Natural spices and flavour substitution in zobo tea and drink production: A review

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Article history
Received: 29 September 2021
Received in revised form: 3 February 2022
Accepted: 7 April 2022

Abstract
This paper reviews the effects of natural spices and flavour on the overall quality of zobo tea and drinks. Zobo is made from the calyces of Hibiscus sabdariffa, also known as roselle. Zobo tea and drinks are rich in nutrients (carbohydrate, fibre, ash, vitamins A and C), minerals (potassium, magnesium, sodium, calcium, and iron), and bioactive compounds (organic acids, anthocyanins, flavonoids, and phenolic acids). These components make them predisposed to microbial proliferation. However, nutrient composition and product quality vary with the variety of raw materials used and methods of production. Zobo can be consumed unsweetened or sweetened with honey, maple syrup, sugar cane, or fruit juice extracted from orange, pineapple, apple, or strawberry. Spoilage activities of microorganisms can be minimised with spices when they are used in place of chemical flavouring and preservatives. Several natural preservatives or spices of organic or natural origin could improve the quality attributes of zobo tea and drinks, and reduce both microbial diversity and density. Some of the widely utilised and potential spices include garlic, ginger, mixture of garlic and ginger, lime, clove, cinnamon, nutmeg, kola nut, and pepper. These spices, along with the dried calyces of H. sabdariffa, have antimicrobial properties, and are rich in phytonutrients, including vitamins and minerals. The overall effects are highly dependent on the biological composition of natural additives and the synergistic or antagonistic effects between roselle calyces and the additives used. If properly packaged, zobo tea can be kept longer than zobo drinks, thus resulting in a product with longer shelf life. The use of natural additives in zobo production would go a long way towards enriching both the zobo tea and drinks, and subsequently replenishing the lack of nutrients.

Keywords
Calyces, tea, zobo, spices, flavour

Introduction
In Nigeria, zobo drinks are locally made as non-alcoholic beverages that are consumed by people of all socioeconomic strata (Olayemi et al., 2011; Izah et al., 2016). The name zobo is of Hausa origin from the northern parts of Nigeria, where it gained its popularity. Zobo drink is also called “yakwua” or “zoborodo” in Hausa, “aukan” in Igbo, “ishapa” in Yoruba, “bissap” in Senegal, “da Bilenni” in Mali, “drink of the Pharaohs” in Egypt, “karkanji” in Chad, “wonjo” in Gambia, “meiguqie” in China, “krajeap” in Thailand, “rosella” in Australia, “flor de Jamaica” in Mexico, “cranberry” in Florida, and “sorrel drink” in other western parts of the world (Olayemi et al., 2011; Izah et al., 2015; Mohammed et al., 2017; Salami and Afolayan, 2020; Adebayo et al., 2021). The various names of the drink reflect its popularity and worldwide acceptance (Adebayo et al., 2021).

Roselle, which is known scientifically as Hibiscus sabdariffa, belongs to the family Malvaceae (Izah et al., 2015; Adeoye et al., 2018). Zobo is obtained by steeping, boiling, and extraction or...
filtration of the flower’s calyx in water (Braide et al., 2012; Adeoye et al., 2018). It could be consumed as hot liquor or cooled, refrigerated, and served chilled for consumption as a refreshing drink. Due to the numerous benefits of zobo, lots of research exist on its nutritional values, medicinal properties, microbial quality, and is sensory characteristics. Zobo is consumed as an alternative to carbonated drinks and alcohols and considered a healthy drink, especially when consumed without sugar (Obi, 2015) because it is rich in vitamins, minerals, and antioxidants. Vitamins A and C, phenols, potassium, sodium, and phosphorus were all found to be abundant in zobo (Egbere et al., 2007). Zobo is also believed to have medicinal properties, and has low glycaemic index when not sweetened with sugar (Adeniji, 2017; Salami and Afolayan, 2020). Zobo contains dietary fibres and phytochemicals necessary for maintaining an ideal body weight, and also for optimal digestion (Akujobi et al., 2018).

Roselle calyces are a good source of phenolic compounds and anthocyanins and are used to make juice, wine, herbal tea, and as colouring for jellies, jams, beverages, and meals (Gbadejesin et al., 2017). According to Salami and Afolayan (2020), zobo contains major bioactive components, including anthocyanins and flavonoids, which have several pharmacological functions. Daphniphylline has been discovered as the primary pigment formerly known as hibiscin. There are also trace amounts of delphinidin 3-monoglucoside (myrtillin), cyaniding-3-monoglucoside (chrysanthenin), and delphinidin (Gbadejesin et al., 2017). The two principal anthocyanin compounds found in zobo calyx are delphinidin-3-sambubioside and cyaniding-3-sambubioside (Adebayo et al., 2021). Some of the beverage’s acclaimed medicinal properties include antihypertensive, diuretic, cough, scurry, and cancer treatment (Obi, 2015). Other than its nutritional and health benefits, dried roselle flowers are easily accessible in most communities, and zobo drink is easy to produce and affordable (Izah et al., 2015; Adeniji, 2017). However, the drink’s rapid deterioration rate at ambient temperature without preservation is the greatest drawback and limitation of large-scale production of the drink (Braide et al., 2012). If not refrigerated, zobo drink has a shelf life of 24 - 26 h after manufacturing at ambient temperature, and approximately three days post-production if refrigerated (Omemu et al., 2006; Izah et al., 2015; Adeoye et al., 2018). The drink’s short shelf life diminishes its capacity to impact long-term wellness for consumers. Most of the deterioration that occurs may be attributed to nutritional deterioration induced by spoilage microorganisms and fermentation of the drink (Izah et al., 2016). Although the majority of the isolates detected in zobo drinks relate to food, the high acidity of the juices may give an explanation for the low quantity and few species of microorganisms isolated (Omemu et al., 2006). Several fungal and bacterial groups (Aspergillus flavus, Aspergillus terreus, Fusarium oxysporum, Bacillus subtilis, and Staphylococcus aureus) that have been associated with zobo drink during storage, have devastating health implications ranging from food intoxication / poisoning to death (in worst case scenarios). Zobo tea, a formulation of dehydrated zobo extract, could be kept longer if properly packaged (Mohammed et al., 2017).

