J. Agric. Food. Tech., 9(2)1-14, 2019

ISSN 2090 – 424X
Journal of Agriculture and Food Technology
www.textroad.com

Shelf Life and Nutritional Quality of Sorghum Beer: Potentials of Phytogenic-Based Extracts

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ABSTRACT

Increasing agricultural production and value addition through careful use of appropriate technologies is necessary to ensure food security and combat hunger and malnutrition. Through alcoholic fermentation, local beverages such as sorghum beer are made from cereals in developing countries. Sorghum beer production basically comprises malting, mashing, filtration, boiling, fermentation, and maturation. However, due to poor hygiene, low ethanol levels, varying organoleptic characteristics and poor maintenance, sorghum beer seem less attractive, unstable and generally has a short shelf life. Therefore, it is necessary to employ technologies that will improve its nutritional and marketable qualities. Chemical additives are generally undesirable in food preservation. Also, the use of pasteurization seems limiting in sorghum beer production. However, phytogenic-based extracts are considered safe, ecofriendly and not prone to severe microbial resistance. They contain bioactive compounds that may impair the activities of unwanted microorganisms and ultimately extend the shelf life of beer. This review focuses on the role of phytogenic-based extracts in the shelf life of sorghum beer.

KEY WORDS: Antimicrobial activity; essential oil; fermentation; shelf life; sorghum beer

INTRODUCTION

In developing countries, the idea of food security remains at its infant stages causing a lag in the alleviation of hunger and malnutrition [1]. Therefore, increasing agricultural production and value addition to local products through careful use of technical knowledge becomes necessary. Beverages are usually made from cereals like maize, sorghum, and millet through alcoholic fermentation [2, 3].

Sorghum, which belongs to the family, Gramineae is adapted to the semiarid and sub-tropical environments in Africa [4, 5]. Sorghum is the main cereal crop from which traditional beers are produced in many developing countries [2, 5, 6]. These beers are known as pito in Ghana, burkutu in Nigeria [5, 7, 8], ikigage in Rwanda [9], dolo in Burkina-Faso [10], tchoukoutou in Benin and Togo [11], doro or chibuku in Zimbabwe [12], bili bili in Chad [13], amgba in Cameroon, mtama in Tanzania, merissa in Sudan, and kaffir in South Africa [5].

The production and consumption of local beverages are an inherent part of African culture [14]. Sorghum beer is rich in minerals like calcium, sodium, potassium, magnesium, zinc and iron [15].

The production process of sorghum beer generally includes malting, drying, milling, souring, boiling, mashing and alcoholic fermentation, with occasional differences depending on the geographical location [16]. Unlike European beer, lactic fermentation occurs during sorghum beer processing. Also, sorghum beer contains high amounts of insoluble materials such as starch residues and dextrins [5] and is consumed while fermentation still takes place [5, 17]. However, due to poor hygiene, low ethanol levels, organoleptic variation and substandard preservation, sorghum beer seem less attractive especially when compared with Western beers [9]. Also, sorghum beer production process is hindered by the lack of appropriate measuring instruments while wort is often inoculated with yeast from a previous production process making the beer unstable [3]. Therefore, it is necessary to improve the technologies involved in the production and preservation of sorghum beer in order to maintain its nutritional and marketable qualities.

Additives such as calcium chloride, sulphites, benzoates and citric acids are commonly used in food preservation [18]. However, these chemical preservatives may be harmful with risks of cancer, mutagenicity and chromosomal aberrations [18, 19] and thus may present environmental and health threats [20] when used without caution. These concerns have challenged researchers to pursue natural and ecofriendly alternatives that will improve the quality and shelf life of sorghum beer without associated risks. Phytogenic plants have been used extensively in traditional medicine and as additives in food preservation. Most of these phytogenic plants owe their beneficial properties to

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essential oils (EOs) which are secondary metabolites contained in them [21]. Also, such plant extracts are considered safe and not prone to severe microbial resistance [22]. The purpose of this review is to summarize research results on the potential application of phytogenic-based extracts in sorghum beer preservation.

Origin and Socioeconomic Features of Sorghum beer

Sorghum beer is of ancient origins [14] and may have originated from Egypt and Mesopotamia, since 3,500 BC or earlier [15, 23]. The earliest references to sorghum beer was in the 6th century from Arabian migrants who indicated the good qualities of beer produced in the Sahel region [15, 24].

