Status and Breeding Requirements for Sorghum Utilization in Beverages in Nigeria

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Abstract

*Sorghum [*Sorghum bicolor *(L.) Moench] grain has traditionally been used in Nigeria for malting and brewing opaque beers such as pito and burukutu on a domestic scale, while the beverage industries depended completely on imported barley malt. Since the imposition of a ban on imported barley and other cereals in 1988, beverage industries have successfully substituted barley malt with sorghum grain as malt and adjunct in the production of lager beer and non-alcoholic malt drinks. Industrial use of sorghum as adjunct requires cultivars with uniform grain size and shape (round or oval), hard endosperm, higher extract and soluble proteins, lower polyphenol or tannin and fat contents, and low gelatinization temperatures. Grains required by the malting industry should possess fast water uptake and high germinability, higher malt extract and enzyme (β-amylase) activities, soft endosperm, low polyphenol/tannin content, and less mold and rootlet activity during germination. Choice of appropriate cultivars, locations, and growing conditions could improve the quality of industrial raw material. Increased collaboration between research and industry is required.*

Nigeria is the foremost country in Africa in both total area cultivated with sorghum and sorghum production (4 million t; FAO, 1994). Commonly called *dawa*, sorghum is the staple cereal in northern Nigeria and is consumed in traditional foods such as *tuwo* (thick porridge), *ogi* (thin fermented porridge), *kunu tsamia* and *massa*. Traditionally, sorghum is also used in some parts of Nigeria in the production of opaque beers such as *burukutu*, *pito* and *otika* by the small cottage industry. Until the 1970s, however, the food and beverage industries in Nigeria totally depended on imported barley malt, wheat, maize, and other cereal products as raw materials (ICRISAT, 1990).

During the 1980s, the government of Nigeria introduced a Structural Adjustment Program (SAP) with emphasis on the local sourcing of raw materials to save foreign exchange and increase self-reliance. Earlier research and development efforts in Nigeria on the prospective use of local cereals such as sorghum came to light, and the Nigerian beverage industries made a strong and successful effort to substitute imported barley malt with local sorghum. It has been estimated through specific surveys in Nigeria that about 120,000 metric tons of sorghum were used per year by the industries (Forson and Ajayi, 1995). The objective of this paper is to summarize the current use of sorghum by the various Nigerian food and beverage industries, review the grain quality requirements for such end uses, and discuss their implication in breeding.

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Current Status of Utilization

Lager Beer

The potential use of sorghum as grain and/or malt in lager beer production was under investigation by researchers in Nigeria during the 1970s and early 1980s (Aisien, 1982; FIIRO, 1976; Okafor and Aniche, 1980; Okon and Uwaifo, 1985; Olaniyi, 1984; Skinner, 1976). Encouraging results led to pilot production trials in 1984 (Koleoso and Olatunji, 1992). However, the brewing industry was not obliged to use sorghum grain and malt in lager beer production until January, 1988, when the ban on barley imports became effective. The breweries have subsequently modified their brewing processes and equipment to a considerable extent to suit sorghum processing and brewing.

Currently several brands of lager beer and stout, such as *Star, Gulder, Satzenbrau, Harp, 33 Export, Trophy, Rock* and *Kronenburg,* are being produced and marketed with a major proportion of their cereal extract derived from sorghum. Several of these are produced by using 50-80% sorghum and 50-20% maize as the cereal source. Preferences for the form of sorghum used in lager beer production vary with brewers. It is used either as raw grain (broken pieces or fine grits) or malt. Different brewers use different proportions of sorghum malt, sorghum grits, and maize grits. For example some brewers use 40% sorghum malt, 40% sorghum grits, and 20% maize grits. However, all the breweries are using significant quantities of external enzymes such as α-amylase, neutral protease, β-glucanase, cellulase, and amyloglucosidase to obtain complete saccharification and wort clarification during the brewing process (Aisien, 1990). Bogunjoko (1992) estimated that one ton of sorghum grain could produce 70 hL of lager that would require 4 kg of exogenous enzymes. Hallgren (1995) described the clear beer brewing procedures required for sorghum substitution mixtures and their associated problems.

