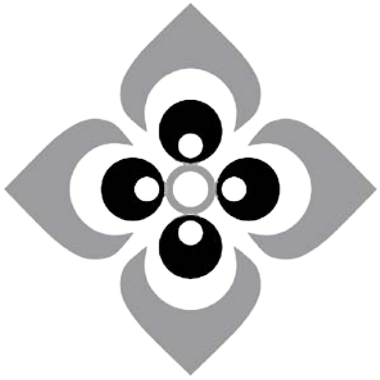

Consortium for Educational Communication

Module
on
Sorghum And Its Products

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TEXT

Introduction:

Sorghum is a summer crop, superior to maize and millet due to its ability to tolerate extremely harsh environments with abiotic stress from the factors like salt, drought and heat stresses (Ghani et al., 2015). It is an indigenous crop to Africa and a basic staple food for many of its rural communities. This is especially because it provides better household food security than maize in the more drought prone areas of South Africa.

Sorghum is mainly cultivated in drier areas, especially on shallow and heavy clay soils. The production of sorghum in South Africa varies from 100,000 ton to 180,000 ton per annum. Globally, it has been considered as an important dietary food of more than 500 million people in 30 countries, and a major feed or forage source for animals. When compared to other cereals, sorghum grows rapidly, and produces both high quality grains and large quantities of nutritious fodder. In rainfed areas, sorghum is stored as silage and hay in order to meet the livestock requirement in periods of fodder scarcity during the winter season (Ghani et al., 2015).

Structure and anatomy of sorghum seed/grain:

The ripe seed (grain) of sorghum is usually partially enclosed by glumes, which are removed during threshing and/or harvesting. The shape of the seed is oval to round and the color may be red, white, yellow, brown or shades thereof. If only the pericarp is colored, the seed is usually yellow or red. Pigments in both the pericarp (fruit coat) and testa (seed coat) result in dark-brown or red-brown color. The sorghum kernel is composed of three main parts: the outer covering (pericarp), the embryo (germ) and the storage tissue (endosperm) (Figure-2).

