

# Amylopectin Aggregation as Function of Starch Phosphate Content Sorghum (*Sorghum bicolor* L.) Grain Composition and Food Nutrition Values

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**Abstract** Sorghum which is one of the world's oldest cereal crops, originated in Africa and is an important food crop and a staple food for nearly 500 million people. Sorghum is a C4 crop with strong drought resistance, waterlogging resistance and salinity tolerance. It is widely grown in arid and semi-arid areas worldwide. Breeding sorghum varieties with high lysine content has always been an important breeding goal. However, conventional breeding has not led to a breakthrough because the gene controlling lysine content in grain is closely linked to seed shrinkage. The genes AK, DHPS and RNAi-LKR which control the accumulation and degradation of lysine in grain were transferred into sorghum. The content of lysine in sorghum grain was improved through metabolic engineering. The contents of lysine and the physicochemical properties of sorghum grains of different transgenic lines were determined, and the agronomic traits were evaluated, providing theoretical basis and germplasm resources for further screening of sorghum lines for high lysine contents. Sorghum grain has high content of resistant starch, low digestibility of protein, rich in fiber and some bioactive substances, so that sorghum has unique nutritional characteristics. Sorghum has been transformed from a traditional staple food into a functional food or as a food additive to improve food quality. The lipids in sorghum grains are mainly composed of unsaturated fatty acids, including oleic acid, linoleic acid, palmitic acid, linolenic acid and stearic acid. Sorghum also contains non-carbohydrate cell-wall polymers such as lignins with proportions constituting up to 20% of the total cell wall materials. Sorghum also has the potential to replace maize as animal feed.

**Keywords:** amylose, food security, grain nutrition quality, sorghum, starch

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## 1. Introduction

Sorghum (*Sorghum bicolor* L.) has emerged as a promising target for sugar as well as lignocellulose biofuel production. It has relatively low input requirements with ability to grow on marginal lands. Cultivated varieties of sorghum exhibit diverse phenotypic and morphological traits. Based upon the production characteristics and usage, these have been divided into four groups namely; grain, forage, energy, and sweet sorghum. Grain sorghum varieties are three to six feet tall with large ear heads and primarily serve as food for humans or livestock feed. The coarse fast-growing forage sorghum varieties are utilized for feed, silage, and grazing [1]. Sweet sorghum may grow up to twenty feet tall and produce significantly higher biomass yields compared to grain sorghum. Stems of sweet sorghum are thicker and fishier than the grain

varieties, though the seed yield is relatively low [2,3]. Due to high sugar content and ease of extractability, sweet sorghum is one of the leading feedstock crops for new-age biofuels and focus of this review. The sugar concentration in sweet sorghum stalks is measured in Brix units, which represents the percent soluble sugars. One degree Brix is equal to 1 g of sugar per 100 g of juice. The Brix content varies in different varieties and also depends on the environmental conditions, internode position, time of the year, and stage of harvesting [4]. Sweet sorghum can accumulate juice up to 78% of the total biomass, whereas the Brix content of sweet sorghum has been estimated to range from 14 to 23% [5,6]. Sorghum is a staple food grain in many semi-arid, and tropic areas of the world, notably in Sub-Saharan Africa because of its good adaptation to hard environments and its good yield of production. Among important biochemical components for sorghum processing are levels of starch (amylose and amylopectin) and starch depolymerizing enzymes.

Sorghum has a resistant starch, which makes it interesting for obese, and diabetic people. The proportion of total free amino acids in seed dry weight of transgenic Jinliangwu was 0.22-1.07 times higher than that of wild type, and the content of free lysine was 13.24%-84.31% higher than that of wild type [7]. Gene, compared with no change in most of the rice protein, rare plants appear significant or extremely significant changes related to its growing environment and planting year, concluded that the improvement of lysine in rice, little impact on had no effect on protein content or [8]. Breeding high lysine rice, such as the determination of protein content in rice in different gm strains is found that most points transgenic brown rice protein content increased, the protein content in rice have increased to reduce the case, after the draw, lysine content in rice improvement at the same time, the protein content can have different degrees of change, This conclusion is consistent with our research [9]. The effect of overexpression of AK and DHPS genes in rice and AK and DHPS genes in *Escherichia coli* on lysine content of rice and found that the protein content of the endogenous gene changed, but there was no significant difference compared with the control [10]. The AMA1 gene was used to improve the protein quality of wheat grains, and the contents of essential amino acids lysine, methionine, cysteine and tyrosine were increased [11,12]. Angiosperm (flowering plant) lineages, sorghum is thought to be a-200 million years old. Sorghum, maize, rice and wheat diverged from a common ancestor only 50-70 million years ago (Paterson et al., 2003). The main races of cultivated sorghum are: bicolor, vulgare, caudate, kafir, guinea, and durra [13,14]. Common names of sorghum vary from continent to country levels. The most encountered names are kafferkoren, soedangras, suikergierst, or suiker-sorghum (The Netherlands), kaoliang (China), mtatam, shallu or feterita (East Africa), durra (Egypt), chicken corn, sorghum or guinea corn (United Kingdom), jola, jowar, jawa, cholam, bisinga, durra or shallu (India), kaffir corn (South Africa), milo, sorgo, sudangrass or sorghum (USA), milo (Middle East Africa) and great millet, guinea corn, feterita, sorghum or sorgho (West Africa). Sorghum is C4 crop, whom certain varieties also possess "stay green" genes that enable them to perform photosynthesis permanently. It is particularly adapted to drought prone areas: hot, semi-arid tropical environments with 400-600 mm rainfall-areas that are too dry for other cereals. Sorghum is also found in temperate regions and at altitudes of up to 2300 meters in the tropics. It is well suited to heavy soils commonly found in the tropics, where tolerance to water logging is often required. Sorghum is a vigorous grass that varies between 0-6 m in height. It has deep and spread roots with a solid stem. Leaves are long (0.3- 1.4 m), and wide (1- 13 cm).