The tradition of producing sorghum beer is preserved for younger generations by women [15]. Sorghum beer is generally used in festivals, marriages, prayers, rituals, birth ceremonies, and burial rites [9, 25]. For instance, in Burundi and Rwanda, the consumption of sorghum beer marks the beginning of handing over dowries during traditional marriages. The concerned families share pleasantries around a clay jug of sorghum beer. This beer signifies the bond between the couple and their respective families [15, 26]. Also, meetings and community work often end with the consumption of sorghum beer [15, 25].

Nutritional Composition of Sorghum beer

Sorghum beer contributes significantly to the diets of many people in developing countries and is largely consumed by the poor [15, 25]. The beer has high B-group vitamins such as riboflavin, folic acid, and nicotinic acid and is rich in amino acids (Table 1). Sorghum beer undergoes a significant loss of dry matter during the production process. This results in a corresponding increase in protein and amino-acid digestibility, as well as availability of minerals and vitamins [5, 25]. Also, amino acid availability is increased by germination [27]. Fe solubility slowly rises during the germination and fermentation stages of beer production and is greatly associated with phytate and phenolic compounds. However, substantial mineral loss is recorded especially during the mashing stage of production, hence the amount of Fe in the final product is limited [28]. Tannins and phenolic compounds in sorghum impair its nutritional quality through endogenous and exogenous sequestration of proteins in the form of indigestible complexes [29]. Conversely, tannins are removed through the beer brewing process [30, 31]. Generally, sorghum beer has higher nutritional value than European barley beers (EBB) owing to its high yeast content, lactic acid bacteria and other suspended materials (Table 2).

TABLE 1. Compositional difference between sorghum grain and sorghum malt

Chemical composition	Grain	Malt
Protein (g)	9.4	9.8
Calories (kj)	381	380
Calcium (mg)	11	9.3
Non-digestible sugars (g)	2.3	3.7
Total sugars (g)	2.3	3.7
Ash (g)	2.1	1.7
Sodium (mg)	14.5	14.7
Niacin (mg)	4.3	5.3
Phytic phosphorus (mg)	166	85
Total phosphorus (mg)	319	327
Riboflavine (µg)	98	231
Thiamine (µg)	407	426
Lysine (g % proteins)	3.3	3.7
Lipids (g)	2.8	2.2
Potassium (mg)	391	361

Adopted from Chevassus-Agnes, Favier [32]; François, Jacques [5]; Maoura and Pourquie [29]

TABLE 2. Nutritional difference between sorghum beer and European barley beer

Nutrients	Sorghum beer	European barley beer
Dry matter (g)	7.9	4.0
Insoluble dry matter (g)	3.9	0
Alcohol (g)	2.9	4.0
Calories (kj)	155	164
Protein (Nx 5,7)	0.6	0.3
Carbohydrate (g)	4.8	3.2
Vitamin B1(mg)	0.11	0.003
Vitamin B12 (µg)	0.03	-
Vitamin B2 (mg)	0.05	0.04
Vitamin C	0.04	-
Calcium (mg)	2.2	6.3
Iron (mg)	2.55	0.1
Potassium (mg)	84	47
Sodium (mg)	1.1	3
Niacin (mg)	0.43	0.71
Phosphorus (mg)	39	40
Pantothenic acid (mg)	0.09	0.18

Adopted from: François, Jacques [5]; Nout [33]

Sorghum Beer Production

Generally, the traditional production of sorghum beer involves malting, mashing, filtration and boiling, fermentation, maturation, and filtration (Figure 1).

Figure 1. Sorghum beer production chart [34]