Various spices have been used in food preparation due to their aroma and certain preservative qualities (Obi, 2015). In zobo production, ginger (Zingiber officinalis), garlic (Allium sativum), and clove (Syzygium aromaticum) are the most popularly used spices (Izah et al., 2016). Other spices that have been used include nutmeg (Myristica fragrans), cinnamon (Cinnamomum zeylanicum), pepper (Dennettia tripetala), lime (Citrus aurantifolia), and kola nut (Ezearigo et al., 2014; Izah et al., 2016). Obi (2015) experimented on the preservative effect of Nigerian local spices like uziza (Piper guineense), uda (Xylopia aethiopica), ehuru (Monodora myristica), and ehu (Aistonei boonei) on zobo. Overall, the use of spices improves the nutrient content, flavour, and health benefits of zobo (Izah et al., 2015).

There has been research on using sodium benzoate and acetic acid to make zobo drinks last longer (Braide et al., 2012; Izah et al., 2016). However, with growing concerns about the adverse effects of chemical preservatives (Mohammed et al., 2017; Adeoye et al., 2018), the use of natural spices as potential antimicrobials and preservatives has been investigated (Adeoye et al., 2018; Salami and Afolayan, 2020). Microorganisms associated with zobo drinks are bacteria (Staphylococcus, Escherichia, Proteus, Pseudomonas, Salmonella, Shigella, Enterobacter, Klebsiella, Serratia, Bacillus, Streptococcus, Lactobacillus, Clostridium, Corynebacterium, Aeromonas, Micrococcus, Stenotrophomonas, Leuocobacter, Pantoaea) and fungi (Aspergillus, Saccharomyces, Penicillium, Candida,
Rhizopus, Fusarium, Mucor, Geotrichum) (Izah et al., 2015; Adeoye et al., 2018). Salami and Afolayan (2020) found that a zobo drink made with lime extract had a lower microbial load than a zobo drink without it. This could be due to its acidic nature, which inhibits the survival of many pathogens while promoting the growth of acidophiles. Izah et al. (2016) reported that both ginger and garlic had antibacterial properties, but that combining the two spices in zobo had a greater effect than using them separately, while Adeoye et al. (2018) reported that despite the fact that ginger extracts are effective against both Gram-positive and Gram-negative bacteria, the combination of clove and ginger is more effective in suppressing microbial activity than either of the spices when they are used alone in zobo. Braide et al. (2012) stated that lime was the most effective in reducing microbial activity in zobo as compared to garlic, ginger, and clove. The ability of natural spices to inhibit pathogenic growth was found to be in this ascending order: nutmeg, cinnamon, kola nut, clove, garlic, ginger, ginger + garlic, lime (Izah et al., 2016).

Obi (2015) reported that zobo drinks treated with ehuru had no microbial growth, and were better than those treated with ginger, after six days. Due to the numerous benefits of zobo drinks, this paper reviews the effects of fruit and spice extracts on the overall quality of zobo tea and drinks.

Zobo drink

The calyx of the red variety of Hibiscus sabdariffa is used in zobo drink and tea production, while the green variety is used to prepare stews, soups, and sauces (Izah et al., 2015). According to Olayemi et al. (2011), the three types of Hibiscus sabdariffa used in zobo drink preparation are the dark red, bright red, and wine-coloured varieties, while the leaves are used in soup preparations, and the oil from the seeds is considered a source of nutritional minerals. The leaves could also be used to produce syrup, jelly, jam, and gelatine, while the seeds are a good source of oil (Akujobi et al., 2018). Although zobo tea and drinks are rich in nutrients, minerals, and bioactive compounds, which make them predisposed to microbial proliferation, their nutrient composition and quality vary with the variety of raw materials used and methods of production (Olayemi et al., 2011). Generally, zobo drink has a tangy / sour profile, with low pH as the plant is naturally acidic, and contains glycosides, alkaloids, tannins, polyphenols, saponins, sterols, and phenols, as well as oxalic, tartaric, malic, and succinic acids (Bola and Aboaba, 2004; Builders et al., 2010; Olayemi et al., 2011; Salami and Afolayan, 2020).

Zobo drink is made using locally available technology from the acid-succulent roselle plant calyx (Adeniji, 2017) by aqueous extraction in preferred solid-solvent ratios (Izah et al., 2015). Production processes for zobo production are very crude and not mechanised. It needs to be fully standardised and regulated (Braide et al., 2012; Obi, 2015). Experimentation with various plant materials included as a blend in zobo production is now frequent, with the goal of improving the drink's nutritional quality, flavour, and shelf life. Honey, maple syrup, or sugar cane are used to sweeten the harsh sour flavour of Hibiscus sabdariffa raw extract (Salami and Afolayan, 2020), or with fruit juice of orange, pineapple, apple, or strawberry (Fasoyiro et al., 2005; Egbere et al., 2007; Adeniji, 2017; Akujobi et al., 2018).

Zobo tea

In an effort to increase the shelf life, convenience, and acceptance, and overcome the limitations of large-scale production and distribution of zobo, novel zobo tea is being investigated and developed. Infusion, dehydration, and size reduction processes were used to create an instant zobo drink / tea combination by Mohammed et al. (2017). The calyx was cleaned, sorted, and infused with water at about 72°C for 90 min, then dehydrated at 72°C for 5 h and 45 min before being cooled and pulverised to instant powder, which was subsequently mixed with pulverised granulated sugar. To obtain the beverage, the instant powder was directly mixed with water and reconstituted. Other methods suggested by the researchers for zobo tea production include extraction, concentration, and dehydration by freezing or spray-drying to reduce the loss of nutrients. Ibeabuchi et al. (2019) formulated a zobo mix recipe of dried roselle calyx powder, moringa leaf powder, dried ginger, and clove powder, together with orange flavouring. The zobo-moringa mix was packaged in teabags and reconstituted by extraction using hot water. Zobo tea, a formulation of dehydrated zobo extract, could be kept for longer, thus giving the product an extended shelf life if properly packaged. The use of tea bags in zobo tea packaging would reduce quality loss, contamination, and discoloration while allowing for large-scale production and storage with optimal nutritional value.
Natural spice and its importance in zobo tea and drink production