## 2. Sorghum Grain Composition and Nutrition Values

Starch is the main component of sorghum grain, followed by proteins, non-starch polysaccharides (NSP) and fat (Table 1). The average energetic value of whole sorghum grain flour is 356 kcal/100g. Sorghum has a macromolecular composition similar to that of maize and

wheat [17]. However, sorghum contains resistant starch, which impairs its digestibility, notably for infants [18]. Foods prepared from high tannin sorghums varieties have a longer passage in the stomach [19]. Edible products incorporating slowly digestible starch are known to exhibit a low glycemic index and increase satiety [20]. Sorghum contains non-starch polysaccharides (NSP), mainly located in the pericarp and endosperm cell walls, with proportions in the kernel ranging from 2 to 7% depending on variety [21]. The NSP in sorghum grain are essentially constituted of arabinoxylans and other b-glucans representing 55% and 40% of the total NSP [21]. Verbruggen and co-workers (1993, 1998) found arabinoxylans from sorghum to be glucuronoarabinoxylans containing ferulic acid and p-coumaric acid. Arabinoxylans, being one of the major NSP present in sorghum cell walls, play an important role in the processing of sorghum for baking and brewing [21,22]. The other b-glucans comprise cellulose (1,4-b-D-glucans), curdlan-type glucans (1,3-b-D-glucans), and lichenan-type glucans (1,3; 1,4-b-D-glucans) [21,23]. These b-glucans are predominantly water-unextractable, and form viscous and sticky solutions. In brewing, together with arabinoxylans, they are associated with processing problems like poor wort and beer filtration rates and the occurrence of haze [24]. Sorghum also contains non-carbohydrate cell-wall polymers such as lignins with proportions constituting up to 20% of the total cell wall materials. The protein content in whole sorghum grain is in the range of 7 to 15% [17]. Sorghum proteins have been divided into albumins, globulins, kafirins (aqueous alcohol-soluble prolamins), cross-linked kafirins and glutelins. The kafirins comprise about 50-70% of the proteins [25,26].

### 2.1. Starch Content

Starch is the primary source of stored energy in cereal grains. Starch is deposited as granules in the endosperm cells, being the main constituent of the endosperm. Sorghum starch granules have diameters ranging from 5 to 25  $\mu\text{m}$  (average 15  $\mu\text{m}$ ). Sorghum starch has a specific particularity because of its high gelatinization temperature (70-75°C), which decreases its industrial application [27,28]. Native starch granules are essentially insoluble in cold water. The term "gelatinization" is used to describe the swelling and hydration of granular starches [29]. Starch gelatinization is the disruption of molecular orders within the starch granule manifested in irreversible changes in properties such as granular swelling, native crystalline melting, loss of birefringence, and starch solubilization. These changes render all or part of the material in granules soluble and consequently enable to contribute to food properties such as texture, viscosity, and moisture retention [30]. The point of initial gelatinization and the range over which it occurs is governed by the starch structure. Sorghum starch is classified as type-B, e.g. a moderate swelling starch compared to type-A starches (potato, tapioca, waxy sorghum, etc.), which are high swelling starches [32]. The retrogradation involves association of the molecules and occurs when the starch is cooled, and this is dependent on the ratio of amylose and amylopectin. Enzymatic sorghum starch hydrolysis or chemical treatment can improve its

technological properties [33]. The interior of the helix is hydrophobic, allowing amylose to form a complex with free fatty acids, iodine, etc. [34]. Amylopectin is constituted of short chains of  $\alpha$ -(1-4)-D-glucopyranose (majority 10-20 units in sorghum starch) branched to  $\alpha$ -(1-6)-D-glucopyranoses to form a highly ramified structure.

