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Review

Traditional cereal processing technologies and their importance to African communities: A review

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***Abstract*— Traditional cereal technologies have long been applied in Africa since the dawn of time. Cereal technology is the processing of cereal grain into starch and other nutrients for consumption by humans or animals. The technology involves all processes that the grain is taken through from the farm till it reaches the table for consumption. Examples of traditional cereal technologies employed are sun drying, parboiling, roasting, malting and fermentation. Poor livelihoods and inadequate nutritious foods for some African communities may be alleviated through use of the indigenous cereal technologies. The objective of this review is to discuss various traditional cereal technologies and explain their influence on the life of communities. This review is based on traditional cereal technologies that have been employed over the years and their importance to the livelihood of communities in Africa. Technologies employed by various communities and how they have paved way for the development of current technologies were explored. Information in the review was extracted from various journals and papers on cereal technologies. Some of the information was obtained from different rural communities thereby giving details of technologies being employed todate. The techniques used are an effective way of improving nutritional quality, reducing anti-nutritive compounds and improving the functionality of cereals. Traditional cereal technologies improve sensory properties and shelf life of foods. The technologies are also important in reducing post-harvest food losses and increasing food availability. As reviewed, these technologies bring variety to diets and increase the bioavailability of some nutrients, serve as a source of income and encourage unity in communities. By creating employment opportunities in rural areas, use of traditional cereal technologies contribute to reduction of rural-urban migration. Cereal processing technologies are an important part of community livelihoods, food and nutrition security especially in rural areas. However, there is need to continuously improve some of these techniques to ensure sustainability of livelihoods and food security.**

Keywords*— Africa, cereal technology, fermentation, food security, livelihoods

I. Introduction

Cereal crops are members of the grass family grown for their edible starchy seeds [1]. Cereal grains, such as wheat, corn, rye, oat and rice are important sources of nutrients and energy for humans [2]. Africa is the centre of origin and also a major producer of cereals like sorghum, pearl millet, finger millet, teff and African rice. Another major cereal, maize, has overtaken the traditional cereals while wheat is widely cultivated in North Africa, Sudan and Ethiopia [3]. Production levels of small grains are low due to a lag in improvement of sorghum and millets relative to other cereals such as maize for which stress resilient and nutritionally enriched varieties have been developed [3]. The hybrid maize varieties have higher yields than those of small grains grown from land race varieties of seeds. Cereals like sorghum, millets, wheat, maize and rice are staple foods of populations in most countries [4].

Traditional cereal producers and processors are practitioners of organic cereal food production and processing. This is possible because improvement of soil organic composition on which the cereals are grown is achieved through application of organic fertiliser sources such as organic manure, compost, crop residue retention and crop rotation[5] . Use of organic fertilisers allow sustainable production of organic cereals and other food crops. Therefore, the traditional producers who include small scale farmers have an important role of producing safe organic cereals that are affordable to consumers. A survey conducted in Tunisia revealed that 41% consumer participants were unwilling to spend more on an organic cereal product while 20% were willing to pay more than the original price for the same product [6]. Implementation of organic farming allow consumers to purchase healthy foods produced without use of agrochemicals or processed without food additives.

Cereal technology is the processing of a cereal grain to prepare starch and other nutrient components for consumption by humans or animals. The technology involves all processes that the grain is taken through from the farm till it reaches the table for consumption. Cereal grains are sources of carbohydrates, proteins, vitamins, minerals and fibre for consumers [7]. However, the protein content of cereals is lower than that of animal products like milk and meat [8]. The lower protein content is due to deficiency of certain essential amino acids like lysine, presence of anti-nutrients (phytic acid, tannins and polyphenols) and the course nature of grains [9]. A number of methods have been employed to improve the nutritional qualities of cereals which include thermal processing (cooking, sun drying, par-boiling and roasting), milling, malting and fermentation [10]. Traditional cereal technologies have been used to modify cereals and produce a diverse range of palatable foods.

Techniques such as grinding have been used traditionally for millennia and have sustained most communities [11]. Any kind of processing alters the nutritional quality of grains depending upon type and severity [12]. Distribution of constituents in grain is not uniform, thus processes such as milling can greatly influence the composition of the resultant grain or flour [12]. The capacity of a process to preserve food as well as enhance its qualities is directly related to the level of technological development. The slow progress in upgrading traditional food processing and preservation techniques contributes to food and nutrition insecurity in parts of the world especially Africa. Simple low-cost traditional cereal processing technique enterprises are important to the development of many communities in Africa and other developing parts of the world.