As a result of the search for natural sources of antimicrobial additives that are harmless and effective when used in foods, extracts and essential oils from spices, herbs, and other plants have been studied, and their antimicrobial activities have been reported (Youssef et al., 2013). Common everyday spices have been used to enhance the flavour and aroma of foods for centuries. Spices are aromatic or strong-tasting plant substances that are native or exotic in origin, and are used to enhance the flavour of foods. Leaves (coriander, mint), buds (clove), bulbs (garlic, onion), fruits (red chilli, black pepper), stems (cinnamon), rhizomes (ginger), and other plant parts can be used as spices (Pundir et al., 2010; Izah et al. 2016). Obi (2015) also reported that apart from spices being used as flavour enhancers, some spices are traditionally used as food preservatives. Food preservatives are any chemicals or ingredients added to food to aid the retention of its physicochemical and microbial quality over a longer period of time than is naturally possible. With growing concerns about the adverse effects of chemical additives, the use of natural spices as potential antimicrobials and preservatives has been investigated (Egbere et al., 2007; Nwachukwu et al., 2007; Omoruyi and Emefo, 2012; Braide et al., 2012; Adesokan et al., 2013; Adeoye et al., 2018; Mahomoodally et al., 2018; Salami and Afolayan, 2020). Alkaloids, phenolics, flavonoids, tannins, and saponins are secondary metabolites that are accountable for herbal plants’ medicinal and antimicrobial properties (Youssef et al., 2013).

Fruit juice extract has also been used in place of artificial flavours in food production (Fasoyiro et al., 2005; Akujobi et al., 2018). Moreover, spices and fruits are readily available and inexpensive; also, some synthetic / chemical food flavourings contain compounds that are toxic, mutagenic, carcinogenic, and genotoxic (Izah et al., 2016). Some plant additives with applications in zobo drink production are highlighted in the present review, giving bearing to expectations for their application in zobo tea powder production.

Clove

Clove (Syzygium aromaticum) contains several metabolites, including terpenoids, glycosides, phylobatannin, tannins, saponins, sugars, steroids, flavonoids, and coumarins (Youssef et al., 2013; Izah et al., 2016). Clove oil, which is produced from the plant’s flowers, contains β-caryophyllene, which represents 14 - 21% of its compounds and 10 - 13% of tannins, as well as sesquiterpenes and phenols. Apart from eugenol, which is a major component of clove oil, and responsible for the plant’s scent, phenylpropene is the most important component (Izah et al., 2016). Clove buds and essential oils have been known to have antimicrobial and antioxidant properties, with the major constituents being eugenol acetate, eugenol, and caryophyllene, with the latter two having antibacterial and antifungal properties (Pundir et al., 2010). Clove has diuretic, odontalgic, stomachic, tonicardiac, and aromatic condiment activities, as well as carminative, stimulant, antibacterial, and anti-inflammatory properties (Izah et al., 2016). Clove has antibacterial effects against Escherichia coli, Escherichia cloacae, Klebsiella pneumoniae, Salmonella Paratyphi, Citrobacter sp., and Staphylococcus aureus ATCC 25923 (Ayoola et al., 2008), and antifungal effects against Aspergillus flavus, Aspergillus niger, Aspergillus ostianus, Fusarium solani and Candida albicans (Youssef et al., 2013). Pundir et al. (2010) reported that clove has effects against Bacillus subtilis, Bacillus megaterium, Bacillus sphaericus, Bacillus polymyxa, Staphylococcus aureus, Escherichia coli, Penicillium oxalicum, Aspergillus flavus, Aspergillus luchuensis, Rhizopus stolonifer, Scopulariopsis, and Mucor sp.

Braide et al. (2012) studied clove as a preservative for zobo drinks. They reported that bacterial density was higher than control after 24 h of production, dropped between 48 - 72 h, and then increased again after 96 h. After 24 h, no fungal growth was observed, and the population was lower than the control throughout the 24 - 36 h period, according to the authors. Clove appeared to have a better effect on the zobo fungal population than on the bacterial population. Clove significantly lowered the density of Micrococcus roseus, Staphylococcus aureus, and Enterococcus faecalis bacteria; moderately lowered the growth of Rhizopus stoloinfer, Aspergillus flavus, Saccharomyces cerevisiae, and Saccharomyces ellipsoideus fungi; only slightly lowered the growth of Mucor spp. and Penicillium.
caseicolum fungi, while entirely eliminating Fusarium poae fungus (Braide et al., 2012). Adeoye et al. (2018) also reported that 0.25% clove and above in zobo drink had inhibitory effects for up to 16 days of storage at ambient temperature after pasteurisation, with better inhibition against fungal colonies observed. Reports from Youssef et al. (2013) showed very high antifungal activity of clove oil extracted with n-hexane on Aspergillus ostianus and Alternaria alternata after 72 h of inoculation. In comparison to other medicinal plants evaluated, ethanol-extracted clove oil had better inhibitory effects against the tested fungi but had the most impact against Alternaria alternata. The use of Moringa oleifera extract for the enrichment of zobo drink produced with ginger, garlic, and clove impacted on its overall sensory acceptability. The contents of the enriched zobo drinks improved. They contained vitamins A and C, iron, manganese, magnesium, and phosphorus contents. However, Moringa enhanced the growth of microorganisms in zobo drinks, hence the need to identify alternative natural preservative methods to increase the shelf life of zobo drinks if the goal of commercialisation is to be achieved (Bassey et al., 2020).