### 2.1.1. Biological Characteristics of Sorghum

Sorghum is the fifth largest cereal crop in the world, after maize, wheat, rice and barley. Sorghum has the agronomic performance of color, and the growth period is generally about 100 days. It can adapt to a variety of growing conditions, such as: dry, high temperature, salt, poor and high altitude land. The growth and development period of crops is closely related to the frost-free period. The frost-free period of Shanxi Province is short in the north and long in the south, and short in the Pingchuan long mountain. It is generally 110-140 days in Datong area, 135-155 days in Xinzhou, and the eastern mountainous area, and 200-220 days in Linfen and Yuncheng in the south. Moreover, the terrain of Shanxi is mostly mountains, and the land is arid and barren, but the phenological conditions are suitable for the growth of sorghum, so Shanxi has a long history of sorghum cultivation. With the policy adjustment of the multigrain industrial structure, the planting area of sorghum, one of the key crops in Shanxi Province, has been greatly increased [35].

### 2.1.2. Nutritional Quality of Sorghum

In addition to its excellent agronomic characters, sorghum grains are also rich in nutrients. Starch is the main carbohydrate in the starch and is stored as granules in the endosperm. The starch content of different varieties varies greatly, and the starch content in grains is generally 70%-76.5% [36]. Sorghum starch is mainly composed of amylose and amylopectin, and some waxy sorghum has low amylose content [37]. Due to the high content of highly resistant starch and indigestible starch, as well as the strong interaction between starch particles, endosperm protein and concentrated tannins, the starch digestibility of sorghum is low [38]. The protein content in sorghum is generally 7 % -12 %, which is divided into gliadin, globulin, gluten and egg white. Gliadin is the main form of protein storage in sorghum grains, accounting for 70% of the total protein in sorghum grains, while gluten, albumin and globulin account for the rest [39]. Sorghum glycolin has highly polymerized disulfide bonds, which can resist the digestive function of enzymes in the digestive tract, and their strong interaction with tannins and starch leads to low protein digestibility [40]. The lack of the first limiting essential amino acid lysine in sorghum resulted in the imbalance of amino acids in grain and poor nutritional quality. The lipids in sorghum grains are mainly composed of unsaturated fatty acids, including oleic acid, linoleic acid, palmitic acid, linolenic acid and stearic acid. The lipid distribution is similar to that of maize, but the unsaturation is higher [41]. The vitamins in sorghum mainly include the B complex and some fat-soluble vitamins (vitamins A, D, E and K), Potassium, phosphorus, magnesium and zinc are the main minerals.

### 2.1.3. Food Processing

Sorghum has been a staple food for millions of people around the world for centuries and is particularly important in some developing countries such as Asia and Africa. Sorghum food can be broadly divided into: steamed, boiled products, baked goods, fried products and fermented alcoholic beverages. But with increasing consumer demand for healthy plant-based foods, sorghum has great potential to develop healthy, functional foods and food additives. Traditionally, sorghum is usually cooked and eaten [42]. Sorghum grains to produce various novel foods. For example, sorghum is used to make functional staples, and noodles [43,44] Low glycemic index have been made using sorghum, while sorghum flour bread has a lower glycemic index than other gluten-free bread (buckwheat and quinoa bread) and gluten-free bread (wheat bread) [45]. Sorghum staple can promote health and provide an option for a select group of people. Sorghum is also used to make healthy snacks. Although the cookie made with tannic sorghum has low sensory acceptance, its phenolic content and antioxidant activity are 20 times higher than those of wheat cookie, which is of great benefit to health [46]. The sensory acceptability of sorghum cookies without tannin was similar to that of wheat cookies, but the phenolic content and antioxidant activity were slightly lower than those of sorghum cookies with tannin. Puffed foods made from corn, wheat and oats have long been popular for their crispy texture and ease of use. Sorghum can also be used as a raw material to make extruded food. Ready-to-eat grains made from extricable sorghum combined with probiotic yogurt can reduce oxidative stress and inflammation in people with chronic kidney diseases [47]. Foods made from tannic sorghum are rich in dietary fiber and phenolic compounds with high antioxidant activity; however, their low protein digestibility makes them less acceptable to consumers than non-tannic sorghum and oat grains [48]. The nutritional composition and sensory acceptability of non-tannic white sorghum grains are not different from those of commercial oat grains [49]. Eating sorghum food can improve health, but further improvements in sensory quality are needed. In recent years, as cereal health tea is widely favored by consumers in the market, some researchers have also tried to use sorghum to make tea drinks. A sorghum grain tea developed using red sorghum grains containing tannins and traditional processing techniques (soaking, cooking and baking) not only has antioxidant activity but also inhibits  $\alpha$ -glucosidase and  $\alpha$ -amylase activities [50,51]. Create people drink sorghum tea at leisure to promote good health. Sorghum solid powder beverage made by processing technology has been accepted by people in a new form. For example, a sorghum powder drink developed by extrusion technology is made by injecting sorghum powder into water or milk. This drink has less fat, but high dietary fiber and protein content, and rich phenolic compounds, which has high sensory acceptance and purchase intention [52,53]. The breakfast powder made of sorghum and broad bean is studied. Broad bean makes up for the deficiency of sorghum lysine, and this compound breakfast powder has balanced nutrition and good quality [54]. The mixed beverage made from sorghum has a good market application prospect. In