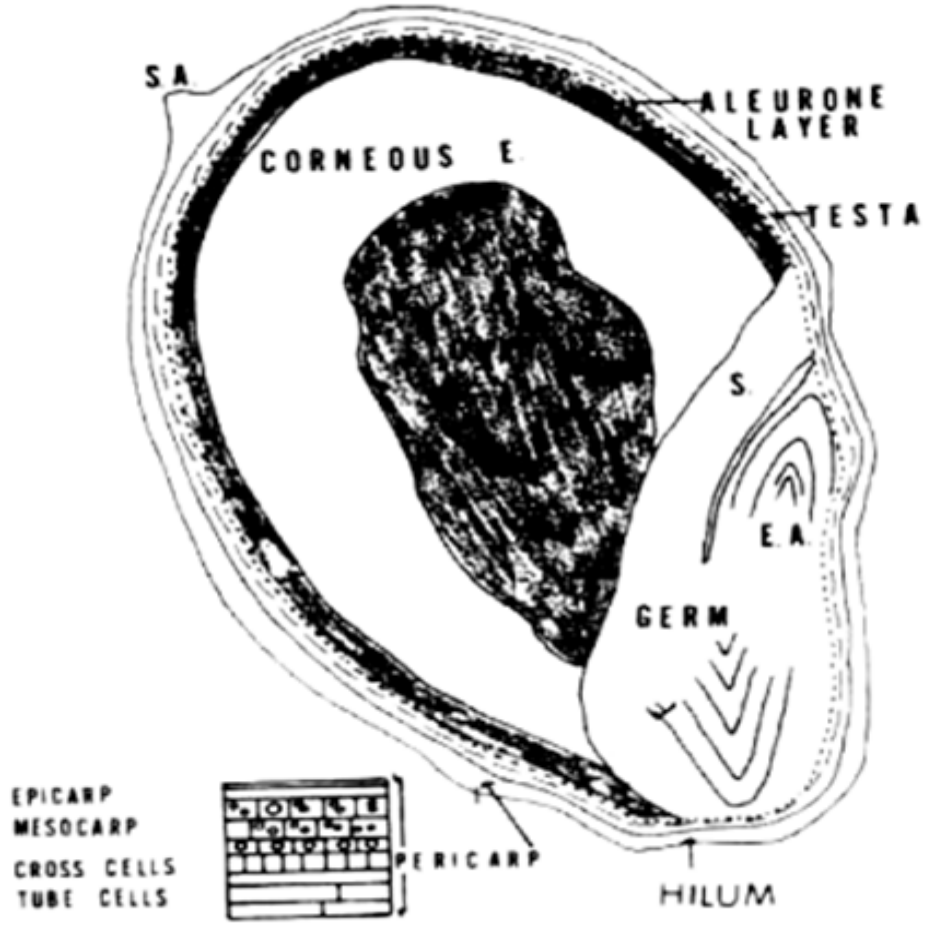

Figure-2: Structure of the sorghum kernal

Pericarp:

Sorghum Kernel is a caryopsis in which the ovary wall dries and adheres strongly to the mature ovule. The pericarp, originating from the ovary wall can usually be divided into four parts: epicarp, mesocarp, cross-cell layer and tube cell layer. Epicarp is the outermost portion of the kernel and is often divided into the epidermis and hypodermis. The first cell layer is epidermis consisting of thick-walled rectangular cells coated by a cutin layer and often contains pigments. The hypodermis layer can be one to three cell layers thick but the cells are smaller than those in the epidermis. The middle portion is the mesocarp. It may vary in thickness from a few remnant cells without starch with a thin, translucent appearance to several layers of cells containing starch granules, which gives a thick, chalky appearance. Mesocarp thickness is controlled by

the Z-gene where thin is dominant over thick, but a wide range in mesocarp thickness can be observed existing in different plants. Mesocarp thickness is involved in mold resistance. Sorghums with a thin mesocarp, in general, appear to be more resistant to molds. However, for hand milling, a thick starchy mesocarp associated with a hard endosperm is preferred. The innermost layer of the pericarp is the endocarp consisting of the cross and tube cell layers. The cross cells are long and narrow with their long axis perpendicular to the long axis of the kernel. The tube cells are wider and up to 200 µm long with their long axis parallel to the long axis of the kernel. The cross and tube cells function to transport moisture throughout the kernel. The cross and tube cells appear to be a major point of breakage when the pericarp is removed during dry milling of the grain.

Just beneath the cross and tube cell layers, some sorghum kernels have a highly pigmented layer called the testa or subcoat. It develops from the inner integument which has a definite cellular structure. The presence or absence of the testa is controlled by the complementary B1 and B2 genes. Some sorghum lines contain a partial testa that is found at certain places around the kernel. Testa thickness varies among sorghum genotypes and within the individual kernels with the thickest part at the crown and the thinnest area over the embryo. The color of the testa can also vary among sorghum lines.

Embryo:

The embryo or germ is composed of two major parts: the embryonic axis and the scutellum. The germ cells are modified into transfer cells, which function in the movement of moisture, microorganisms, and solubilized endosperm components. Glueck and Rooney (1980) showed that the embryo plays a major role in water uptake and mold susceptibility of sorghum kernels. The scutellum cells contain oil globules, protein bodies, and only a few starch granules. The relative proportions of the pericarp, germ and endosperm in kernels vary among varieties of sorghum. For medium-sized sorghum kernels, the bran, germ, and endosperm have been approximately found as 6, 10, and 84 % of the kernel dry weight, respectively. This data was obtained for kernels that had a relatively thick, starchy mesocarp with a prominent germ. Many sorghums with very small germs and thin pericarp exist that would probably have up to 90 % endosperm, 3 - 5 % bran and 5 - 7 % germ. These figures are approximations

based on milling yields obtained from some kernels with a thin pericarp, small germ, and very hard corneous endosperm. The germ of some sorghum cultivars is more deeply embedded inside the endosperm and is extremely difficult to remove while others protrude from the kernel. Kernel size, shape, and details of germ placement inside the kernel affect milling properties, water uptake and mold susceptibility as well.

Endosperm

The sorghum endosperm consists of the aleurone layer, peripheral, corneous and floury portions. The aleurone cell layer is a single layer of block-like rectangular cells located directly beneath the pericarp or below the testa, if it is present. The aleurone cells contain large amounts of minerals, water soluble vitamins, autolytic enzymes and oil. The aleurone cells also contain spherical bodies high in protein, phytin and minerals.