During the early 1980s, the sorghum cultivar SK5912, developed at the Institute for Agricultural Research (IAR), was identified as suitable for brewing and malting (Andrews, 1970; Curtis, 1967; Koleoso and Olatunji, 1992; Obilana, 1985). Due to insufficient supply of this grain, however, brewers have been using local Kaura and Farafara grains procured from the markets. The grains of SK5912 and Kaura have yellow endosperm while Farafara has normal white endosperm. The brewers are not satisfied with the grain lots available in the local market because they frequently represent a mixture of different cultivars with similar grain color, and impurities are high. Some breweries have invested in large agricultural farms, where they could grow sorghum and maize cultivars of their choice and obtain uniform and dependable raw material. Guinness (Nig.) PLC has undertaken a contract grower scheme for grain procurement of another recently bred early maturing white grain sorghum cultivar, ICSV400.

The qualities of sorghum malt available to brewers in the Nigerian market vary from lot to lot, and non-uniform grain lots and malt affect their milling and brew house performance (ICRISAT, 1990). The sorghum malting technology in Nigeria is in its infancy and undergoing constant improvement. Only a few companies can supply sorghum malt in commercial quantities; some breweries have acquired their own malting facilities. Floor malting is still widely used, while box malting and various other locally modified methods are upcoming. Problems encountered during industrial malting in Nigeria include molds, cyanogenesis, high malting losses (up to 20%), insufficient modification, and non-uniform germination (Ikediobi, 1990). There also is a shortage of good quality brewers' grits in the market, and some brewers use a coarse meal of whole sorghum grain obtained by hammer milling. The milling quality of the grain available in the market and the milling process are not satisfactory; as a result, millers are able to achieve only a maximum of 50% extraction of grits after dehulling (Hallgren, 1995).

Non-Alcoholic Malt Drinks

The production of lager beer by the brewing industry in Nigeria has declined considerably over the years (ICRISAT, 1990). In 1995, most breweries operated at 50% of their installed capacity and unofficial estimates of total beer produced that year are around only 4 million hL, compared to the original installed production capacity of 18 million hL in 1988 (Bogunjoko, 1992). However, the production of non-alcoholic malt drinks by the same breweries is apparently increasing. A variety of malt drinks with brand names such as *Malta, Maltina, Amstel Malta* and *Evamalt* are being increasingly and successfully marketed.

The production process for malt drinks is similar to that for lager beer until the wort separation stage; alcoholic fermentation is avoided. The wort is further boiled; flavor and coloring agents are added before bottling. Since the ban on imported barley came into effect, the breweries have successfully substituted sorghum grain and malt for barley malt and other adjuncts used in malt drinks. The use of sorghum malt for production of non-alcoholic malt drinks and other food drinks appears to be much more widespread than for production of lager beer. There seem to be no major problems in consumer acceptance and marketing of these malt drinks, which are highly popular and liked across various religious communities. However, problems related to the acquisition of good quality sorghum malt and adjunct by the breweries are the same as those mentioned for lager beer production.

Weaning Food Drinks

Malt cocoa-based weaning food drinks are highly popular in Nigeria. The industries in this sector traditionally used barley malt extract as the base material. However, since 1988, these industries also have successfully substituted sorghum malt or grain extract for barley. The production process involves the preparation of a clear wort, concentration of the wort to a syrup, addition of cocoa, whey, and other nutritive ingredients, and preparation of a dry cake followed by packaging in a granulated form. Several malt cocoa drinks, such as *Milo* and *Bournvita,* are being marketed with considerable sorghum extract contents. The quality of sorghum malt extract is, in general, similar to that of barley malt extract; therefore, locally sourced sorghum malt extract can substitute for imported barley malt in a range of weaning foods at a cheaper price, and some Nigerian companies are selling sorghum malt extract (Solabi, 1990). Recently baby food formulations also have been supplemented with sorghum malt extract.