addition to the above uses, sorghum can also be used as an active ingredient to be incorporated into other foods to improve food quality. For example, the incorporation of sorghum whole grain flour at a ratio of 20%-30% of wheat semolina can significantly improve the anti-starch and antioxidant activities of pasta, which has sensory qualities similar to wheat, and can also play nutritional and health functions [55]. The health benefits of adding sorghum to pasta depend on the type of sorghum. A study compared the difference between eating pasta containing tannic sorghum and that without tannic sorghum, and found that

tannic sorghum could significantly improve the health status of healthy people by increasing the phenolic content and antioxidant activity in plasma [56]. The changes of postprandial blood glucose and insulin in healthy adult males after eating muffins made of whole wheat and sorghum were studied, and it was found that the content of resistant starch and slowly digested starch in sorghum muffins increased, while the content of functional starch decreased, reducing glucose and insulin responses [57]. Sorghum is a functional food that can control human blood glucose and insulin levels.

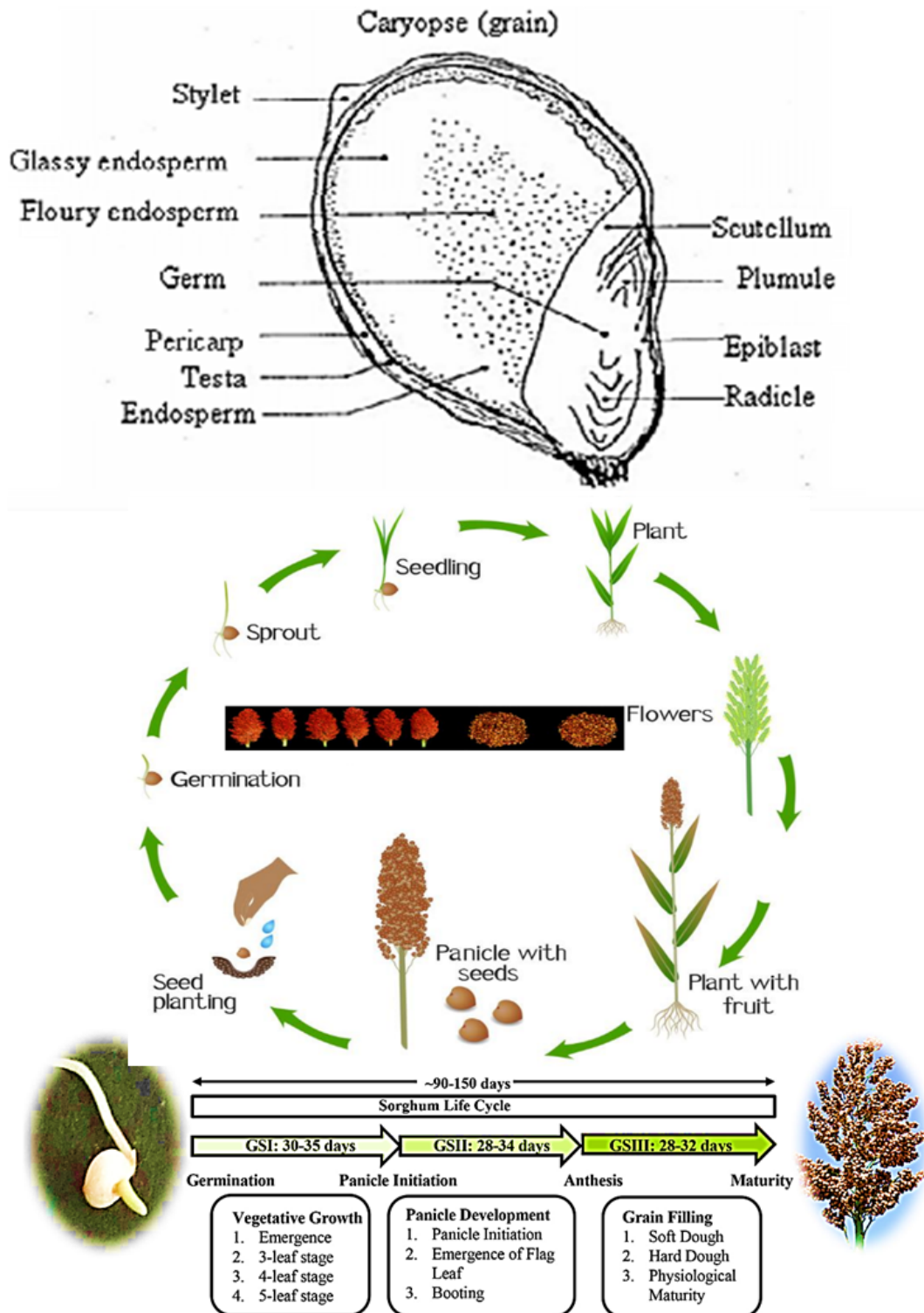


Figure 1. Growth phases and stages during sorghum life cycle

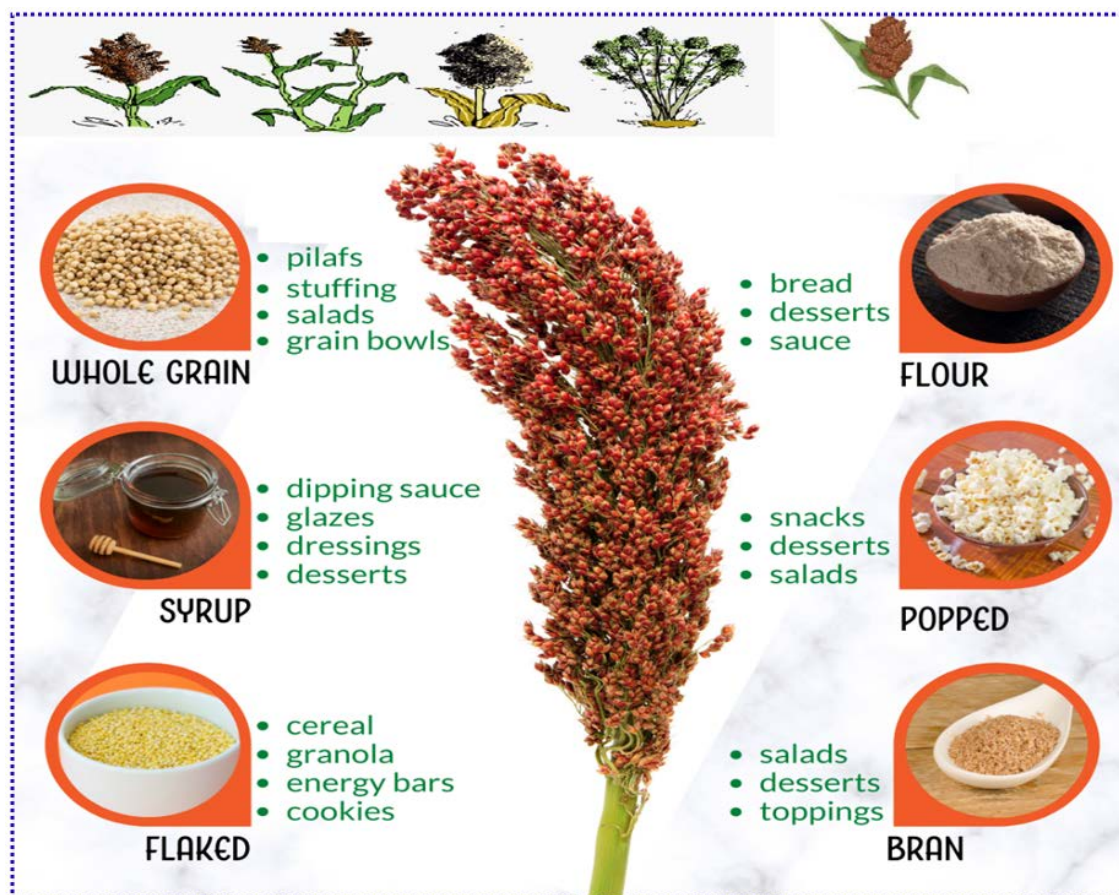
The key developmental stages and growth phases during sorghum life cycle have been illustrated. Structure of sorghum grain [15]. Reproduced with the permission of Harmattan Editions, Paris. With flat or wavy margins. The flower is a panicle, usually erect, but sometimes recurved to form a goose neck. Grain or caryopse is usually covered by glumes. Glumes are the maternal plant tissues in the panicle that holds the developing caryopses after pollination. The caryopse is rounded and bluntly pointed, from 4–8 mm in diameter and varying in size, shape and

color with variety. Caryopse color is an important trait that affects grain quality in sorghum. Sorghum caryopses is composed of three main parts: seed coat (testa or pericarp), germ (embryo) and endosperm (storage tissue). In some sorghum genotypes the testa is highly pigmented. The presence of pigment, and the color is a genetic character controlled by the R and Y genes [16]. The thickness of the testa layer is not uniform and is governed by the Z gene. In some genotypes there is a partial testa, while in others it is not apparent or is absent.