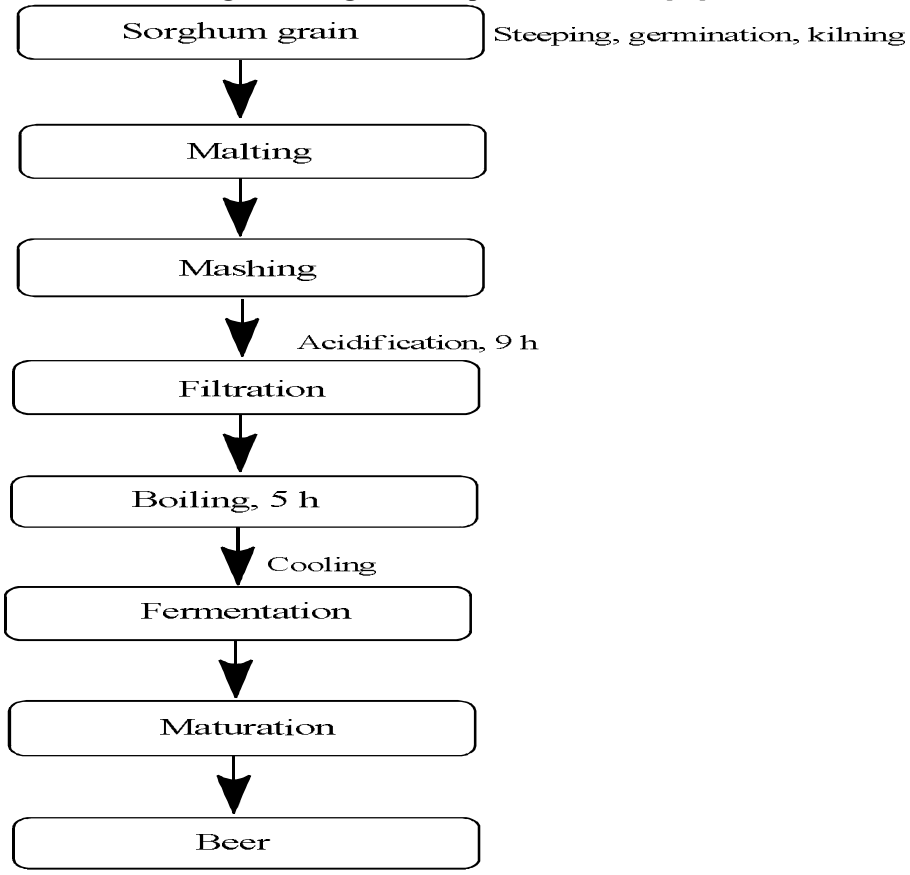
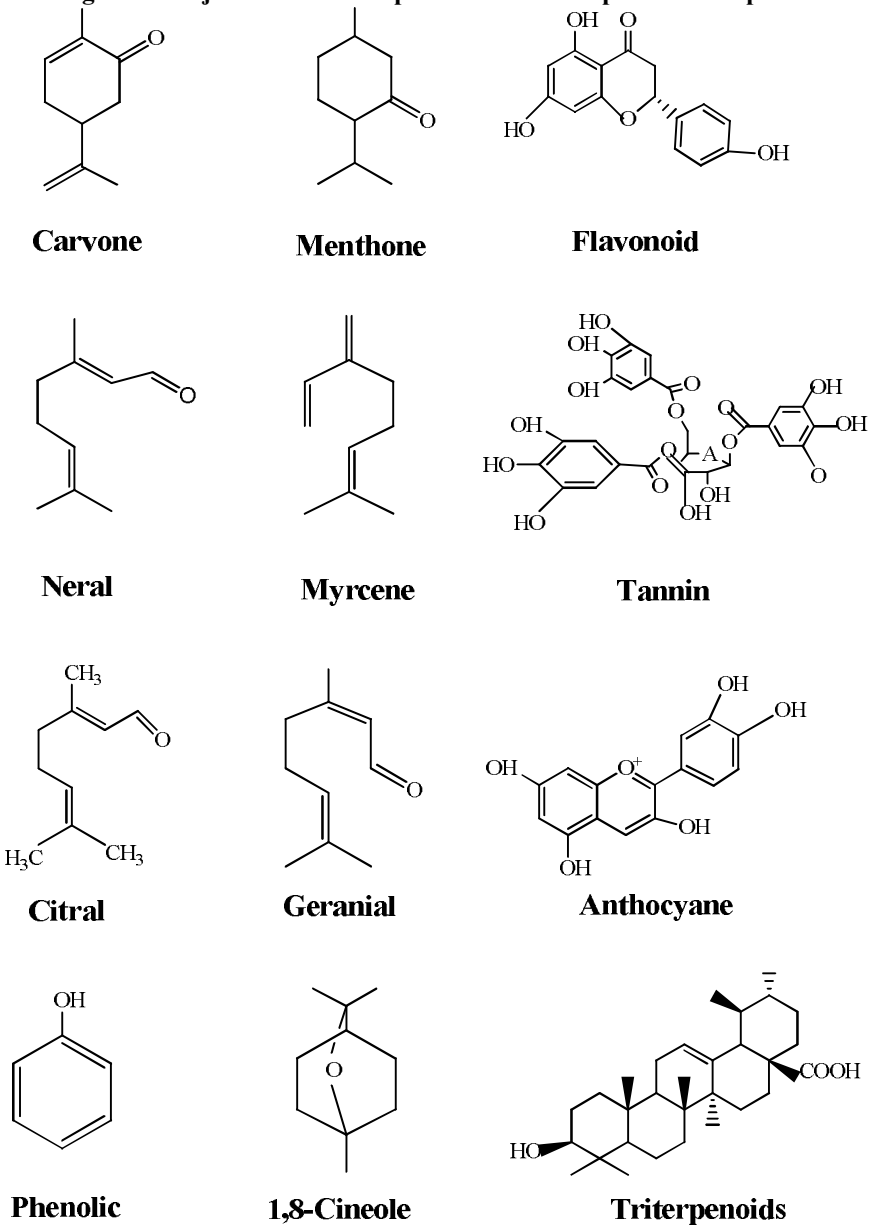