Ginger

Ginger (Zingiber officinale) is one of the most widely used herbs for food flavouring and health benefits, as well as a key ingredient in zobo production, and belongs to the family Zingiberaceae (Izah et al., 2016). Bioactive compounds in ginger include tannins, flavonoids, alkaloids, phlobotannins, glycosides, saponins, and terpenoids. Bello and Osho (2012) reported 42.31% tannin, 5.04 × 10^{-5} saponin, 28.60% alkaloid, and 0.78% total phenol in ginger. Ginger’s ability to reduce inflammation helps to stimulate the heart and circulatory system; it also has hepatoprotective, nephroprotective, antioxidant, larvicidal, antidiabetic, antidiarrheal, anti-inflammatory, antifungal, antibacterial, antihelminthic, cytotoxic, and analgesic properties (Izah et al., 2016). As such, ginger is commonly used to treat ailments such as arthritis, rheumatism, sprains, muscular aches and pains, sore throats, cramps, constipation, indigestion, vomiting, hypertension, dementia, fever, infectious diseases, and helminthiasis. According to Izah et al. (2016), Zingiber officinale has been found to have antimicrobial properties against Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, Enterococcus faecalis, Klebsiella pneumoniae, Bacillus cereus, Enterobacter aerogenes, and Proteus mirabilis. Braide et al. (2012) reported the high microbial effects of ginger against Micrococcus roseus, Staphylococcus aureus, and Enterococcus faecalis bacteria, and Rhizopus stoloifer, Aspergillus flavus, Mucor spp., and Penicillium caseicolum fungi. The presence of secondary metabolites in ginger is thought to be responsible for its ability to influence the microbial quality of zobo.

Adeoye et al. (2018) reported that 0.25% and above ginger in zobo drink had inhibitory effects for up to 16 days of storage at ambient temperature after pasteurisation, with better inhibition against bacterial colonies observed. As compared to when ginger and garlic were used separately, the combined effect on bacterial density of zobo was superior (Adesokan et al., 2013; Izah et al., 2016). Also, a blend of ginger and clove had higher inhibitory effects than when used individually (Adeoye et al., 2018). Ogiehor et al. (2008) reported that extracts of local spices (ginger), alone or in combination with low temperature storage (refrigeration), extended the shelf life of zobo beverages for a minimum of six weeks, and contributed to the overall quality and acceptability. In addition, the findings are useful in developing measurable and reliable indices for the production, processing, and handling of zobo beverages.

Garlic

Garlic (Allium sativum), like ginger, belongs to the family Alliaceae, and is a common spice used to flavour meals. Garlic is a bulbous, erect herb that grows 30 - 60 cm tall, and has a strong odour when crushed, thanks to aromatic sulphuric chemicals that are responsible for its odour and flavour (Pundir et al., 2010). Garlic has been shown to reduce the risk of heart disease, stroke, and high blood pressure (Izah et al., 2016). Terpenoids, glycosides, flavonoids, saponins, tannins, and hydrocynaides are bioactive substances found in garlic (Youssef et al., 2013; Izah et al., 2016). Bello and Osho (2012) reported 40% tannin, 4.87 × 10^{-5} saponin, 26.60% alkaloid, 0.68% phenol, and 124.95% phytate in garlic.

The antimicrobial properties of garlic are largely attributed to allicin, a volatile compound responsible for garlic’s pungent odour (Pundir et al., 2010). It has antiviral and antibacterial properties, and recent applications against congestion, bronchitis, and cold symptoms, and protection against re-infection (Bello and Osho, 2012). Garlic has
traditional and medicinal applications as an anti-
inf ective agent. Garlic has ant imyco tic properties
against Aspergillus flavus, Aspergillus niger,
Aspergillus ostianus, Alternaria alternata, Fusarium
s olani, and Candida albicans (Youssef et al., 2013),
Bacillus subtilis, Bacillus megaterium, Bacillus
 sphaericus, Bacillus polymyxa, Staphylococcus
 aureus, Escherichia coli, Penicillium oxalicum,
Aspergillus flavus, Aspergillus luchuensis, Rhizopus
stolonifer, Scopulariopsis, and Mucor sp. (Pundir et
al., 2010). At various times, garlic has been utilised
as a spice in the production of zobo. According to
the literature, zobo drink treated with garlic had lower
microbial counts than a control sample (Braide et
al., 2012; Adesokan et al., 2013). Braide et al. (2012)
reported a reduction in the population of Micrococcus
luteus, Micrococcus roseus, Staphylococcus aureus,
 Bacillus subtilis, and Enterococcus faecalis bacteria,
and the complete elimination of Rhizopus stoloni fer,
Aspergillus flavus, Penicillium caseicolum, and
F usarium poae fungi, in zobo treated with garlic.
Reports from Youssef et al. (2013) show high
inhibition of garlic essential oil extracted with n-
hexane on Aspergillus sp., Alternaria alternata, and
Fusarium solani, while Pundir et al. (2010) reported
maximum activity of the spice against B. subtilis.

Tamarind

Dialium guineense, the African black velvet
tamarind, is a huge tree that can be found throughout
Africa, including west Africa, the Central African
Republic, and Chad. The tree belongs to the family
Fabaceae - Caesalpinioideae, and can reach a height
of 30 meters. It has a dense, leafy crown, is typically
shrubby, and its leaves are broadly elliptic, blunt at
the tip, leathery, and have a depressed midrib. It has
pale flowers on horizontally spread branches that
grow wild fruits (Osanaiye et al., 2013). Tamarinds
are typically round and flattened in shape, black in
colour, with a 6 mm long stalk, a small collar near
the apex, and a bristle shell enclosing a dry, brownish /
orange edible pulp. It is locally referred to as
“tsamiyarkuru” in Hausa (Abd El-Ghani, 2016), and
as “icheka” in Igbo. Wild tamarind is used as a dietary
 supplement for Nigerians living in rural areas, and in
medicinal cures, as a source of vitamin C, and as
flavouring for snacks and non-alcoholic beverages
(Osanaiye et al., 2013). The bark and leaves of the
tree are used to treat a variety of diseases, including
malaria, bronchitis, cough, and as a diuretic (Abd El-
Ghani, 2016). The leaves can be crushed and used on
wounds, while the pulp is used as a traditional cure
for diarrhoea and stomach discomfort. Based on a
study carried out on the proximate composition of
African tamarind by Osanaiye et al. (2013), the fruit
pulp was found to have a high level of micronutrients
such as sodium, magnesium, and potassium, as well
as high amounts of vitamin C. The values obtained by
the researchers are as follows: moisture, 10.53%; dry
matter, 88.40%; ash, 12.52%; organic matter,
41.55%; crude fat, 5.34%; crude fibre, 1.05%;
carbohydrate, 58.65%; protein, 3.94%; nitrogen,
0.65%; magnesium, 0.40 mg/L; sodium, 2.88 mg/L;
iron, 1.43 mg/L; calcium, 0.35 mg/L; and potassium,
1.21 mg/L. Despite its nutritional composition and
potential as a beverage additive, there is currently no
research on tamarind-flavoured zobo.