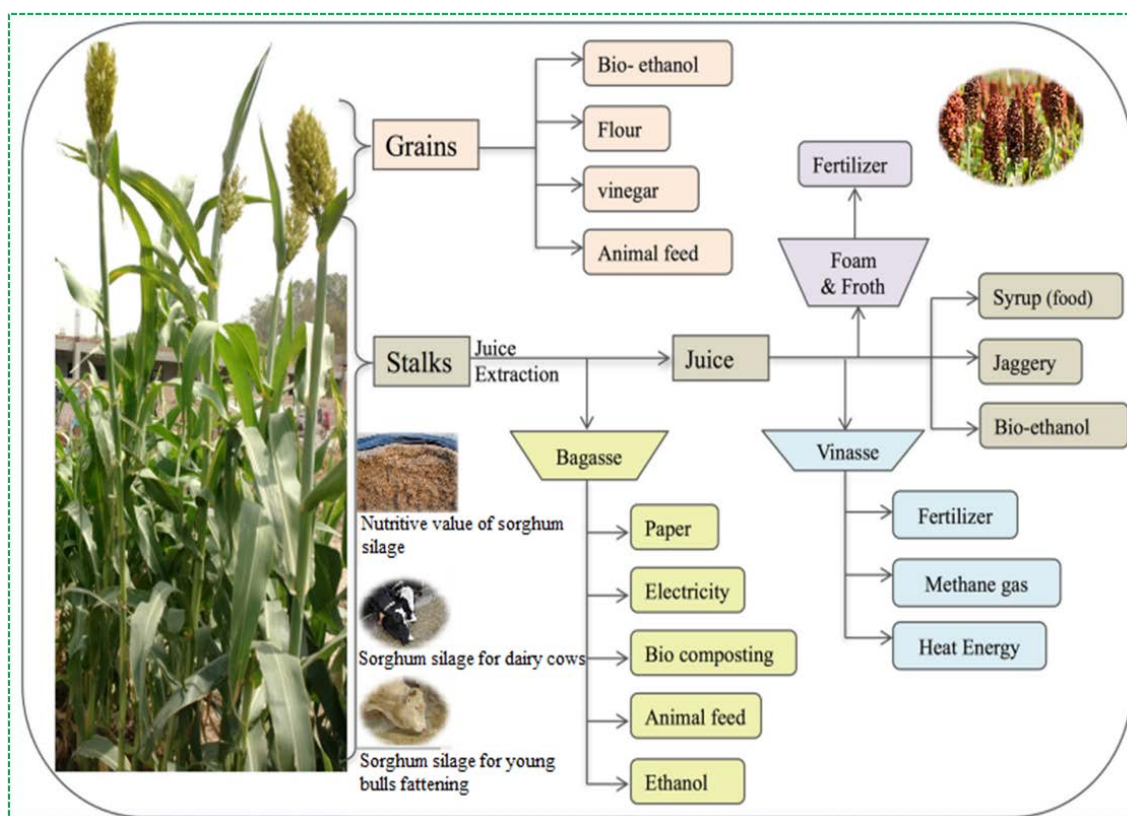
**Table 1. Proximate composition of sorghum grain<sup>a</sup>**

Macro-components (g/ 100g f. m.)	Essential amino-acids	Vitamins (m g / 100g d. m.)	Minerals (mg/ 100g d. m.)			
Carbohydrates	Leu	832 -1480	Vit. A	21RE**	Ca	21
Starch	Ile	215 -460	Thiamin	0.35	Cl	57
Amylose	Met / Cys*	190 -244	Riboflavin	0.14	Cu	1.8
Amylopectin	Lys	126 -277	Niacin	2.8	I	0.029
Non starch	Phe / Tr*	567 -286	Pyridoxine	0.5	Fe	5.7
Low Mw carbohydrates	Thr	189 -425	Biotin	0.007	Mg	140
Proteins	Trp	63 - 187	Pantothenat	1.0	P	368
a-Kafirins	Val	313 -607	Vitamin C	<0.001	K	220
β-Kafirins	Arg*	500 -537			Na	19
γ-Kafirins	His*	200 -234			Zn	2.5
Other proteins						
Fat	Leu					
Ash	Ile					
Moisture	Met/Cys*					

<sup>a</sup>Sources: [17,21,23], \*Not strictly essential amino-acids, \*\*RE = retinol equivalent; f. m. = fresh matter, d. m. = dry matter; NSP = non starch polysaccharides



**Figure 2.** Different product of Sorghum; Flour, popped, bran, flaked, syrup and produce various novel foods



**Figure 3.** Sorghum as a multipurpose crop. The various uses of sorghum juice, grains, and other byproducts have been illustrated