The development of small-scale food industries is hampered by adoption of inappropriate technologies, poor management and inadequate resources that include working capital [13]. While a lot still needs to be done, there have been successes in upgrading traditional cereal processing techniques including the production of traditional opaque beer in parts of Africa [14]. It is important for these techniques to be given the attention they deserve as they are important to the daily lives of many communities. The objective of this review is to discuss various traditional cereal technologies and explain their influence on the life of communities. This research paper is important because after evaluating the role of traditional cereal technologies on communities, new ways to improve cereal processing can be generated [15].

II. Materials and Method

The review comprise of information extracted from journal articles and technical reports on cereal technology. Articles and reports used were selected on the basis of their focus on African cereal technologies. Published literature on cereal technologies was accessed using the Google search engine. Some of the details were obtained through consulting different rural communities in Zimbabwe who provided information on traditional cereal technologies employed to date. Technologies applied in other African countries were sourced from published literature. Post-harvest processes that include grain drying, grinding and milling were reported from observations made on rural community activities. Details of heat processing of cereals that include roasting and cooking were gathered from observation and consultation of the community members. Procedures for preparation of biscuit like products called zvambwa were sourced from Mutoko and Murewa rural communities and published literature. Murewa and Mutoko are districts in Mashonaland East Province of Zimbabwe. Technologies such as preparation of fermented cereal-based products like mahewu and opaque beer were reported on the basis of information obtained through consultation and observation of practices by rural communities. Where applicable, technologies were related to similar cereal processing techniques used by communities of other countries in Africa.

III. Results And Discussion

A. *Analysis of research papers consulted*

(Figure 1) illustrates research articles reviewed in different areas related to traditional processing of cereals. The review mainly consulted papers published on nutritional composition, brewing fermentation, other fermentations and other cereal processing technologies. Cereal fermentations had the highest number of publications consulted followed by other cereal processing technologies. Cereal production had the lowest number of research papers referred to. The review revealed that there is remarkable research in traditional cereal technology being conducted in Africa. The magnitude of research work conducted demonstrated that research on nutritional composition and processing of cereals has the potential to promote value addition of the cereals from which communities may earn income to sustain their livelihoods.

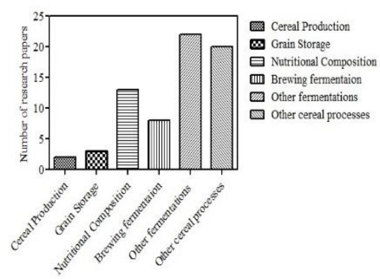

Fig. 1. Analysis of Cereal Science Research Papers reviewed

B. *Traditional Methods of Processing Cereals*

i) Sun drying

Natural drying or sun drying is the traditional and economical practice of drying harvested crop, and is the most popular method in developing countries [16]. The procedure is applied before harvesting when the grain crop is still in the field. For example, maize cobs or sorghum husks may remain on standing plant for several weeks after attaining maturity to allow for sufficient drying of the grain. However, field drying may predispose the grain to attack by birds, insect infestation and mould growth [17]. This method of drying prevents preparation of the land for the next crop and leaves the crop vulnerable to theft and damage by animals. Drying in the field may also be carried out before harvest with the plants laid in stacks with the maize cobs or panicles raised above the ground and exposed directly to the sun [18]. After removal of cobs from plants, the cobs are further dried in direct sunlight as illustrated in (figure 2). Sun drying is part of the post-harvest processes applied to increase the shelf life of cereal grains. This is possible as drying reduces the water activity of the grains which reduces chances of moulding and fungal growth thereby preserving the grains.