Lime

Citrus aurantifolia is a member of the family
Rutaceae. Nigeria and numerous other tropical
countries have a large population of this species. C.
aurantium (bitter orange), C. sinensis (sweet orange),
C. reticulata (tangerine), C. limon (lemon), C. grandis
(pomelo), C. paradisi (grape), C. indica (India wild orange), and C. tachibans (mandarin) are
other species of this genus (Izah et al., 2016). Lime
juice, together with its peels, has been used in zobo production (Salami and Afolayan, 2020). Akujobi et
al. (2018) experimented with substituting zobo with
sweet orange. Lime has a variety of therapeutic
characteristics that are used to treat a variety of skin
disorders, as well as antioxidants, throat, and
mouthwash. Lime is high in phyt o nutrients which
provide numerous health advantages. Alkaloids,
 flavonoids, phenols, saponins, and tannins are among
the bioactive substances found, as well as vitamins
such as ascorbic acid, thiamine, and riboflavin, also
minerals such as potassium, phosphorus, magnesium,
sodium, and calcium (Izah et al., 2016). The acidic
nature of lime may contribute to its ability to reduce
the microbial load of zobo. Many pathogens are
inhibited by acidic foods, whereas acidophiles, such
as Bacillus spp., Lactobacillus spp., and
Saccharomyces cerevisiae thrive in them. Lime's
acidity is organic, making it less damaging to the
gastrointestinal tract (Salami and Afolayan, 2020). In
a study by Braide et al. (2012), lime had a lower
microbial load than other organic spices /
preservatives like garlic, ginger, and clove. At the
same concentration of preservatives added for 24 h of
preservation, the authors found a lower microbial
population than sodium benzoate. However, from 24 to 36 h, the bacterial density was comparable to that of other preservatives. Higher fungal density was reported for other organic preservatives as compared to lime in zobo drink from 24 to 48 h, while from 12 to 336 h of lime completely eliminated *Staphylococcus aureus* bacterium and *Fusarium poae* fungus in zobo drink (Braide et al., 2012).

**Pineapple**

Pineapple (*Ananas comosus*) is a tropical fruit from the family Bromeliaceae with a fruity flavour and taste. Pineapple is rich in nutrients such as calcium, vitamin C, potassium, carbohydrates, dietary fibres, and phytochemicals that are vital for the maintenance of an ideal body weight and a functional digestive system (Akujobi et al., 2018). It is common for pineapple peels to be used as natural flavouring in zobo production, subsequently reducing wastage (Gbadegesin et al., 2017). Akujobi et al. (2018) showed the effect of artificial flavour substitution with pineapple and orange juice in zobo drink production. The authors reported that zobo with orange flavour + pineapple juice and orange + pineapple juice had higher ash, crude fibre, and natural carbohydrates with a significant difference, than zobo produced with artificial flavour. Proximate composition for zobo with flavour was given as moisture (93.53%), ash (0.24%), crude fibre (0.08%), fat (0.05%), protein (0.76%), carbohydrate (5.34%), iron (0.85 mg/100 g), potassium (23.45 mg/100 g), zinc (0.84 mg/100 g), calcium (12.27 mg/100 g), vitamin C (17.87 mg/100 g), and vitamin A (28.57 µg/100 g); while proximate composition for zobo with orange flavour + pineapple juice was given as moisture (91.77%), ash (0.32%), crude fibre (0.2%), fat (0.06%), protein (0.82%), carbohydrate (6.91%), iron (1.05 mg/100 g), potassium (35.73 mg/100 g), zinc (0.92 mg/100 g), calcium (13.94 mg/100 g), vitamin C (24.16 mg/100 g), and vitamin A (41.42 µg/100 g); while zobo substituted with only natural juices (pineapple and orange) was given as moisture (91.19%), ash (0.35%), crude fibre (0.22%), fat (0.07%), protein (0.87%), carbohydrate (7.29%), iron (1.14 mg/100 g), potassium (40.98 mg/100 g), zinc (0.97 mg/100 g), calcium (14.42 mg/100 g), vitamin C (28.93 mg/100 g), and vitamin A (49.44 µg/100 g). An increase in flavonoids, phytate, and phenol was reported for naturally flavoured zobo. High tannin and alkaloid levels were observed in zobo produced with an artificial flavour additive.

**Uziza**

*Piper guineense* is the most pungent and flavourful of all the leafy vegetables, and its fruits are used in preparing soups for women post-partum. The leaf consists of alkaloids (0.86%) and tannins (1.19%), which are of very high pharmacological value; saponin (1.88%), which is used to some extent as an expectorant and emulsifying agent; flavonoids (0.72%), which have antibacterial functions; and phenolic compounds (0.66%), which are known to have antimicrobial effects (Chinwendu et al., 2016). Research carried out by Obi (2015) showed that uziza had a moderate preservative effect on zobo drinks with a microbial count of 29 CFU/mL after six days.

**Ehuru**

*Monodora myristica* is a plant in the family Araceae. It can be found all over the world, from Africa to Asia, to central and south America, to Australia. Its range extends from Sierra Leone through Uganda, Kenya, Congo, and Angola in west, central, and east Africa. In west Africa's evergreen forest, it is one of the most important spice trees, with a strong presence in the southern half of the country. Almost every part of the tree is useful economically. It is known locally in Nigeria as “abo-lakoshe” in Hausa, “ehuru” or “ehiri” in Igbo, “ariwo” in Yoruba, Jamaica nutmeg, or Calabash nutmeg (Enwereuzoh et al., 2015; Abd El-Ghani, 2016). Its seeds are used in treating constipation, lice, and guinea worms (Abd El-Ghani, 2016). The nutritional value of ehuru is centred on its use as a beverage additive due to its aromatic qualities, with the seeds embedded in the white, sweet-smelling pulp of the sub-spherical fruit being the section of interest (Enwereuzoh et al., 2015). According to the literature, the proximate composition of ehuru seed was obtained as: moisture, 6.0%; ash, 4.9%; crude fat, 24.33%; crude fibre, 3.3%; crude protein, 18.69%; and carbohydrate, 42.78%. Obi (2015) assessed the preservative effects of local spices on zobo drink. It was observed that zobo spiced with ehuru had no colony growth after six days of production.