Peripheral endosperm is an ill-defined area directly beneath the aleurone layer. It consists of small, blocky cells containing small starch granules. This endosperm contains free protein bodies that are embedded in the protein matrix and those that are glued together by the glutelin proteins. In the peripheral endosperm, the starch granules are embedded in a dense mixture of protein bodies and matrix and are difficult to remove.

The corneous endosperm (often called hard, flinty, vitreous or horny) is located beneath the peripheral endosperm and has a continuous interface between the starch and protein. The starch-protein bond is strong and starch granules often break rather than pull from the protein matrix. The floury endosperm area, on the other hand, has loosely packed endosperm cells. Small voids occur between the spherical starch granules with little or no matrix protein seen. These voids permit the passage of light through the floury endosperm area causing it to look opaque or chalky in appearance. Protein bodies are present in the floury endosperm but in much smaller amounts than seen in the corneous or peripheral endosperm areas.

Sorghum starch granules are polyhedral with large variation in size from 2 to 30 µm in diameter. Some sorghums have a yellow endosperm containing high levels of carotenoid pigments. Other varieties have bronze hue due to the combination of a thin red pericarp with the yellow endosperm thereby modifying the kernel color. However,

in some varieties the presence of a thick mesocarp causes the masking of color.

Two other anatomical portions of the sorghum kernel are the stylar area and the hilum. The stylar area is the point at which the style was attached during pollination of the seed. The hilum is the scar tissue resulting from detachment of the seed from the funiculus. It is an entry point for moisture and microorganisms to move inside the pericarp. The hilum is sometimes referred to as the black layer, which forms when the kernel reaches physiological maturity, thus acting as maturity indicator.

Nutritional value of sorghum:

Sorghum grains contain 10-13% protein, 2-3% fat and 70-80% carbohydrates. Compositionally sorghum is very similar to the other cereal grains and can be used almost interchangeably with maize. Therefore, its future is very promising towards replacing other grains in feeding programs of dairy cattle and poultry (Ghani et al., 2015).

Unfortunately, the potential of this promising crop has not been realized fully because of several drawbacks that have kept its production at lower levels as compared to other cereals. According to The National Academy of Sciences (1996), the major drawbacks of sorghum include (i) lack of status, with the crop being regarded as a “coarse grain” fit for animal feed and being food of the peasant classes, (ii) regard as crop of low food value, though it hardly differs from maize and wheat. It is regarded as food of low value mainly because of tannins which occur in the seed coats of brown sorghum grains and a large proportion of the protein is prolamine, an alcohol-soluble protein that has low digestibility in humans. Starch digestibility in sorghum is also noted to be lower than maize (iii) difficulty in processing. These drawbacks have contributed to low production of sorghum.

Worldwide distribution:

Sorghum species originated in the semi-arid region of Africa and have been adapted to a wide range of climates, including temperate, humid environments and semi-arid areas of central and southern Great Plains. Sorghum is crucially important to food security in many developing countries, particularly in Africa. Similarly, it is considered a vital crop in arid regions as it requires less irrigation and can successfully tolerate hot summer conditions. Sorghum is cultivated successfully under irrigated and

rainfed areas with a total area under production of 40 Mha in Asia, Africa, Oceania and the Americas. The largest producers of sorghum are India, USA, Mexico, Nigeria, Sudan and Ethiopia. However, Africa and South Asia alone contribute more than 70% of the area for global sorghum production (FAOSTAT, 2015). In the subtropical north-east Australia, dryland sorghum has become an important rotational crop in large cropping regions with about 0.82 Mha.

Types of sorghum

Sorghum is generally classified as waxy and non-waxy on basis of the endosperm composition. These are described below:

- ***Non-waxy sorghum***:

Normal or nonwaxy sorghum starch has approximately 75% amylopectin and 25% amylose. It stains deep purple with iodine.

- ***Waxy sorghum***:

Waxy sorghum starch contains nearly 100% amylopectin. It stains reddish-brown with iodine. Waxy sorghum was first used in the United States in World War II as a substitute for tapioca starch. It has unique cooking and gelation properties of industrial importance. The gross composition of waxy sorghum is nearly identical to that of nonwaxy sorghum. The test weight, 1000-kernel weight and density of the waxy grain are slightly less than non-waxy grain. Also, the starch in waxy sorghums is hydrolyzed more rapidly than that of the nonwaxy counterparts. This explains why waxy sorghums do not generally have acceptable food quality. However, waxy sorghum food products are being consumed in some areas of China.