Fig. 2. Maize drying in the sun after harvest

Sun dried maize seeds retained higher levels of ash, fat, fibre and protein than seeds dried in an oven at 50 and 100^{o}C [19]. Consumers are set to benefit from the high nutrient content of naturally dried seeds. The sun dried seeds had higher germination capacity (93%) than oven dried seeds whose value was 0% [19]. This implies that community members who cannot afford to buy commercial hybrid seeds may use sun dried grain for planting.

ii) Post-harvest operations

Threshing is a post- harvest operation done to detach grain kernels from the panicle. A panicle is a branched indeterminate inflorescence in which the branches are racemes, such that each flower has its own stalk called a pedicel attached to the branch [16]. This type of inflorescence is largely characteristic of oats and sorghum. Threshing is carried out by trampling on the grain or beating it with sticks. For example, in maize the grains can be removed from the cob after drying by placing cobs in a bag and hitting the cobs in the bag thereby detaching grains from the cob. This process is labour intensive, and it is an important step as it involves loosening the edible part of cereal grain from the husks and straw. This process may be tiresome but it also provides a way to exercise body muscles. The seeds may be detached by swizzing them from the cob by the hands. This procedure is rather painful and slow if the amount of grain to be shelled is large. However, the method results in minimum damage of the grain.

Winnowing is another post-harvest operation used to separate chaff from the grain [20]. This is traditionally done using a winnowing basket whereby grains are thrown into the air allowing grain to separate from chaff on the basis of their different densities. The basket is made from reeds that grow in river banks, making the technique affordable. The process of winnowing takes time but it leaves the grains clean. After winnowing, the cereals can be treated with pesticide powders which prevent pest growth after which the cereals will be stored [21].

After winnowing, dried grain is stored in bulk in a traditional granary. The granary is a hut divided into boxes that can be sealed after placing grain for storage. Each grain is stored in its own box, to prevent mixing of different grains. Using traditional practice, each box containing specific grain is sealed using wet clay. Sealing resulted in pests such as grain borers and weevils dying due to lack of oxygen. Grain stored under the sealed environment remains undamaged for a year or longer. The technology can be afforded by most rural communities since they use locally available resources for construction and maintenance of the facilities. Nowadays, special plastic bags called hermetic bags are used for storing grain [20]. After placing grain into the bags, the bags are sealed resulting in suffocation of weevils or other insect pests due to lack of oxygen. The hermetic bag technique is an example of storage method developed from the traditional sealing of grain storage rooms. Hermetic metal silos designed for storing larger quantities of grain operate on the same principle as hermetic bags. An additional advantage of hermetic metal silo is that it acts as a barrier for moisture exchange between the environment inside and outside the storage structure, thus limiting mould growth [17]. The metal silos design also tap from the traditional storage technology. Storage of grain is done to preserve the grain for consumption throughout the year.

iii) Milling

Milling is done to reduce particle size of grain and prepare it for processing into various products. Traditional milling technologies include the use of a pestle and mortar (pounding) as well as grinding. In Zimbabwe and parts of Southern Africa, pounding of grain is a common cereal processing method. The mortar is a container made of wood while pestle is a wooden pole of about 1.5 m long. Pounding involves moving the pestle up and down striking grain in the mortar with great force using both hands to reduce grain particle size.

During the process, the grain is crashed over and over until the desired grain size has been attained. After pounding, the grain could be boiled and consumed. An example of a product prepared from ground maize is samp or maize meal. Samp can be cooked in a way similar to rice and served with stew, soup or peanut butter. This is done to provide people with a meal that is different from the usual milled maize products. Pounding is an affordable method that is still being used in villages to date compared to hammer mills that cost money. Pestle and mortar method is used traditionally to remove husks from cereals like rice, sorghum and millets. Pounding removes the bran and or germ from cereals [22]. The removal of bran may in turn reduce phytates content localized in the outer aleurone layer in the case of rice and sorghum or in the germ in the case of maize [22]. It has been demonstrated that processing maize by pounding with mortar and pestle to effect dehulling enhanced the bioavailability of iron, zinc and calcium [23]. Decortification was found to have no effect on protein and fat content of millets, but it significantly decreased the content of crude fibre, dietary fibre, minerals, total phenols and antioxidant capacity [11]. It was also established that dehulling of finger millet grains reduced total phytic acid, polyphenols and tannins and significantly increased protein digestibility [11, 24]. Lost nutrients may be restored by fortifying products of the milling process. Alternatively, consumers may compensate for the lost nutrients through implementing dietary diversity.