**Uda**

*Xylopia aethiopica* is a spice in the family Annonaceae. It is locally known as “uda” or “eevu” in Nigeria, and is commonly referred to as “Negro pepper” or “grains of Selim”. Its roots, bark, seeds, and leaves are traditionally used in the treatment of fever and jaundice (Abd El-Ghani, 2016). According
to Obi (2015), uda-flavoured zobo had the highest microbial count of 90 CFU/mL. In comparison to other locally spiced zobo, it showed the least preservative effect.

**Effect of natural spices on nutritional composition of zobo tea and drinks**

Macronutrients required by humans are measured in gram amounts daily. Since zobo drink is deficient in macronutrients like protein, the drink should be substituted with protein-rich plant parts to enhance its quality (Adeniji, 2017). The effects of various spices and added plant extracts on the nutritional composition of zobo tea and drinks vary (Izah et al., 2015). The effects are highly dependent on the composition of additives and the synergistic or antagonistic effects between the zobo and the additives used (Adeoye et al., 2019). Generally, an overall increase in carbohydrate, ash, fibre, and crude protein has been reported with added fruit juice extracts, while a decrease in moisture and fat, depending on the spice or fruit extract added, has also been recorded (Adelekan et al., 2014; Akujobi et al., 2018).

**Carbohydrate**

Carbohydrates are macronutrients that are essential for life processes. Carbon, hydrogen, and oxygen make up the compound, which is divided into monosaccharide, disaccharide, oligosaccharide, and polysaccharide, depending on the number of carbon atoms. Carbohydrates serve as an immediate energy source for cellular function. Vegetables, whole fruits, legumes, nuts, seeds, whole grains, and tubers are considered good sources of carbohydrates. The carbohydrate content of zobo tea and drinks has been reported as high, and more so with the addition of sweeteners. Ezearigo et al. (2014) showed ginger-spiced zobo had 11.12% carbohydrate, while garlic-spiced zobo had 10.98% carbohydrate. Akujobi et al. (2018) reported an increase in the carbohydrate content of zobo produced with pineapple juice and artificial orange flavour. The carbohydrate content was 6.91% as opposed to the zobo produced with orange juice and pineapple flavours only, which had 5.34% carbohydrate. The researchers further showed that zobo with orange and pineapple juice extract had the overall highest carbohydrate content of 7.29%. Fasoyiro et al. (2005) enriched the roselle beverage with fruit juice in various ratios. The resulting roselle-pineapple beverages of ratios 1:1, 1:2, and 1:3 had 8.70, 8.30, and 10.40% carbohydrate, respectively. Zobo enriched with ginger and pineapple juice had 21.60% carbohydrate (Adelekan et al., 2014).

**Fat**

Fats are esters of fatty acids, which could be saturated or unsaturated. Plant oils, dairy products, meats, nuts, and baked goods are sources of fatty acids. The fat content of most fruits and vegetables, as with zobo calyx, is generally low, making them suitable for weight loss due to their low glycaemic index. Spices, on the other hand, are packed with aromatic oil compounds. The fat content of zobo produced with pineapple juice and orange flavour was 0.06%, in contrast to zobo tea and drinks produced with pineapple and orange flavour of 0.05% (Akujobi et al., 2018). Fasoyiro et al. (2005) found that roselle-pineapple beverages of ratios 1:1, 1:2, and 1:3 had 0.67, 0.93, and 0.98% fat, respectively, showing that fat content increased with increasing fruit ratio, thus implying higher fat content in pineapple. Adelekan et al. (2014) reported 1.92% fat for pineapple- and ginger-spiced zobo, while Ezearigo et al. (2014) reported 0.38 and 0.40% fat for ginger- and garlic-spiced zobo, respectively.

**Protein**

Crude protein is calculated as the amount of nitrogen mineral multiplied by 6.25, following that proteins contain about 16% nitrogen on an average. Proteins consist of amino acids joined together by peptide bonds. Amino acids are categorised into essential and non-essential based on those that can be synthesised in humans. Sources of protein are mostly from meat, poultry, and sea foods. Seeds and nuts are good plant sources of protein. Zobo tea and drinks have been considered as good source of natural protein; therefore the supplementation increases the protein content. Akujobi et al. (2018) reported a higher protein content of 0.82% in zobo drinks enriched with pineapple juice than zobo drinks with artificial flavours (0.76%), while Fasoyiro et al. (2005) reported 0.93, 0.92, and 0.94% crude protein for roselle-pineapple beverages of ratios 1:1, 1:2, and 1:3, respectively. Adelekan et al. (2014) reported 4.13% protein for pineapple- and ginger-flavoured zobo. Ezearigo et al. (2014) reported 8.00 and 8.13% crude protein for garlic- and ginger-enriched zobo, respectively. This indicated increased protein with the addition of spices rather than fruits.
**Fibre**

Crude fibre is necessary in the diet because it increases faecal bulkiness due to its water retention properties, thus softening stool, promoting peristalsis within the intestinal muscles, and subsequently reducing intestinal and rectal health problems. Fruits and vegetables contain high fibre content, and *zobo* calyx is not left out. *Zobo* tea contains a high level of fibre content, and supplementing it with fruits further increases the fibre content. *Zobo* enriched with pineapples had 0.20% fibre, while that enriched with both orange and pineapple juice had 0.22%, in comparison with *zobo* produced with artificial flavour which only had 0.08% fibre (Akujobi et al., 2018). Fasoyiro et al. (2005) reported 0.64, 0.66, and 0.72% fibre in roselle-pineapple beverages of ratios 1:1, 1:2, and 1:3, respectively; 0.52, 0.55, and 0.57% fibre in roselle-orange beverages of ratios 1:1, 1:2, and 1:3, respectively; and 1.44, 1.93, and 2.02% fibre in roselle-apple beverages of ratios 1:1, 1:2, and 1:3, respectively, thus indicating increased fibre with increased fruit ratio.