#### 2.1.4. Wine

The grain quality of sorghum affects the liquor quality and yield. Generally, sorghum grains with high starch content, medium protein content, appropriate tannin content and unfavorable fat content are used for brewing. In Africa, sorghum is used to produce low-alcohol beer. For example, sorghum in Nigeria has been used in large-scale industrial production of beers, including yellow opaque beers and dark beers, which are gluten-free, can be drunk by people with celiac disease, and have a pleasing fruit flavor, resulting in great commercial success [58]. The most popular beer in Namibia, is made from wheat, sorghum and millet and can be eaten within a day [59]. Studies have shown that the phenolic content in the beer brewed by white sorghum is more than twice that of barley beer, so the beer has high antioxidant activity, and also contains a large amount of  $\gamma$ -aminobutyric acid, which has potential blood pressure lowering activity. Moderate consumption can promote human health [60]. The potential of white sorghum and red sorghum hybrids for beer production. By measuring the osmotic capacity and  $\beta$ -amylase activity, they found that white sorghum hybrids were the best raw materials for producing higher enzyme activities in the sorghum beer industry. According to the protein content, color and the ether extract of grain germination of sorghum hybrids, it was found that the red sorghum hybrid has the potential to produce excellent biological functional drinks [61]. In many European countries, barley, wheat, rice and corn are commonly used to produce beer, oats and sorghum they have great potential in creating new types and flavors of beer and in saving costs. Sorghum is produced in Europe on a brewing scale less mature than oats, but its versatility makes it a very promising crop. Asian sorghum is mostly

used to make high-alcohol white spirits. Liquor has a long history in China, and it gradually evolves into a special culture - wine table culture. Liquor has now become a part of people's life and plays an important role in the economic development of the country. Studies have found that red sorghum grains are more suitable for the production of white liquor, which has a unique aroma produced by tannin [62]. China have high quality liquor such as Kweichow Maotai, Luzhou Laojiao, Lang jiu, Wuliangye, and so on are made of red glutinous sorghum with high amylopectin content, such as red silk. Shanxi aged vinegar brewed by traditional technology is one of the four famous vinegars in China. Its production has a history of more than 3000 years. The traditional brewing technology has been handed down till now, and the sorghum industry in Shanxi has established a complete industrial chain including research and development, breeding, cultivation, storage and brewing.

#### 2.1.5. Animal Feed

It is generally believed that the nutritional value of sorghum accounts for 95 % of maize, but the market price of maize is much higher than that of sorghum, so sorghum has the potential to replace part of maize in feed applications. In western countries such as America, Mexico and Australia, sorghum is mainly used as animal feed, while the application of sorghum in feed in China is still in the preliminary stage [30]. Palatability, protein and lysine content should be considered when sorghum is used as feed. Generally, appropriate amounts of sorghum are used to feed cattle, pigs, laying hens and other poultry [31,32]. When weaned piglets, growing pigs, finishing pigs. Sorghum in feed of pigs is different in different growth and development periods [33,34,35,36]. Mixture

for feeding laying hens, which could improve the uniformity of laying hens, and sorghum accounted for 4% of the total mixture [37]. Were used to replace corn in different proportions to feed laying hens, and it was found that laying performance and egg nutritional composition of laying hens were not affected, which proved that sorghum could be used as a substitute for conventional feed [38]. When partial or complete sorghum feed was used to feed lambs, it was found that lamb meat color storage was stable, but nitrogen digestibility was low [39]. When sorghum was fed to grass carp and growing otter rabbits, no adverse reactions occurred [40,41]. Tannins is red sorghum production of puffed food, with made of wheat, rice and maize similar commercial dog food flavor, although its flavor intensity than commercial dog food is strong, you need to add other components to make it more delicious, but made from sorghum dog food similar to commercial dog food nutrients, so pets and pet owners can accept [42]. To sum up, sorghum is still the staple food in many areas, and various functional foods are also recognized by people. These functions are mainly based on the low digestibility of sorghum starch and protein, and the high antioxidant properties of tannins. However, like other cereals, the lack of lysine in sorghum grains seriously affects its application. Therefore, to improve the nutritional value of sorghum, we should start with increasing the lysine content of sorghum grains.

#### 2.1.6. Gene gun Transformation Method

Gene marksmanship, also known as particle bombardment of cells. The method relies on a gene gun to help introduce foreign genes. It has the advantages of wide application, simple method, short conversion time, high conversion rate and low experimental cost. Herbicide resistance genes into sorghum by bombarding young sorghum embryos for the first time and obtained two herbicide resistant

materials [43]. Subsequently, many scholars at home and abroad adopted this method to transform sorghum. However, the tissue transformed by the gene gun method will be damaged and the regeneration ability will be reduced, which is the biggest missing point of the gene gun method, and the large copy number will also affect the transformation efficiency. The physicochemical factors leading to low conversion efficiency mainly include: projectile velocity, target distance, bombardment times, and physicochemical properties of the projectile, DNA purity and DNA precipitant.