Sorghum for Malting

Sorghum has traditionally been malted for centuries in Africa to make alcoholic and non-alcoholic beverages. Industrial malting of sorghum based on scientific principles and modern technology has been well established in South Africa, but is only a recent enterprise in Nigeria (Daiber and Taylor, 1995; Ikediobi, 1990; Novellie, 1968). Sorghum can be malted by soaking clean grain in water at 25-30°C for 24-48 hours, then draining the excess water, and allowing germination and growth for about 5 to 6 days at 25-30°C (Palmer, 1992). The moisture level of the grain is kept high (>40%) by frequent sprinkling of water. The germinating grains are frequently turned and aerated, and a high level of humidity is maintained. Microbial infection can be reduced by using 0.1% formaldehyde during the steeping process. The malted grain is dried rapidly at 50°C for about 24 hours to a moisture level of about 10%. In Nigeria, the dried malt is agitated and derooted by screening. Unlike barley, the application of gibberillic acid during steeping of sorghum doesn't trigger enzyme synthesis (Palmer, 1989). Sorghum grain used for malting must meet more stringent and specific requirements than that used for food, feed, or adjunct. However, no official standards of sorghum malt quality have been established in Nigeria, but the following grain and malt characters are desired by the maltsters and brewers.

Clean and Mold-Free Grains

Sorghum grains for malting should be generally clean and free from molds and bacteria. Grain molds are the major problem in sorghum malting, and, in spite of treatment with formaldehyde, fungi located in the endosperm could create mold problems on the malting floor under high humidity and warm temperatures. Sorghum grains produced under hot and humid conditions are ideal for development of fungi such as *Aspergillus flavus* and *Fusarium* spp on the grain surface and can pose mycotoxin problems in the malt (Dufour and Melotte, 1992). Although grain mold-resistant cultivars are desirable, molded grain can be avoided by choosing production environments less prone to mold attack.

High Germinability (95%)

The importance of good germinability of grains used for malting should not be overemphasized. Germinability must be assured by harvesting grain at complete maturity and appropriate moisture content (<12%) and storing it under clean and dry conditions to protect the grain from insect and microbial attack.

Uniform Grain Size and Fast Water Uptake

Uniform grain size is desired in malts for lager brewing because the undersized grains potentially yield lower extract, albeit relatively more protein due to the improved embryo to endosperm ratio. Fast water uptake by the grain is also desired for rapid mobilization of enzyme activity, increased soluble protein, and endosperm modification (Dufour and Melotte, 1992; Ikediobi 1990).

Low Malting Loss

One disadvantage of sorghum as a source of malt is the relatively higher malting loss compared to barley. Malting losses of about 18 to 28% were reported by different researchers after 96 hours of germination, and there were significant differences between cultivars (Illori et al., 1990; Jayatissa et al., 1980; Subramanian et al., 1995). Average malting losses of 20% may have to be tolerated in sorghum while selection for relatively lower malting loss continues.

High Malt Extract (80%)

Percentage of total malt extract is the most important trait considered by lager brewers since it is the net result of enzyme activity, endosperm modification, and solubilization. In opaque beer production, complete solubilization is not required, so percentage of total extract is of secondary importance to diastatic enzyme activity. Palmer (1989) and Dufour and Melotte (1992) suggested improved three-step mashing procedures to obtain higher percentage of malt extracts in sorghum. Swanston et al. (1992 and 1993) observed wide differences between sorghum cultivars for percentage of total extract. Large grain size is important for obtaining a higher percentage of total malt extract.

High Diastatic Power

Diastatic power is the inherent ability of the malt to enzymatically hydrolyze carbohydrates. Diastatic power of sorghum malt is due to the joint activity of α-amylase and β-amylase, both of which are synthesized *de novo* during germination in the embryo and scutellum (Daiber and Taylor 1995; Novellie, 1984). The diastatic power of sorghum malt is much lower than that of barley malt. Also in contrast to barley, in sorghum malt α-amylase is the major component (60-80%) and β-amylase is the minor. The methods employed to measure and express diastatic power by various workers have varied. The joint activity of the two enzymes has frequently been measured and expressed in Sorghum Diastase Units (SDU/g dry malt); one SDU is roughly equivalent to 0.5° Lintner.

The diastatic power of sorghum is widely recognized to vary between cultivars (Novellie, 1984; Daiber, 1988; Jayatissa et al., 1980; Subramanian et al., 1995). The activity of one amylase could be determined by the inactivation of the other. Munck and Mundy (1984) identified two α-amylase isozymes and a homogeneous α-amylase. The saccharification power of malted sorghum is restricted mainly because of limited β-amylase (Nout and Davies, 1982). However, some cultivars can develop significantly higher levels of β-amylase during germination (Palmer, 1989). Munck and Mundy (1984), Swanston et al. (1992), and Dufour and Melotte (1992) analysed sorghum grains from a large number of cultivars and found highly significant differences for β-amylase activity. The α-amylase activity levels were found to be generally acceptable for brewing and sometimes even higher than those found in barley. It is therefore important to select sorghum cultivars with relatively higher levels of β-amylase or a higher ratio of β-amylase to α-amylase.