**Mineral**

Minerals and vitamins are referred to as micronutrients, as they are needed in small quantities of less than 100 mg daily. They are major components of vegetables and fruits. Mineral content in food refers to the inorganic residue left after the meal has been ignited or completely oxidised. Fruit-enriched *zobo* tea and drinks had higher ash values than non-enriched *zobo*. This is most likely attributed to the high mineral content of fruits, and the synergistic effects of various *zobo* tea and drink combinations. Ezearigo et al. (2014) reported a 0.44% ash content for garlic-enriched *zobo*, and a higher content of 1.33% ash in ginger-enriched *zobo*. Adelekan et al. (2014) reported 2.51% ash for *zobo* produced with pineapple and ginger. Akujobi et al. (2018) reported an ash content of 0.32% for pineapple juice enriched *zobo*, and 0.35% for pineapple and orange juice enriched *zobo*, as opposed to 0.24% ash for *zobo* not enriched with fruit juice extract. Fasoyiro et al. (2005) found 0.32, 0.33, and 0.31% crude ash in roselle-pineapple beverages with ratios of 1:1, 1:2 and 1:3, respectively.

**Potassium**

Potassium assists nerve function and muscle contraction, aids a regular heartbeat, acts as a cell electrolyte, and is also essential in co-regulating ATP with sodium. *Zobo* enriched with pineapples had 35.73 mg/100 g of potassium, while that enriched with both orange and pineapple juice had 40.98 mg/100 g of potassium, which was higher than *zobo* produced with artificial flavour (23.45 mg/100 g) (Akujobi et al., 2018). Ezearigo et al. (2014) reported 9.87 mg/100 g potassium in garlic-enriched *zobo*, and a higher content of 10.08 mg/100 g in ginger-enriched *zobo*.

**Phosphorus**

Phosphorus is found in abundance in bones and teeth, bodily cells, DNA, and ATP, and is necessary for energy processing. It is needed for the body to synthesise protein, and to adequately utilise carbohydrates and fats. Fasoyiro et al. (2005) reported 2.40, 2.62, and 2.63 mg/100 g of phosphorus in roselle-pineapple beverages of ratios 1:1, 1:2, and 1:3, respectively; 1.71, 1.80, and 1.82 g/100 g of calcium in roselle-orange beverages of ratios 1:1, 1:2, and 1:3, respectively; and 1.60, 1.80, and 1.87 g/100 g of phosphorus in the resultant roselle-apple beverages of ratios 1:1, 1:2, and 1:3, respectively.

**Calcium**

Calcium is needed for strengthening bones and teeth, for heart, muscle health, as well as digestive system health, bone growth, and blood cell production and function. Other than fish and meat, green vegetables and dairy are good sources of calcium. *Zobo* enriched with pineapples had 13.94 mg/100 g of iron, while that enriched with both orange and pineapple juice had 14.42 mg/100 g of iron, which was higher than *zobo* produced with artificial flavour (12.27 mg/100 g) (Akujobi et al., 2018). Fasoyiro et al. (2005) found 1.54, 1.66, and 1.71 mg/100 g of calcium for roselle-pineapple beverage with ratios of 1:1, 1:2, and 1:3, respectively; 2.11, 2.42, and 2.34 mg/100 g of calcium for roselle-orange beverage with ratios of 1:1, 1:2, and 1:3, respectively; and 2.51, 2.62, and 2.63 mg/100 g of calcium for roselle-apple beverage with ratios of 1:1, 1:2, and 1:3, respectively. Adelekan et al. (2014) reported 0.54 and 1.68 mg/100 g of phosphorus, 35.73 mg/100 g of potassium, while that enriched with both orange and pineapple juice had 40.98 mg/100 g of potassium, which was higher than *zobo* produced with artificial flavour (23.45 mg/100 g) (Akujobi et al., 2018). Ezearigo et al. (2014) reported 9.87 mg/100 g potassium in garlic-enriched *zobo*, and a higher content of 10.08 mg/100 g in ginger-enriched *zobo*.

**Iron, zinc, and copper**

Iron is required by many enzymes and proteins, notably haemoglobin to prevent anaemia. The conversion of beta-carotene to vitamin A is also aided...
by iron. Zinc is necessary for many enzymes such as carboxypeptidase, carbonic anhydrase, and liver alcohol dehydrogenase, while copper is required in the production of redox enzymes, including cytochrome oxidase. These minerals are needed by various enzymes, and are necessary for cell division and growth. Zobo enriched with pineapples had 1.05 mg/100 g of iron, while that enriched with both orange and pineapple juice had 1.14 mg/100 g iron, which was higher than zobo produced with artificial flavour (0.85 mg/100 g) (Akujobi et al., 2018). Adelekan et al. (2014) reported 0.54, 1.25, and 1.68 mg/100 g of iron in zobo produced with pineapple + ginger, zobo produced with pineapple + pepper, and that produced with pepper only, respectively. Zobo enriched with orange juice had 0.94 mg/100 g, that enriched with pineapples had 0.92 mg/100 g of zinc, while that enriched with orange + pineapple juice had 0.97 mg/100 g of iron, in comparison with zobo produced with artificial flavour (0.84 mg/100 g) (Akujobi et al., 2018). Adelekan et al. (2014) reported 0.15, 0.18, and 0.42 mg/100 g copper for zobo produced with pineapple + ginger, zobo produced with pineapple + pepper, and that produced with pepper only, respectively.

Vitamin

Olayemi et al. (2011) and Salami and Afolayan (2020) both agree on the high vitamin content of zobo beverages, especially vitamin C, which was found to be nine times higher in zobo than in orange. The role of vitamins, including combating oxidative damage, preventing some DNA-damaging free radicals, and reducing the likelihood of major respiratory diseases like asthma and so on, cannot be overemphasised. There is therefore a need for supplementation of zobo tea and drinks to ensure a ready supply of necessary vitamins.