Another milling technology is the use of grinding stones to make refined cereal products. A small stone with a partly flat surface is used to grind grain like finger millet on a large flat rock into a pulverised meal that can be used for preparation of different food products [11]. An example of a fine powder produced is malt which is formed on grinding malted millet. The powder is used for preparation of traditional beverages like opaque beer. Other products formed on grinding cereals are mealie meal and flour used for cooking and baking respectively. Rural communities apply this technology to milling small grains at no cost as rocks used are obtained from nearby mountains or hills. Modern hammer milling technology has been developed to effect particle size reduction by grinding the grain to yield pulverised meal similar to the traditional procedure. For example, finger millet is ground or milled with the testa which is generally rich in dietary fibre, minerals, phenolics and vitamins to prepare whole meal used for preparation of traditional foods such as roti (unleavened breads), ambali (thin porridge) [25] and sadza/nshima/ugali. Consumption of whole grain finger millet and its products is known to prevent cardiovascular diseases, type II diabetes and gastrointestinal cancers among other health issues [24].

iv) Thermal processing

Thermal treatment is another method of processing cereals. This involves application of heat to the cereals. Thermal processing improves the bioavailability of micronutrients such as thiamine and iodine by destroying certain anti-nutritional factors for example goitrogens and thiaminases [26]. Thermal processing can also enhance the bioavailability of vitamin b-5, niacin, folate and carotenoids by releasing them from entrapment in the plant matrix [27]. Examples of thermal processes are roasting, parboiling and cooking.

Roasting is a traditional processing technique which uses forced convection of heated air as a source of energy. Roasting converts starches to sugars and the process greatly enhances palatability and flavour of the grain. The final product has an appealing and attractive appearance, is dust free and has good colour retention properties. Maize is roasted by stirring in hot sand or in a flat-bottomed frying pot or pan over a hot flame to form a traditional snack of roasted maize. The cereal grains are roasted until golden brown. Roasted grains have an extended shelf life. Roasting ensures a more rapid rate of starch digestion. Roasted grain is nutritionally healthy since no extraction of nutrients will be done on the maize during the process [28]. Roasting enhanced the nutritional value of quality protein maize (QPM) by increasing the bioavailability of lysine, methionine, mineral, vitamins, fat and fibre [29]. However, the content of anti-nutrients namely phytate, oxalate and tannins decreased on roasting the maize [29]. In another study, processing of pearl millet and sorghum that involved a roasting step increased the protein content and significantly reduced the phytic acid and tannin levels [30]. When it dries, the grain could be popped as an alternative method of grain processing. Millets and sorghum are roasted to give an appealing flavour when cooked into porridge. Roasting is applied especially during the harvest season when people have fresh mealie cobs which they roast over fire (Figure 3). Roasting is an important process to the livelihood of communities because roasted maize can be sold for income generation and eaten as a snack.

Fig. 3 Green mealies being roasted for sale by road side vendors

Roadside traders of roasted green maize are evident along major roads in urban and rural areas in Zimbabwe.

v) Cooking

Cooking involves the application of heat which causes change in chemical, physical and nutritional aspects of food to make it more palatable and appetizing. Cooking is done to reduce microbial load and impart desirable sensory qualities. Some of the microorganisms associated with cereals are Lactobacillus plantarum and Streptococcus lactis [31].

Maize meal can be cooked into porridge or a thicker porridge named sadza in Zimbabwe, nshima in Zambia or ugali in East Africa. The dish is prepared almost in the same way as porridge. After boiling, mealie meal is then added while continuously stirring until it becomes a thick porridge. The process of cooking porridge and sadza/nshima/ugali can also be scientifically described as gelatinisation [32]. During gelatinisation, water is imbibed into individual starch granules and causes the granules to swell significantly. The gelatinised starch mixtures become opaque and fragile resulting in loss of the ordered crystalline structure of the starch [33]. Sadza/nshima/ugali is served with a relish that may include meat, vegetables, and pulses like beans or a mixture of the different accompaniments. The maize meal based product is a staple food for most communities in Zimbabwe and parts of Eastern and Southern Africa. Other forms of the same product are prepared using meals of finger millet, pearl millet and sorghum [34]. This is important because communities in regions where maize is difficult to grow due to low rainfall use the same technology to prepare sadza/nshima/ugali or porridge from such grains. The small grains grow in low rainfall regions because of their high drought tolerance.

The syrup made from the pulp of Parinari curatellia fruit and meal of finger millet (Eleusine coracana) are used by people in Mrewa and Mutoko areas of Zimbabwe for the preparation of biscuit-like products called zvambwa [35]. No other vernacular language or Ndebele name is provided because the products are made by communities in Murewa and Mutoko districts of Mashonaland East Province only. The products are used as snacks when the fruit is in season. Some members prepare zvambwa for sale to generate income. When food is inadequate, some communities use zvambwa (Figure 4) as food supplement [36]. The major nutrients in zvambwa are carbohydrates, potassium, magnesium and calcium [37]. Consumers are expected to benefit from the nutrients available in the biscuit-like products.