Figure 2. Major bioactive compounds in selected preservative plants



4.1. Malting

Malting is the first stage of sorghum beer production. It involves the germination of sorghum in moist air in order to enhance the development of hydrolytic enzymes [14]. Malting comprises steeping, germination, and drying [15, 35, 36].

Steeping involves the metabolic process of germination by soaking until the grain has imbibed enough water. The time for steeping depends on the cultivar used. A moisture content of 32.4 to 43.4% was recorded when 26 sorghum cultivars were steeped for 24 h [37]. However, steeping time is indicated to have little influence on the ultimate diastatic power of sorghum malt [15, 38].

Germination stimulates the production of hydrolytic enzymes like proteases and starch degrading enzymes. For optimum development of amylase and diastatic power in sorghum malt, the best germination temperature ranges from 25 to 30 °C [38, 39]. Germination also decreases some flavonoids, phytic acids and proanthocyanidins [40] and increases mineral, essential amino acids (mainly Lys, Tyr and Met) [41] and vitamin C [42] availability. However, despite the beneficial effects of germination, it also increases nitrilosides (cyanogenic glycosides) in sorghum grain

[40, 43] which releases cyanide (prussic acid). however, this may be eliminated by heating or removal of shoots, roots and germs [40, 44].

Drying of sorghum malt is usually done at a high temperature in order to turn the rootlets brittle. This is aimed at ending embryo development and enzyme activity, while reducing enzyme denaturation [14]. Drying also produces flavor and color (melanoidin compounds). For example, in Africa, drying is usually done outdoors for 2-3 days depending on intensity of the sun. Drying at a very high temperature (80 °C) may impair enzyme activity of the malt and decrease volatile compounds [14, 45]. A two-stage drying process (first at 55 °C and then at 65 °C) is known to yield malts with high sugar contents and reduced moisture [46] and allows for greater survival of hydrolytic enzymes.

4.2. Mashing

Mashing is done to produce and extract fermentable sugars, amino acids, vitamins and other components from the malt into a solution. Malt generally produces several fermentable constituents and adequate enzymes to produce a well-balanced medium for fermentation. Sorghum beer requires starch as a sugar source and also as an agent for thickening and suspension. Sorghum beer owes its distinctive creamy nature to gelatinized starch which also keeps grain and malt particles in suspension [14].

4.3. Filtration and boiling

In sorghum beer production, mashing is usually followed by filtration and then boiling. Filtration is done by decantation [9] or by the use of a simple press filter stretched over a container with gentle stirring of the solution [29]. Filtration in sorghum beer is generally poor [45] mainly because of insufficient endo-β-glucanase (a cell wall degrading enzyme) in malt resulting in improper endosperm cell wall degradation [47, 48].

Many reasons account for the boiling of wort but mainly, it is done to promote denaturation of malt enzymes and other enzyme supplements as well as malt sterilization [14]. In EBB, hops (flower cones of *Humulus lupulus*) are included during boiling to give the beer its bitter flavor, inhibit the action of some spoilage bacteria, and maintain foam stability [49]. Hops are not grown in tropical regions [14], but tropical plants such as *Vernonia amygdalina, Gongronema latifolium,* and *Garcinia kola* may be used [50-54].