Sometimes the classification of sorghum is also carried out on basis of the presence of lysine content. High lysine sorghum is generally grown in Ethopia. The grains are soft and floury having a dented structure. The kernel shrivels or dents due to its attribute of synthesizing less starch and loosing water at maturity. Two high-lysine Ethiopian sorghum varieties identified are IS 11758 and IS 11167. The average lysine content of the whole kernel of IS 11758 is approximately 3.13 g per 100 g protein and the total protein content of the kernel is approximately 17.2 percent. S 11167 contains approximately 3.33 g lysine per 100 g protein and 15.7 percent

protein. Normal sorghum varieties are generally found to contain 12 percent protein and 2.1 g lysine per 100 g protein.

Grain processing

Generally, sorghum is dehulled prior to use. After dehulling, grains are made into flour (dry milling) via different methods, depending on the food dish to be prepared and available resources. The various steps of grain processing are described below:

- **Dehulling:**

The equipments required for dehulling of the grains include deep mortar and pestle, winnower, some water, a fairly large container and a flat surface or mat for drying. The method involves putting sorghum into the mortar. The grains are moistened by sprinkling little quantity of water on them. The damp grains are pounded with the pestle to loosen the bran until dehulling of all grains is complete; the dehulled grains are winnowed using local winnower. The winnowed, dehulled grains are put into a large container and washed with water until clean. The method described is a domestic procedure used by all housewives in the areas where dehulling is done. Grains used in the dehulling process are naturally dried to moisture contents as low as 6-9 %. Mechanical equipment for dehulling is not available.

- **Dry Milling:**

Dry processing of sorghum for flour is done in three ways: (a) by using a grinding stone, (b) by pounding with the wooden mortar and pestle, and/or (c) by using a commercial grinder or mill.

- **Grinding Stone Method**

The dehulled grains are washed and spread on a mat to dry. Portions are taken after drying and ground between the mother stone and top hand stone into a fine powder. The powder (flour) is sieved intermittently until all grain particles pass through the sieve. Considerable energy is required to grind the sorghum.

- **Pounding Method**

The dehulled grains are washed, excess water is drained out, and the washed grains are left to temper for 1-3 hr without additional water. Soaking softens the grains.

When the grains are soft enough, portions are put in the mortar and pounded with the pestle. The pounded grains are sieved, at intervals, until all are pounded into flour.

- **Commercial Milling Method**

The dehulled grains are washed, drained, and dried by spreading on a mat or mats. Then the dried, dehulled grains are dry milled using the machine grinder or mill. The most common models of such mills are the Premier Grinding Mill which uses electricity, and the Amuda Grinding Mill which uses a diesel engine. The electric mills are more common in urban areas while the diesel mills are common in the smaller towns and villages.

Wet Milling

Like the flour processing, paste processing from dehulled grains using wet milling is usually achieved by using stone grinding, machine grinding or milling. Unlike flour processing, however, paste processing goes through two phases—the grinding or milling phase followed by the straining phase. The grinding phase produces a rough paste which contains both starch and chaff (pericarp plus bran) while the straining phase produces the smooth paste containing mainly starch and protein, the chaff having been sieved off, dried, and then fed to livestock.

- **Grinding Stone Method**

In this method, dehulled grains are soaked in cold water overnight (about 24 hr) to soften and ferment. The duration of soaking depends on the physical characteristics of the sorghum varieties used. Usually, overnight soaking is for softer, floury grains while harder, corneous grains would have to be soaked for 24 to 48 hr. Then the grains are washed and ground to a coarse paste. The slurry of ground grain is screened through a sieve which usually consists of a muslin cloth. The muslin removes mainly the bran glumes and other coarse particles which are referred to as chaff. Straining procedures are tedious and time consuming. The slurry that passes through the muslin consists of starch, endosperm chunks, and parts of the germ depending upon the extent of the grinding procedure. The strained material is allowed to stand for 5-6 hr and some water is poured off leaving sufficient water to cover the settled paste. In some areas, the steep and wash waters are used for cooking.