Fig. 4 Cereal biscuit-like products, *zvambwa* made from syrup of *Parinari curatellifolia* fruit and meal of finger millet

Zvambwa are prepared in the same way as sadza/nshima/ugali, the only difference being that water used in preparation of sadza/nshima/ugali is replaced by syrup made from Parinari curatellifolia fruit. Similar to sadza/nshima/ugali, zvambwa are formed by gelatinisation. The traditional procedure for preparation of zvambwa was described by Benhura [36] and applied to the preparation of zvambwa using Parinari curatellifolia fruit syrup and meals of maize, pearl millet, sorghum, and wheat [37]. This allows communities living in different regions where the cereals are grown to prepare similar products using the different grains. The sustainability of the traditional procedure is based on use of locally grown cereals and Parinari curatellifolia fruit, an indigenous fruit which grows in indigenous forests.

vi) Parboiling

Parboiling involves soaking and heating cereal which pre-cooks the grains, loosen the hull, sterilises and preserves them [38]. Parboiling is usually used to partially cook an item which will later be cooked under different conditions. It is a traditional method that helps in the preservation of the cereal and at the same time it leads to the development of a new flavour when the grain is cooked. The flavour obtained after parboiling is different from that of fresh or sun-dried cereals. Traditionally, green fresh maize is firstly boiled and sun dried followed by separation of the kernels from the panicle. The pre-cooked dry grain can be reboiled later and eaten as it is or mixed with cow peas or nuts to make a tasty and nutritious traditional food called mutakura consumed in Zimbabwe. Similarly to the case of Zimbabwe, communities in Kenya consume a mixture of cooked maize and beans known as gathri as part of their lunch or dinner [39]. This helps to preserve the maize after the harvest season whereby the maize can still be consumed when the cereal is out of season. The product tastes differently from the sundried grain which introduces variety to meals. The dried parboiled grain is sold by producers for income generation. Currently, limited information is available on the scientific properties of mutakura or gathri, implying that more research needs to be conducted to characterise the products for consumers to realise full benefits of the processing method.

vii) Malting

Malting is the controlled germination of cereal grain in moist air. The objective of malting is to generate hydrolytic enzymes, which are not found in ungerminated grain [40]. The steps of malting of cereal grains are steeping, germinating and kilning. Germination of buck wheat was found to increase total phenolics, flavonoid and condensed tannin contents of the kernels [41] In another investigation, germination of varieties of white, sweet and yellow maize kernels for 5 days produced increases of 92%, 46% and 50%, respectively of available phenolic compounds [41]. Phenolic compounds have antioxidant properties due to their free radical scavenging and metal chelating activities [42]. Therefore, foods rich in phenolic compounds protect humans against oxidative damage of macromolecules such as proteins, carbohydrates and DNA [42]. Germination of seeds plays an important role in improving the functional properties of fermented cereal based food products. After production of enzymes required for the degradation of starch and proteins in the cereal grain, germination is stopped by kilning [40]. A reduction in phytates and tannins is generally observed during the malting of sorghum grains and the rate of reduction is a function of soaking and germination times and temperatures [43].

Steeping of cereal grain is the critical stage of the malting process [44]. The steeping process allows modification of the endosperm structure to progress at a rate that produces malt of the desired quality. Anaerobic conditions which result in grain damage are prevented by periodic removal of water and aeration. Traditional malting of sorghum practiced in Africa also starts with soaking of the grain for 10 to 24 hours at ambient temperature [45] without renewal of water or aeration. After steeping, the sorghum grains are spread out on green leaves or a plastic sheet to form a layer (2 to 3 cm thick) and the grains are covered for 2-3 days at ambient temperature [45]. The grain may be turned over at least twice daily while the expected moisture content is managed by spraying with water.

Kilning dries green malt causing grain rootlets to become friable or brittle [40]. Kilning stops embryo growth and enzyme activity, while it minimizes enzyme denaturation, and allows development of flavour and colour. In the African traditional sorghum beer brewing process, germinated sorghum grains are sun dried and stored under protection during the night to prevent rehydration [40]. Generally, drying takes 2-3 days depending on intensity of sunlight [40].