4.4. Fermentation

The most important step in sorghum beer production is fermentation. Generally, a traditional leaven is used to inoculate sorghum wort, with fermentation time ranging from 10 to 24 h in ambient temperature [14] and influenced by various microorganisms (Table 3). Sorghum beer is characterized by lactic fermentation mainly by lactic acid bacteria, followed by alcoholic fermentation by yeast [55]. Yeast convert sugars in the wort into ethyl alcohol [15]. The most predominant bacteria in sorghum beer are *Saccharomyces cerevisiae* and *Lactobacillus sp*. [15].

TABLE 3. Microorganisms involved in sorghum beer fermentation

Country	Local name	Microorganisms	References
Benin/Ivory Cost	Tchakpalo	*Escherichia coli* ATCC 25922, *Penicillium camembertii, Aspergillus niger, Fusarium oxysporum, Staphylococcus aureus* ATCC 25923	[3]; [15]; [56]; [57]
Benin and Togo	Tchoukoutou	*Saccharomyces cerevisiae, Saccharomyces pastorianus, Torulaspora delbrueckii, Lactobacillus divergens, Lactobacillus fructivorans, Lactobacillus fermentum*	[58]
Rwanda	Ikigage	*Saccharomyces cerevisiae, Issatchenkia orientalis, Lactobacillus fermentum, Lactobacillus buchneri*	[59] [11] [25]
Chad	*Bili bili or Amgba*	*Saccharomyces cerevisiae, Cryptococcus albidius, Kluyveromyces marxianus, Lactic acid bacteria, Debaryomyces hanseni,*	[13]
Ghana and Nigeria	Pito, Burkutu	*Saccharomyces cerevisiae, Saccharomyces chavelieri, Torulaspora delbrueckii, Lactobacillus spp., Leuconostoc spp. Leuconostoc mensenteroides, Hansenula anomala, Candida tropicalis, Candida acetobacter, Kloeckera apiculata, Schizosaccharomyces pombe, Kluyveromyces africanus*	[60] [61] [62]
Burkina Faso	Dolo	*Lactobacillus delbruecki, Lactobacillus fermentum, Pediococcus acidilactici, Lactobacillus lactis, Saccharomyces cerevisiae, Lactococcus lactis*	[61] [63] [64]
Zimbabwe	*Doro* or *Chibuku*	*Saccharomyces cerevisiae, Lactobacillus plantarum, Lactobacillus delbrueckii, Lactococcus lactis, Lactococcus raffinolactis*	[65] [12]
Southern Africa	Kaffir	*Saccharomyces cerevisiae, Candida krusei, Kloeckera apiculata, Lactobacillus fermentum, Lactobacillus plantarum, Lactobacillus brevis, Lactococcus dextranicum*	[66]
Cameroon	Safari	*Salmonella Penicillium expansum, Listeria. monocytogenes, P. verrucosum, Aspergillus ochraceus, A. flavus*	[67] [15]

4.5. Maturation

Sorghum beer matures when flocculated yeast is removed. The maturity period for beer varies from 2 weeks to 2 months under cool conditions (2°C) [49]. This process allows for the saturation of beer by fermenting and transforming the remaining sugar into alcohol and CO_2. A complete clarification of the beer takes place at the end of maturation [68].

Shelf Life of Sorghum beer

Sorghum beer is generally characterized by poor stability and short shelf life which remains the main challenge confronting local brewing industries [3, 9, 15, 69, 70]. Generally, yeast is added to untreated wort, resulting in the buildup of residual microorganisms (Table 4). In addition to diarrhea, microorganisms such as *E. coli* are associated with gastroenteritis and urinary tract infections [15, 71]. Yeast increase in number at the beginning of fermentation [14] and either die or go through autolysis where their cell components are discharged into the beer. At this stage, mesophilic lactic acid bacteria and other contaminating microorganisms tend to increase rapidly and the flavor of beer changes because of the metabolites of these microorganisms. Such microorganisms produce acetic acids, pellicles, fruity odors, and off-flavors which make beer taste, odor, and texture intolerable [14, 15]. These occur over a short period of time (generally, not exceeding 5 days) mainly because fermentation takes place under high temperature [15].

In European beer making, the flash-pasteurization method is used to increase the shelf life of beer. Sadly, this method seems unsuitable in sorghum beer due to high increase in beer viscosity through starch gelatinization and removal of amylolytic enzymes and active yeasts which also yields poor effervescence [72].