PRODUCTS AND USES OF SORGHUM

Sorghum is used in many different applications, such as animal feed, biofuel feedstock, and increasingly in food systems. Compositionally, sorghum is very similar to the other cereals; however both the starch and protein are less digestible than the other cereals. Different products prepared from sorghum include:

1. **Sorghum ogi**

Ogi is a free-flowing, thin, fermented porridge with a creamy consistency and smooth texture. Light colored ogi is preferred with bland to sour taste. The light color results from the color of the grain used, the most preferred being white or cream while yellow grains are also used. Ogi is prepared from paste (endosperm fractions) developed by wet milling. The ingredients include approximately two tablespoons of the wet sorghum paste and 6 cups of water. The paste is mixed to a smooth, thin consistency in two tablespoons of water. Then the paste is poured into boiling water with continuous stirring until the paste gelatinizes. The bowl is covered with a lid and cooked for an additional 2 min. The thin porridge can be sweetened as desired. It is consumed immediately without storing. Some other products like kafa, eko or agide are made similarly except that the water is reduced and the porridge is a stiff, solid mass that is served with soup, stew, or vegetables.

2. **Sorghum Tuwo**

In the northern parts of the Nigerian savanna where sorghum production is greatest, the thick porridge *tuwo* is more extensively consumed than *ogi. Tuwo* is usually a molded or shaped solid processed from dry-milled non-fermented whole grain flour. It exhibits little variation across different places and forms the major source of food for the main meal. The flour from dehulled or whole sorghum is mixed with water and cooked into a thick stiff porridge that is eaten with a soup (sauce) composed of vegetables, meat, and other items depending upon the availability of the ingredients. The basic formula consists of four cups of flour and nine cups of water. Most of the water is brought to boiling. The remaining cold water is used to make a paste of the flour. Then the paste is added to the boiling water. This prevents the formation of lumps. The mixture is stirred vigorously and small amounts of flour are added to prevent lumps from forming. The thick porridge is cooled and consumed immediately;

any leftovers can be stored overnight.

3. **Bogobe**

Bogobe is a sorghum porridge of Botswana prepared from fermented and non-fermented sorghum meal. Fermented *bogobe,* a soft porridge is known as *"ting".* This fermented porridge requires a starter that is made by fermenting a small quantity of sorghum meal in water for 48 hr. A firm non-fermented *bogobe* is called *mosokwane.* Ting is usually eaten in the evening and morning and *mosokwane* eaten for lunch. A variation of *mosokwane* exists in which a small amount of wheat flour and sugar is added to sorghum meal before boiling into porridge. Both fermented and non-fermented *bogobe* may be eaten with meat and vegetables.

4. **Sankati**

Sankati is a type of thick porridge made from sorghum and consumed in several parts of South India. It is prepared by cooking coarse flour grits from either dehulled grain or whole grain. Sankati is called by different names in various regional languages, e.g., *mudda* (Telugu), *mudde* (Kannada), and *kali* (Tamil). Sorghum *sankati* is consumed in Andhra Pradesh, the southern tracts of Karnataka, and all over Tamil Nadu. There is no authentic information on the extent of *sankati* consumption. However, keeping in view the dietary habits in various regions, it is estimated that in the state of Tamil Nadu, about 60 to 70% of sorghum consumed is taken in the form of *sankati.* On the basis of the statewide sorghum production figures (Government of India 1980), approximately 15 to 20% of the sorghum produced in India is consumed in the form of *sankati.* It is eaten by adults as well as children from the age of 4 years.

5. **Sorghum ugali:**

The cooked stiff porridge that is prepared from sorghum is commonly known as *ugali.* For preparation of ugali, a clay pot is used to boil an estimated amount of water. When the water starts boiling, a little flour is sprinkled on the surface of the water and heating is continued. As soon as the water begins boiling again, most of the flour is poured into the pot and allowed to cook for about 2 min. After this one-fourth to one-half of the hot slurry is removed and kept in a separate container. The remaining boiling water and flour in the pot are vigorously mixed with a wooden stick, which has a cylindrical handle and a flat end. Additional slurry or flour is added as required

until ugali with the right consistency is obtained. Then the ugali in the pot is allowed to continue cooking on a reduced fire for an additional 45 min before being served. Sometimes, tamarind water, mango or lemon juice, or milk is added to boiling water to improve the taste and flavor of ugali. Ugali is usually served with beans or peas, vegetable soup, meat or fish stew, etc. To prepare a high quality ugali, the flour used should be ground from clean grain, free of mold and weevil damage.