High Free Alpha-Amino Nitrogen (Fan) Content

During malting, the grain proteins are hydrolysed by the proteolytic enzymes to yield soluble peptides and free a-amino nitrogen (FAN). The ratio of FAN to total nitrogen of the malt naturally indicates the proteolytic activity. In germinating grains, FAN supports the growing seedling, while in brewing, FAN is critical for rapid multiplication of the yeast followed by normal fermentation of the wort (Pickerell, 1986; Taylor, 1983; Taylor and Boyd, 1986). Normally an optimal level of 130-150 mg/L of FAN is required for satisfactory growth of yeast (Hallgren, 1995). Variation due to cultivars and environments has been recognized to be equally important for FAN of malted sorghum (Daiber, 1988 ; Daiber and Taylor, 1995; Chitsika and Mudimbu 1992; Subramanian et al., 1995). Good monitoring and selection of sorghum cultivars with a favorable FAN ratio and optimal fertilization of production fields is required.

Low Polyphenol or Tannin Content

In clear or lager beer production, only white or cream colored grains free from tannins or polyphenols are used for malt and adjunct. Grains of local white grain cultivars procured from Nigerian markets exhibit impurities with brown grains containing testa. White grains with red or purple spots on the pericarp could leach pigment into the endosperm. The polyphenolic compounds not only inhibit enzyme activity, but also lead to color problems in the wort. White grains from tan plant types cause the least color problems of the wort.

Medium to Soft Endosperm Texture

Sorghum malt is relatively hard and less friable than barley malt; therefore endosperm cell wall breakdown is relatively poor and slow during the malting process, which leads to wort clarification and separation problems in lager brewing (Palmer, 1992). During the malting of barley, endogenous β-glucanases degrade the cell walls rapidly, while in the malting of sorghum, endosperm cell walls do not break down, but develop portals through which starch and protein-degrading enzymes pass to access the cell reserves (Palmer, 1991). It has been suggested that sorghum endosperm cell walls might require application of β-glucanases and cellulases to obtain improved modification and wort separation (Etok Akpan, 1993).

Since the peripheral corneous endosperm resists complete modification, Ikediobi (1990) identified loosely packed starch granules and easily accessible protein bodies as desired properties for improved malting. Swanston et al. (1992) found a close relationship between malt milling energy and percentage of total extract. Rooney et al. (1986) suggested that sorghum grains with intermediate texture could be suitable for beer products. Palmer (1989) felt that grains with mealy endosperm may be required by maltsters. Since soft and floury endosperm types are generally known to be vulnerable to molds and storage insects, medium endosperm texture types with a limited peripheral corneous layer and a relatively large central floury area might be suitable for malting.

Sorghum as Adjunct

Sorghum is used by the lager beer industry, as well as the non-alcoholic beverage and baby food industries in Nigeria, as an adjunct or a source of cereal extract. It is used either as a coarse meal or uniform grits, depending upon availability and price. Because of either the lack of well-established industrial sorghum milling technologies or insufficient supply of grain of uniform and consistent quality, there is a shortage of sorghum brewers' grits in the market. Hallgren (1995) discussed the problems associated with brewing a sorghum meal of non-uniform particles, particularly when the flour content is high. Therefore, for sorghum grain to be used as an adjunct, the dehulling and milling qualities are most important. Various grain quality characters that affect milling quality and brewers' grits are considered below.

Uniform Size and Shape

It is now well established that uniform size and symmetrical (oval or round) shape of the sorghum grain are important for mechanical dehulling and processing to grits with minimum milling losses (Murty, 1992).

Low Phenols and Tannin Content

Polyphenols and tannins in the adjunct impart an off color and astringency problems to the extract, in addition to causing enzyme inhibition. In general, grains with testa exhibit poor milling qualities. Therefore grains with white or yellow pericarp (and endosperm) free from colored spots are preferred for milling.