Application of Plant Extracts as Additives in Sorghum Beer

Phytogenic based extracts and their components are highly volatile, ephemeral, generally biodegradable in nature and broadly acceptable to consumers [66]. Aromatic plants (over 17,000) of the angiospermic families, Asteraceae, Lamiaceae, Myrtaceae, Verbenaceae, Rutaceae, and Zingiberaceae [73-76] contain bioactive compounds that may impair the activities of unwanted microorganisms and improve the shelf life of beer [14]. Such compounds are suggested to counteract the activities of many foodborne pathogens such as *E. coli* O157:H7, *Staphylococcus aureus*, *Salmonella Typhimurium*, *Listeria monocytogenes*, Campylobacter among others [15]. Also, they destroy fungal cells through binding action to ergosterol, which is the main sterol in fungal cellular membrane [15]. This binding action terminates the osmotic properties of the membrane and causes the escape of intracellular sugars, magnesium, potassium, and metabolites which results in apoptosis [15, 77]. This makes such extracts a worthy alternative to synthetic preservatives. The potential applications of extracts of some key phytogenic species in sorghum beer are discussed herewith.

6.1. Mentha spicata

Mentha spicata belongs to the family Lamiaceae (Labiatae) [78, 79] and known for its high polyphenolic compounds and antioxidant properties [78]. Species of the Mentha genus are well known for their volatile oils which are of high economic value and as such, widely used in food, confectionery, pharmaceutical, cosmetic and liquor industries [78]. Essential oils from *M. piperita* extended the shelf life of a low-fat yoghurt drink, fish and vegetables [15]. Reports on the antimicrobial and antioxidant properties of *M. spicata* are limited [78]. A study on the chemical composition and antifungal properties of EO in *M. spicata* revealed carvone (69.5%) and menthone (21.9%) as the main bioactive compounds (Figure 2) [80]. Another study by Kanatt, Chander [78] on the antioxidant potentials of *M. spicata* in radiation-processed meat showed that the inclusion of *M. spicata extracts* could prevent lipid peroxidation and improve the flavor and taste of meat. The strong antimicrobial and antioxidant properties possessed by *M. spicata* [80] make it a potential preservative in sorghum beer. The preservation potentials of *M. spicata* are presented in Table 4.

TABLE 4. Potentials of phytogenic-based extracts in sorghum beer production

Extract Source	Dosage	Measured Parameters	Reported Findings	References
Mentha spicata	1000µg	b-carotene bleaching assay	Strong antioxidant activity	[78]
	50 µg/ml	DPPH RSA		
	1000 µg/ml	Hydroxyl RSA		
	400 µg/ml	Superoxide RSA		
	-	Phytochemical analysis	Major compounds; Carvone, Menthone and Limonene	[80]
	-	Antifungal activity	Antifungal activity	
Cymbopogon Citratus	-	Phytochemical analysis	Presence of geranial, neral, myrcene, geraniol, and geranyl acetate (main compounds)	[3] [15]
	1100 ppm	In vitro antimicrobial analysis	Inhibition of *Aspergillus niger*, *Fusarium oxysporum, Penicillium camembertii, Saccharomyces cerevisiae, Escherichia coli* ATCC 25922 and *Staphylococcus aureus* ATCC 25923	
	0.1%	Sorghum beer stabilization	Improved physico-chemical properties of sorghum beer	
	30%	Antibacterial activity	Inhibition of *Staphylococcus aureus, Bacillus cereus, Bacillus subtilis, Escherichia coli, Klebsiella pneumonia,* and *Pseudomonas aeruginosa*	[81]
	4000	Antifungal activity	Antifungal activity against *Aspergillus ochraceus*, *Penicullium expansum*, and *Penicillium verrucosum*	[82]
Hemizigia bracteosa	-	Phytochemical analysis	Presence of phenolic compounds, flavonoids, anthocyanins, reducing sugars	[83]
	20 µL	Antioxidant activity	Poor DPPH RSA	
	-	Phytochemical analysis	Presence of tannins, flavonoids, anthocyanins, leucoanthocyanes, saponins, mucilage	[34]
		Antibacterial activity	Total aerobic mesophilic bacteria (64% activity); mold (100% activity); coliform (61% activity)	
Callistemon Lanceolatus	0.908 mg/mL	Phytochemical analysis	1,8-cineole, α-apinene, β-apinene, γ-terpinene, isoamyl bromide, p-cymene limonene, geraniol formate	[84]
		Antifungal effect	100% growth inhibition of all fungal isolates observed	
		Antioxidant effect	DPPH RSA was observed	
	100 mg/mL	Phytochemical analysis	Carbohydrates, proteins, saponins, coumarins, quinones, flavanones, volatile oils, phenolic compounds, and tannins detected	[85]
		Antibacterial activity	Antibacterial activity against *Bacillus subtilis, Escherichia coli, Pseudomonas aeruginosa, Proteus mirabilis, Staphylococcus aureus, Agrobacterium tumefaciens, Erwinia carotovora, Pseudomonas syringae, Xanthomonas axonopodis pv. malvacearum, Xanthomonas campestris pv. vesicatoria,* and *Xanthomonas oryzae pv. oryzae*	
	400 mg/Kg	Phytochemical analysis	Terpenoids, saponins, carbohydrates, steroids, fatty acids, flavonoids, phenolic compounds, and alkaloids detected	[86]
		Anti-inflammatory activity	Significantly inhibited carragennan-induced rat paw oedema	

