 9-18.