Hard Endosperm Texture

Grains with hard endosperm texture are suitable for dehulling and gritting. Hardness of the grain could be evaluated through various tests: resistance to abrasive dehulling or pearling, flotation, milling energy determination, particle size index (psi) of milled products, milling time/Stenvert hardness measurement, etc. (Hallgren and Murty, 1983; Pomeranz, 1986). All these methods are useful to breeders, although flotation in sodium nitrate and Stenvert hardness tests require small sample size and simple equipment. A combination of the Stenvert hardness test with psi determination of the milled product might yield complete information to select for grain hardness. Hallgren (1995) suggested particle size index determination to evaluate the quality of grits.

Higher Extract (90%) and Soluble Nitrogen

High starch content in the sorghum grits is important for yielding the desired extract (90% on dry basis). The protein content of the grits should be around 8-9%, but more importantly, the grits should possess a favorable ratio of soluble to insoluble nitrogen.

Low Fat Content

The oil content of sorghum grits used as adjunct in lager beer should be less than 1%, because oil reduces the shelf life of the grits and leads to poor foam stability of the beer (Hallgren, 1995). Normally oil, ash, and fiber contents of the grits and other flour products are routinely evaluated. Efficient degermination and milling techniques applied to hard grain sorghum should yield grits with acceptable low fat content.

Low Gelatinization Temperature

The gelatinization temperature (GT) of sorghum starch can be observed by the loss of birefringence in the hot stage microscope. Normally the GTs in sorghum vary between 68-76°C and are higher than those of barley (Hallgren, 1995). Brewers need to follow modified mashing procedures for sorghum and thus incur extra energy costs. Therefore, sorghum grains with lower GTs and better cooking properties are desired by brewers, although the problems are not insurmountable.

Breeding Implications

For millers to produce a good adjunct and for maltsters to produce malt required by the various industries, sorghum grain quality considerations are generally the same except for the relatively soft endosperm texture and higher diastatic power needs of maltsters. Laboratory methods to evaluate the various physical and chemical parameters desired by the industries are straightforward and simple except for the enzyme assays. Sorghum cultivars suitable for producing adjunct must have white or yellow grains (no testa or phenols) of an optimum size (30g/1000) and shape (round or oval) and a highly corneous texture to permit higher extraction of pearled and gritted products. These traits can be achieved by selecting for increased density and hardness of the grain and high recovery from pearling.

In view of the positive correlation of endosperm hardness and mold resistance among white grain types (Jambunathan et al., 1992), simultaneous progress could be made for improved mold resistance. However, maltsters' requirements suggest selection of medium or soft endosperm types, which are unfortunately known to be vulnerable to grain molds in wet and humid environments. In general, the grain protein content of sorghum is fairly adequate and not a serious limitation for industrial use, provided the production environments are properly managed. It might therefore be practical to choose suitable cultivars and environments less prone to molds for producing grain for malting.

Except for grain color and shape, most of the quality traits desired for malting and brewing are affected by genotype × environment interactions. On the other hand, there is a considerable limitation of enzyme activity levels in sorghum required for satisfactory conversion and solubilization during the malting and brewing of lager beer. In view of reports on significant genetic variation for α- and β-amylase activities in sorghum, breeders should pursue selection for a higher β-amylase component in germplasm and breeding collections. The need for sorghum grains with low gelatinization temperatures and lack of endosperm cell wall-degrading enzymes has been mentioned. It is suggested that mutation breeding techniques could possibly be applied to search for such desired sorghum mutants.

Future

Sorghum utilization by the industries in Nigeria is currently less than 5% of total sorghum production, but is widespread in various beverage, food drink, and baby food industries. Observed market prices in the last decade have generally shown sorghum to be marginally cheaper than maize. If this trend continues into the future, it is expected that sorghum utilization by industries in Nigeria will increase. The problems of procuring sorghum grain of consistent quality would be resolved by intervention of the agrobased industries in seed multiplication of sorghum and contract farming in suitable agroecological production zones. The Nigerian experience during the last decade in the industrial application of locally produced cereals is remarkable and could set the trend in other countries of the continent.

Sorghum is probably the only tropical cereal with increased potential for use in malt-based products in the future. Therefore research should focus on improved knowledge of sorghum malting, assessment and use, and methods to reduce local production costs. It would be profitable to fully explore the sorghum germplasm for malting traits. Further advances in technology for malting and brewing of sorghum, coupled with genetic enhancement, could brighten the prospects for industrial use of sorghum. More intensive collaboration between research and industry is called for.

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