Malting is applied to cereal seeds to obtain the best conditions for fermentation. Malting is traditionally applied to making malt from small grains by some communities in Zimbabwe. Malt contains enzymes which are produced during malting and used during fermentation of cereal malt to produce opaque beer and mahewu. Commercial malting plants have now been commissioned on the basis of traditional malting technology that was applied to small grains.

viii) Fermentation

Fermentation is one of the oldest and most important traditional food processing and preservation techniques [46]. It is a catabolic process in which complex molecules are broken down by microorganisms with a resultant change in flavour, pH and nutrient content. Fermentation is constituted by a desirable process of biochemical modification of primary food matrix brought about by microorganisms and their enzymes [47]. The processes are mediated by lactic acid bacteria or a mixed population of acid producing bacteria and yeasts [48]. An important consequence of these changes is that growth of spoilage and pathogenic microorganisms is inhibited due to lactic acid production that decreases pH making the environment unconducive for most bacteria. For this reason, it has been highly valued over the centuries as a low-cost food preservation method. Weaning cereals based on lactic acid fermentation are very common in Africa [49]. There are four main fermentation types which are alcoholic, lactic acid, acetic acid and alkali. Lactic acid fermentation normally takes place in cereal gruels [50]. Fermentation of cereals leads to a general improvement in the shelf life, texture, taste, aroma, nutritional value, digestibility and significant decrease in the content of anti-nutrients from the cereals [47]. Cereals fermentation decreased levels of non-digestible poly and oligosaccharides, increased amino acid generation and availability of B group vitamins and degraded phytates, which determines availability of minerals [51]. Phytates form complexes with polyvalent cations like iron, zinc, calcium, magnesium and proteins reducing their bioavailability. A reduction in the level of phytates in cereals may increase the bioavailability of iron, zinc and calcium [52]. Fermentation of corn meal increased concentration of available lysine, methionine and tryptophan [53] which was also found to be the same as in millet, sorghum and other cereals whilst in a study of sorghum kisra bread no increase in lysine content was found [54]. The observed increase in bioavailability of vitamins, minerals and proteins points to an improvement in the nutritional value of fermented foods. However, the resulting deficiency in the amino acid, lysine may be addressed by consumers through dietary diversity which enables them to source the nutrient from other food sources.

The type of bacterial flora developed in each of the fermented foods depend on water activity, pH, salt concentration, temperature and composition of food matrix. Lactic acid fermentation contributes to the safety, nutritional value, shelf-stability and acceptability of a wide range of cereal based foods [55]. In many of the processes, cereal grains are soaked for a few days after cleaning during which a succession of naturally occurring micro-organisms will result in a population dominated by lactic acid bacteria. In such processes, endogenous grain amylases generate fermentable sugars that serve as a source of energy for the lactic acid bacteria [52].

Traditional fermented foods prepared from common cereals such as rice, wheat, maize or sorghum are consumed in different parts of the world. Some are utilized as colourants, spices, beverages and breakfast or light meal foods, while others are used as staple foods in the diet [56]. Unfermented traditional foods made from cereal grains usually lack flavour and aroma [57]. Some volatile compounds which contribute to a complex blend of flavours in products are formed from cereals during fermentation. The presence of flavours and aromas produced by di-acetyl, acetic acid and butyric acid makes fermented cereal-based products more appetizing [56]. In light of chemical changes resulting from cereal food fermentation, it is apparent that consumers of traditionally fermented foods benefit from the reactions cited in the literature.

Fermentation is applied locally in Africa for making cereal based non-alcoholic beverages among other fermented foods. Traditional cereal beverage (mahewu) and fermented porridge have a tangy pleasant taste which makes it more appetising for children during the weaning stage. Local cereal based beverages are generally made from grains such as sorghum (Sorghum bicolor), bulrush millet (Pennisetum typhoideum) or finger millet (Eleusine coracana). Mahewu is a fermented, non-alcoholic cereal beverage/gruel and is commonly consumed by all age groups in South Africa [58], Zimbabwe and parts of Central and Southern Africa. Sorghum or millet malt is added to the porridge which is left to ferment. The same beverage may also be prepared using mashed left over sadza/nshima/ugali as a cereal adjunct. Another form of mahewu is prepared by heating a mixture of finger millet malt and water in a clay pot followed by cooling and fermentation overnight. (Figure 4) illustrates traditional preparation of mahewu from finger millet malt/water mixture in a clay pot.