6.2. Cymbopogon citratus

Cymbopogon belongs to the family, Poaceae containing over 120 species mainly in tropical and subtropical regions. Owing to its medicinal properties and extensive uses in cosmetics, pharmaceuticals, food and agriculture, *Cymbopogon citratus* has been cultivated for many years throughout the world. *Cymbopogon citratus* possess antioxidant, antidepressant, antiseptic, antibacterial, astringent, antifungal, nervine, antispasmodic, anti-inflammatory, anti-pyretic, diuretic, and sedative properties and has been useful in traditional medicine for the treatment of malaria, pneumonia, elephantiasis, coughs, ophthalmia, vascular, nervous, and gastrointestinal disorders [87-89]. Main active constituents in *C. citratus* are shown in Figure 2. The properties and effects of *C. citratus* have been studied extensively.

A study on the stabilization of sorghum beer showed that extract of *C. citratus* stabilized the drink for 10 weeks partly because of its antibiotic activity against *E. coli* ATCC 25922 and *Staphylococcus aureus* ATCC25923, and antifungal activity against *Saccharomyces cerevisiae, P. camembertii , Aspergillus niger* and *F. oxysporum* [3]. Furthermore, increasing *C. citratus* essential oil (up to 30%) content resulted in a corresponding decrease in bacterial activity especially gram positive organisms including *Staphylococcus aureus*, *Bacillus cereus* and *B. subtilis* [81]. The potentials of *C. citratus* in the preservation of sorghum beer are presented in Table 4.

6.3. Hemizigia bracteosa

Hemizygia bracteosa (Lamiaceae) is a herbal plant mainly found in the tropics and known to possess strong antimicrobial and hypoglycemic properties [34, 83]. The plant is generally used as a mosquito repellent and for treating malaria and fever [90, 91]. In Southern Africa, smoke from the plant is used for divination purposes and for the treatment of mental illness [92], whereas in Botswana, it is used as an energy source for dancing [93]. Interestingly, *H. bracteosa* is also used as a major component in herbal prescriptions for the treatment of HIV and for reducing the viral load in patients with HIV and/or AIDS [83, 94]. There are limited reports on the potential uses of *H. bracteosa* in food preservation. The effect of *H. bracteosa* on sorghum beer quality was investigated by Konfo, Chabi [34]. The study showed that tannins, anthocyanins, flavonoids, saponins, mucilages and leucoanthocyanes (Figure 2) are major components in the leaves of the plant. Also, the leaves possessed antimicrobial functions and extended shelf life, improved taste and decreased acidity of beer [95]. However, extracts of the plant should be used with care as very high dosages may be cytotoxic [83]. Preservative potentials of *H. bracteosa* are presented in Table 4.