6. **Injera**

Injera is the undisputed national bread of Ethiopians. It normally means a leavened, round flat bread found in most Ethiopian homes. Sorghum is a highly preferred cereal for preparing injera. The best quality sorghum injera is made from the dehulled grain. Injera as a traditional food is normally used everyday by the whole family for the three daily meals. Adults and children over 2 years of age normally take injera as a staple.

7. **Kisra:**

Kisra is thin pancake-like leavened bread made from whole sorghum flour. It is the predominant staple diet of most people in the sorghum-growing regions of the Sudan. Kisra supplies the main dish in the usual type of Sudanese meal. At its best, it is usually served with stews and other side dishes, or at the simplest level it is served with a relish or sauce or even with just water and condiments (salt and chilies). Typically, kisra is served regularly for at least one of the three meals of the day. In rural areas, kisra may be substituted by a stiff porridge called lugma (asida) as the main dish of any meal, while in urban homes wheat

bread is replacing kisra to a great deal. Ironically, the price of home-grown sorghum is often higher than imported wheat.

8. **Sorghum roti:**

Roti (an unleavened bread) is another most popular sorghum food consumed in India. Sorghum roti is known by various names in the different languages of India like chapati (Hindi), bhakri (Marathi), rotla (Gujarati), rotte (Telugu), etc. Roti is consumed by children from the age of 2 years as well as adults. It is eaten at breakfast, lunch, and supper and is frequently stored overnight. Sorghum roti is consumed with several side dishes e.g., cooked vegetables, dhal, meat, milk, curd, buttermilk, pickles, chutneys,

sauce, etc. Rotis are softened with milk or buttermilk before feeding to old people and children.

9. **Popped sorghum:**

Popped sorghum grains are consumed in several states of India by the poor as well as rich as a snack food and as a delicacy. Popping is done by putting small quantities of grain in a hot pan kept over a steady fire. The popped grains are removed immediately after they are formed. Popped sorghum is considered to be superior to popped corn as they are tender, have less hull, do not clog the space between the teeth, and cause less noise when eaten. Besides, the popped sorghum grains have been found to have as much flavor and be as nutritious as popcorn. Popped sorghum grains are used in the preparation of sweet snacks, which are commonly sold in the state of Maharashtra (India).

10. **Other Sorghum Products**

Sorghum is used to produce beverages, beer, and snacks. These are discussed below:

- Malt

Commercial malt is produced from GM cultivars with specific characteristics while industrial malt is produced from GM and GH cultivars. Condensed tannins in GH cultivars are neutralised before malting commences. The malt is used in the industrial production of sorghum beer.

- Beer

Preparation of beer from sorghum is a lengthy process covering 3 days. Ingredients for the preparation of beer are malt, meal and yeast.

- Beer powder

Instant beer powder is a premixed product that consists mainly of sorghum malt, a starch component and brewers yeast. A 24-hour period is needed before the beer can be consumed.

- Sorghum meal

Sorghum meal, also known as *Mabele*, directly competes with maize meal.

Sorghum with condensed tannins is not used for meal production.

- Sorghum rice

Sorghum rice or corn rice is whole, decorticated sorghum.

- Livestock feed and other animal products

Livestock feed is the most important market for surplus sorghum, as it competes effectively with other grain products in terms of price and quality. Sorghum is an important component in poultry feed and good progress has been made in the manufacturing of dog food, as well as pigeon and ostrich food.

Grading of sorghum

For grading purposes sorghum is divided into the following classes:

1. Class GM :

This includes malt sorghum that does not have a dark testa (condensed tannins). It is listed as a GM cultivar and meets the requirements of Class GM sorghum as stipulated by the grading regulations.

2. Class GL

This includes sorghum which does not have a dark testa (condensed tannins) and is from a GM cultivar that cannot be graded in the Class GM sorghum or from a GL cultivar as stipulated in the cultivar list, and meets the requirements of Class GL sorghum as stipulated by the grading regulations.

3. Class GH

This includes malt sorghum which has a dark testa (condensed tannins) and is from a GH cultivar as determined by the cultivar list, and meets the requirements of Class GH sorghum as stipulated by the grading regulations.

4. *Other sorghum*

This includes sorghum which does not meet the requirements of Class GM, Class GL and Class GH sorghum.