Fig. 5 Traditional preparation of *mahewu* from finger millet malt and water mixture over an open fire in a clay pot

Larger quantities of the product may be prepared in larger clay pots than the one shown in (figure 5) to serve large groups of consumers. The drink is consumed after about 24 hours to allow for fermentation. The traditional procedure of preparing mahewu requires longer fermentation time because of the low initial number of micro-flora, lactic acid bacteria [59]. It is a food prepared for consumption by adults, but is also commonly used to wean children [59]. This could stand as a benefit to communities as no expensive foods will then be required for this purpose. Mahewu provides an easy refreshment also considered to be food and drink as the consistency of the beverage is usually thick because it is made from cooked maize meal, finger millet malt or other cereals. It is a common drink provided at occasions where the community works together in assisting a member to weed or harvest crops. The member being assisted provides the beverage for the community on the day when members work on his or her field. Such functions bring the community together thereby promoting unity.

Tobwa is a non-alcoholic beverage, which is similar to mahewu [59]. The beverage is prepared from left over sadza/nshima/ugali that has been broken into small pieces, mixed with water to form a slurry which is fermented overnight [59]. Unlike mahewu, malt is not added to the slurry, resulting in a total lactic acid fermentation process [57]. Tobwa is consumed by communities whose religious affiliations do not accept consumption of beverages prepared with malt.

Communities in Swaziland prepare a non-alcoholic beverage called emahewu for consumption by family members including infants [60]. The product is prepared from maize meal, water and pieces of peeled potatoes which are left to ferment. Similar to the case of Tobwa, no malt is added to the mixture. Damara/Nama people in the Karas region of Southern Namibia make a maize based non-alcoholic beverage, maxau for family consumption [61]. Maxau is made from fermented maize meal and sugar is added to modify the taste. Misihairambwi and Cheikihyoussef, [61] reported the production of a non-alcoholic beverage known as oshikundu from sorghum and pearl millet meals. The beverage is prepared almost daily by Owambo speaking people in Northern Namibia for household consumption and income generation. Oshikundu is served at weddings and traditional ceremonies like initiation of young girls into womanhood [62]. The main ingredients for preparation of oshikundu are water, pearl millet meal and sorghum meal. The beverage was found to contain vitamins B1 and B2, minerals (B, Cu, Ca, Fe, K Mg, Mn, Na, S, Zn and P), protein and fibre [61, 62].

TABLE 1. TRADITIONAL CEREAL BASED ALCOHOLIC BEVERAGES FROM SOME AFRICAN COUNTRIES

Beverage name	Cereal raw materials	Country of origin	References
Burukutu	Red/white sorghum malt and maize adjunct	Nigeria and Ghana	[40]
Pito	Red/white sorghum malt and maize adjunct	Ghana	[40]
Meroissa	Red sorghum/millet	Sudan	[40]
Tchoukoutou/chakpalo	Sorghum malt, millet and maize adjuncts.	Benin and Togo	[65]
Amgba	Sorghum or millet malt	Cameroon	[66]
Mhamba/Utshwala	Red/white sorghum	Zimbabwe	[67]
Chikokiyana	Millet malt and maize meal adjunct	Zimbabwe	[58]
Tella	Barley, maize, millet or sorghum malt	Ethiopia	[68]
Otombo	Sorghum malt	Namibia	[61]
Omalodu	Sorghum and pearl millet	Namibia	[61]
Umcombotsi	Sorghum malt and maize meal	Swaziland	[60]
Umqombothi	Sorghum	South Africa	[64]

Industrial scale production of non-alcoholic beverages from cereals on the basis of traditional practice is now operational in South Africa and other African countries like Botswana and Zimbabwe [63]. The practice is meant to avail the products to urban dwellers. Traditional beverage technology is therefore playing an important role in spearheading industrialization in developing countries.

There are other traditional technologies for producing different forms of cereal based alcoholic beverages. African beers are brewed using various carbohydrate sources such as sorghum, maize, millet and cereal enriched cassava flour [64]. Traditional sorghum beers are produced in several countries of Africa, but variations in the manufacturing process may occur depending on the geographic localization [40]. The beverages are important for social-cultural roles such as leisure drink in social occasions, paying tribute to traditional leadership, source of income and method of payment for labour rendered [43, 64]. Traditional production methods involve malting, mashing, boiling, conversion, straining and alcoholic fermentation. Sorghum or cereal based beers which are mainly consumed by poor members of society contribute to the diet of some African communities [40]. The beers are rich in carbohydrates, minerals, B group vitamins including thiamine, folic acid, riboflavin and nicotinic acid and essential amino acids like lysine [40]. Examples of African traditional beers and raw materials used for their production are presented in (Table I).