#### 2.1.7. Pollen-mediated Transformation

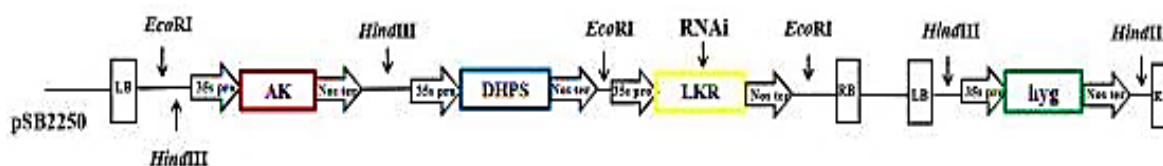
Like other plant cell transformation pollen transformation method uses *Agrobacterium Escherichia coli* as carrier to directly introduce DNA into plant tissues. This method can obtain transgenic plants in a short time, which leads to the application of this method in breeding industry by many breeders. However, due to the thick cell wall of pollen grains, it is generally difficult to transfer genes into mature pollen grains by conventional transformation methods. So techniques were needed to help genes get into pollen grains, and researchers tried a series of experiments: particle gun bombardment, electroporation, vacuum penetration, and ultrasonics. The principle of ultrasonic pollen-mediated transformation is that pollen grains absorb foreign DNA, integrate it into plants and pass it on to offspring [44,45,46], and enhance the entry of foreign genes into pollen granulocytes through ultrasonic treatment technology to improve the conversion rate [47,48]. Because ultrasonic pollen-mediated methods are so easy to use, more and more researchers are trying to transform different species using them. At present, it has been reported that transgenic plants successfully obtained by ultrasonic pollen mediated method include corn [49], sorghum [50].



**Figure 4.** Shanxi Province and its surrounding areas are the enrichment centers of cereal grains. Shanxi sorghum planting and processing has a long history. Volume 7 of *Qimin Yaoshu* recorded the wine-making technology in Shanxi in detail, including "Making Sangluo wine" and "Benqu Sangluo wine", describing the wine-making process and technical details. It shows that Shanxi in the Northern Dynasty has been able to make a variety of fine wine, wine technology also diversified development. In particular, Fenjiu in Shanxi has a history of 4,000 years



**Figure 5.** In western countries such as America, Mexico and Australia, sorghum is mainly used as animal feed, while the application of sorghum in feed in China is still in the preliminary stage



**Figure 6.** Schematic diagram of pSB2250 carrier. CaMV 35S: promoter; NosT: terminator; AK: aspartate kinase; DHPS: dihydrodipicolinate synthase; LKR: lysine ketoglutarate reductase; Hyg: selection gene; Hind III, BamH I, EcoR I restriction endonucleases

### 2.1.8. The Importance of Lysine

Essential amino acids are not synthesized by humans and animals themselves, which need to be obtained from external diet. Usually essential amino acids include lysine, tryptophan, phenylalanine, methionine, threonine, isoleucine, leucine, and valine [51,52,53]. People and animals usually supplement their protein by eating meat and beans, but the diet of people in some developing countries and regions is dominated by sorghum. The content of lysine in sorghum is low and will be destroyed during processing, so it is necessary to increase the content of lysine in sorghum grain. At present, in the feed industry, lysine synthesis is generally added to feed to increase the nutritional value of feed. Commercially available lysine generally exists as salt crystals, which mainly include two types: lysine sulfate and lysine salt salts. These compounds are generally synthesized from corn and other grains through fermentation processing, but they are limited by the production technology of ammoniac acid and have poor competitiveness [54,55]. Therefore, it is of great practical significance to increase the content of lysine in cereal through genetic improvement, which can greatly reduce the production cost of feed and improve the nutritional quality of edible sorghum. Lysine is involved in the synthesis of tissue proteins in human and animal bodies, and it is also the main component of important materials such as enzymes, hormones and antibodies in the body, and has important physiological functions in human and animal bodies [56,57,58]. Medically, it is believed that lysine deficiency can lead to poor appetite, slow growth, weight loss, anemia, mental retardation, reaction retardation and poor disease resistance in children, and infants and young children are prone to eczema due to lysine deficiency [59,60].

## 3. Conclusion

The major goal of this review article is to screen for biochemical markers in sorghum to identify the best suited

sorghum to be used according to the targeted utilization as a source of food ingredient or utilization for specific foods. Sorghum grain composition, and nutrition values, Biological characteristics of sorghum, sorghum grains are also rich in nutrients, sorghum has great potential to develop healthy, functional foods and food additives, sorghum grains with high starch content, medium protein content, appropriate tannin content and unfavorable fat content are used for brewing, sorghum is mainly used as animal feed, People and animals usually supplement their protein by eating meat and beans, but the diet of people in some developing countries and regions is dominated by sorghum.

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