6.4. Callistemon lanceolatus

Callistemon lanceolatus (Myrataceae), usually referred to as bottle brush is a shrub that grows up to a height of 7.5 m and cultivated in gardens all over India [96]. Oils extracted from leaves of the plant are known to have anti-inflammatory, antimicrobial, antifungal, and antinociceptive properties [97-99] owing to activity of several bioactive compounds (Figure 2) such as flavonoids, tannins, fatty acids, triterpenoids, and phenolic compounds [100]. The plant has been used as a traditional herb for the treatment of hemorrhoids [101]. Furthermore, they have been used in weed control [102, 103] and environmental management [103, 104]. Qualitative phytochemical analysis in a study on the antibacterial properties of *C. lanceolatus* leaves revealed the presence of several bioactive principles including saponins, carbohydrates, proteins, coumarins, phytosterols, phenolic compounds, tannins, quinones, and flavanones. Moreover, leaf extracts showed antibacterial activity against several human pathogens (*Escherichia coli, Bacillus subtilis, Proteus mirabilis, Pseudomonas aeruginosa, and Staphylococcus aureus)* and plant pathogens (*Pseudomonas syringae, Agrobacterium tumefaciens, Xanthomonas axonopodis pv. malvacearum, Erwinia carotovora, Xanthomonas campestris pv. vesicatoria,* and *Xanthomonas oryzae pv. oryzae*) [85]. In another study, *C. lanceolatus* leaf extract exhibited high antifungal activity (100% inhibition) at 0.908 mg/mL against fungal isolates (Table 4), aflatoxin inhibition at 0.546 mg/mL and DPPH free radical scavenging activity at 4.54 mg. The authors concluded that *C. lanceolatus* leaf extracts may be suggested as a natural additive for shelf life enhancement in food [84].

Limitations and Future Prospects

Out of over 17000 plants from which active compounds may be extracted, only about 300 are applied commercially [105] owing to limited research in the field. Also, cultivation of such plants is generally expensive due to their low yields [76]. Standardization is necessary for marketing and regulatory purposes. However, variations in the biological expression of plant secondary metabolites at different stages of development, climate, circadian rhythm and phonological stage of plant in relation to proportions of some active compounds, and soil acidity [76, 105-107], make standardization of plant extracts difficult [105, 108]. Moreover, variations in the geography, plant age, harvesting time and extraction methodology [109] causes variations in the chemical composition of plant extracts which may affect biological activity and thus hinder their application as natural additives in sorghum beer [75, 110]. Furthermore, genetic manipulations and new technologies such as ultrasound and microwave assisted extraction methods that aim to increase the production yield and improve the standardized quality in EOs have been suggested to approach these challenges [76]. Again, owing to the strong aromatic properties of some plant extracts even at low concentrations, the organoleptic properties of sorghum beer may be adversely affected. Plant extracts with strong aroma could be applied synergistically with other natural preservation compounds so as to maintain the organoleptic properties of beer [75]. However, further investigation is required to explore options that may reduce the strong aroma of such plant extracts and make them acceptable. Additionally, interactions between plant extracts and food matrix constituents like proteins, starch, and fats may alter the biological activities of plant extracts [111]. Investigation of these interactions before application of plant extracts may be necessary to ensure that their potentials are fully realized. In addition, plant extracts such as essential oils are generally volatile in nature and highly prone to losses during

application and transportation [75]. High essential oil degradation also occurs because they contain more hydrogenated compounds which are susceptible to oxidation, as well as temperature and light which also promote the oxidation process [75, 112]. Modern encapsulation techniques which decrease losses of the bioactive compounds in essential oils may be used to effectively control evaporation [113]. As well, in relation to ecological biodiversity, phytogenic plants that are recognized to possess extracts with strong preservative qualities may face threat of loss in biodiversity especially if options for replanting are not considered. Tissue culture systems using the micro-propagation method to produce large quantities of the plants for commercial purposes may be employed to address this challenge [75].

Conclusion

The nutritional and socio-economic value of sorghum beer makes it the most important local beer in developing countries. However, its poor keeping quality and short shelf life limits its use to full potential. The potential health risks associated with chemical food additives make them undesirable for use. Even though flash pasteurization has been reported to enhance shelf life of beer, gelatinization of beer after pasteurization makes this method unsuitable. Phytogenic plants and their extracts may present a possible safe natural alternative additive for sorghum beer preservation. They contain bioactive compounds that may impair the activities of unwanted microorganisms and prolong shelf life of sorghum beer. According to the findings of this review, extracts from plants such as *Callistemon lanceolatus, Cymbopogon Citratus, mentha spicata* and *Hemizigia bracteosa* possess antioxidant, antibacterial, and antifungal features which make them applicable as natural preservative additives in many foods including sorghum beer. Further research is required to elucidate and fully understand the composition of bioactive compounds in phytogenic food preservatives and to determine the levels that will not significantly alter the quality of beer or pose health threats.

Conflicts of Interest

The authors declare that there are no conflicts of interests.

Acknowledgements

This work was financially supported by the National Natural Science Foundation of China (31601534).

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