The traditional opaque beer is prepared for drinking during social gatherings as well as for sale to generate income. Typical social gatherings where traditionally brewed beer is consumed are communal weeding and traditional religious ceremonies such as praying for rain [68], at funerals and memorial service of the deceased. The technologies used apply to production of beverages required to perform the traditional ceremonies. This also promotes team building in a community as preparation and consumption of these beverages allow members to assist each other [34, 11]. During gatherings where traditional beers are sold, food is made available for sale to patrons. The common food provided is sadza/nshima/ugali served with relish that may be beef, chicken, pork and vegetables. When the brewer cannot provide, then neighbouring women can help with the preparation of the food and thus earn an income as well. Traditional cereal technologies have played an important role in gender development. In some rural communities, women who produce acceptable quality of traditional beer are recognised by their families and communities. Members of the community who enjoy beer can travel to the homestead of the brewer to buy the product. Other products such as opaque beer residue is produced during processing and can be used in the community to enhance livestock nutrition particularly in times of feed shortage thereby strengthening the livelihood system.

Commercial production of cereal based opaque beer has developed from traditional brewing technology. Examples of commercial brands produced from the initiative in Zimbabwe are Chibuku, Simba beer, Rufaro, Ingwebu, Pungwe and Go beer. Chibuku brand is produced in several other countries like Zambia, Malawi, Tanzania and South Africa. The industrial scale production caters for urban consumers of traditional beer and provides employment for some urban communities.

ix) Baking

The flours made from grinding small grains that is sorghum, finger millet and pearl millet were historically processed into unleavened bread [34]. There are also traditional methods of baking unleavened bread from maize meal. In Zimbabwe, traditional baking is done by digging a small pit, and putting hot charcoal inside, then placing the covered pot with the dough and putting hot charcoal on top. The dough gelatinises and gets done on development of a light cream to brown colour. The product is removed from the heat source, cooled, cut into small portions and served with tea. The product serves as an alternative to wheat flour bread.

C. Benefits of traditional cereal technologies

Cereal technologies like milling introduce variety to the diets of families. For example, the crushing of maize grains using a pestle/mortar produces samp which is different from the usual maize meal or the grains in terms of both taste and texture, thereby introducing variety to diets. These traditional cereal technologies usually make use of the whole grain which make the products richer in nutrients and healthier as no refining occurs. Minimal processing increases the nutritional content to some extent as compared to destructive methods like heating which may degrade certain vitamins [69]. Traditional processing helps to improve the shelf life of grains. For example, where sun drying is used, the moisture content is reduced and thus microbial load is also reduced due to decreased availability of water. Bioavailability of nutrients also increases as a result of these processing techniques [55]. Traditional cereal techniques reduce post-harvest losses. For example, drying methods that reduce microbial growth are effective in increasing grain storage time [70]. These techniques also allow for local trading and hence become a source of income for a community. Traditional cereal technologies are affordable and easy to master and perform. The cereal processing technologies are sustainable as community members use crops they grow and materials they gather from their environment. Cereal processing also ensures that grain and grain products can be made available even after crop season period has long passed. Apart from improving nutrient quality of food, several of the traditional cereal processing techniques are a means of introducing dietary diversity.

D. Limitations of traditional cereal technologies

However, the thermal techniques might result in loss of heat unstable minerals and vitamins while also destroying the matrix or structure of the grain. Malting and fermentation could induce the growth of unwanted microorganisms that could lead to the prevalence of gastrointestinal infections. Other disadvantages of some of these technologies are that the product shelf life is not as long as the products produced commercially. This is because the conditions are not as closely controlled and there are no standardised formulations.

IV. Conclusions

Traditional cereal based products serve as a source of nutrients for thousands of people in Africa and the world over. The techniques used are an effective way of improving nutritional quality, reducing anti-nutritive compounds and improving the functionality of cereals. As reviewed these technologies bring variety to diets and increase the bioavailability of some nutrients, serve as a source of income and encourage unity in communities. Cereal processing technologies are an important part of community livelihoods, food and nutrition security especially in rural areas.

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