Ascorbic acid

Vitamin C (ascorbic acid) is a water-soluble, essential vitamin necessary for the repair of tissue, and the enzymatic production of certain neurotransmitters. It acts as an antioxidant which prevents cell oxidation, and is necessary for the prevention and alleviation of scurvy. The United States’ recommended daily allowance (RDA) of ascorbic acid is 90 mg. Citrus fruits, berries, and green leafy vegetables are good sources of the vitamin C (Babalola et al., 2001; Wong et al., 2002; Salami and Afolayan, 2020). Zobo tea and drink enriched with pineapples had 24.16 mg/100 g of vitamin C, while that enriched with orange + pineapple juice had 28.93 mg/100 g of vitamin C, which was higher than zobo produced with artificial flavour (12.27 mg/100 g) (Akujobi et al., 2018). Fasoyiro et al. (2005) reported 35.21, 34.63, and 35.10 mg/100 g of vitamin C for roselle-pineapple beverages of ratios 1:1, 1:2, and 1:3, respectively; 46.21, 47.14, and 48.25 mg/100 g of vitamin C in roselle-orange beverages of ratios 1:1, 1:2, and 1:3, respectively; and 35.63, 36.33, and 36.11 mg/100 g of vitamin C in roselle-apple beverages of ratios 1:1, 1:2, and 1:3, respectively. Adelekan et al. (2014) reported 29.28 and 33.24 mg/100 g of calcium for zobo produced with pineapple + ginger and that enriched with pineapple + pepper, respectively. Adebayo et al. (2021) reported that zobo drinks enriched with turmeric contained higher vitamin C of 725 µg/100 mL when compared with the control, which had 577 µg/100 mL of vitamin C.

Pro-vitamin A

Pro-vitamin A (beta-carotene) is a precursor, and is converted by the body to vitamin A. Vitamin A, otherwise known as retinol, is a dietary fat-soluble vitamin needed for vision, healthy skin, and optimum immune function. Dairy, fish, meat, red and yellow fruits, and yellow, red, and green leafy vegetables are good sources of vitamin A. United States recommended daily allowance (RDA) of vitamin A is 900 µg, which is not completely met by zobo tea and drinks (USDA, 2008). Zobo enriched with pineapple had 41.42 µg/100 g of vitamin A, while that enriched with orange + pineapple juice had 49.44 µg/100 g vitamin A, which was higher than zobo produced with artificial flavour (28.57 µg/100 g) (Akujobi et al., 2018), while Adelekan et al. (2014) reported 28, 68, and 141 RE/L of vitamin A in pineapple + ginger, pineapple + pepper, and enriched zobo drinks, respectively.

Folic acid

Folate, also known as folic acid or vitamin B₉, is a water-soluble B-complex vitamin required for red blood cell formation, and for healthy cellular functions. Liver, green leafy vegetables, and peas are sources of vitamin B₉. United States recommended daily allowance (RDA) of vitamin B₉ is 400 µg, which can be sufficiently met with enriched zobo tea and drinks (USDA, 2008). Adebayo et al. (2021) reported that street vended zobo drinks are generally
high in vitamin B₉, but increase considerably with the addition of turmeric spice. The control had 295 µg/100 mL of vitamin B₉ in contrast to the turmeric-enriched zobo (301 µg/100 mL for 2% boiled turmeric in zobo, and 297 µg/100 mL for 6% boiled turmeric in zobo).

**Effects of natural spices on biochemical composition of zobo tea and drinks**

The phenolic content of zobo beverages was found to be a function of the antagonistic or synergistic effect between the natural additive phenolic content and the roselle calyx used in the drink’s production. The ability of phenolic compounds to scavenge free radicals and reduce iron determines their antioxidant activity (Adeoye et al., 2019).

**Phenolics**

Phenolics are aromatic benzene ring compounds comprising one or more hydroxyl groups. Phenols are synthesised by plants only, as an anti-stress protection mechanism. They act as powerful antioxidants when consumed, preventing oxidative damage and chronic diseases like cancers and cardiovascular diseases. Zobo enriched with pineapple had 0.043% phenolics, while that enriched with orange + pineapple juice had 0.052%, as opposed to zobo produced with artificial flavour, which had 0.038% (Akujobi et al., 2018). According to a study by Adeoye et al. (2019), the phenolic content of zobo tea and spice drinks increased as the spice concentration increased, implying that the phenolic content of the spices and roselle calyx used in drink production had an additive or synergistic effect.

**Flavonoids**

Flavonoids are polyphenolic molecules that are plant metabolites, and soluble in water. The six major flavonoids in plants are chalcones, flavones, isoflavonoids, flavanones, anthoxanthins, and anthocyanins. The typical colours of fruits and vegetables rich in flavonoids are yellow, purple, blue, and red, which is the colour of zobo calyx. Flavonoids aid in the regulation of cellular activity and the prevention of oxidative stress caused by free radicals. Akujobi et al. (2018) reported that zobo enriched with pineapple had 0.06% flavonoids, while that enriched with orange + pineapple juice had 0.08% higher than zobo produced with artificial flavour, which had 0.05%. Meanwhile, Ezearigo et al. (2014) reported 0.6, 0.12, and 0.19 mg/100 g of flavonoid in garlic-, ginger-, and cinnamon-spiced zobo drink, respectively. Similar results are expected in enriched dehydrated zobo tea.

**Scavenging antioxidant activity**

Free radical scavenging activities are important for preventing free radical damage, and diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging is a commonly used method for testing the antioxidant activity of plant extracts. With an increase in spice concentration, increasing free radical scavenging activity was observed in a study by Adeoye et al. (2019), where clove-spiced zobo (DPPH) increased from 77.5 to 82.9% for clove concentrations of 0.05 to 0.45%, ginger-spiced zobo increased from 73.7 to 78.8% for ginger concentrations of 0.05 to 0.45%, and for mixture of ginger + clove spiced zobo, the DPPH increased from 75.7 to 80.1% for concentrations of 0.05 to 0.45%, while the control had a DPPH of 73.2%; all was observed on the first day of zobo drink production. The reports prove that spiced zobo tea would exhibit higher scavenging antioxidant activity.

**Total reducing power**

Total reducing power is a direct measure of the total antioxidant activity of compounds. It is a medium that measures the ability of phenols in food to reduce Fe³⁺ to Fe²⁺. In the reducing power assay by Adeoye et al. (2019), they showed increasing total reducing power with the increase in spice concentrated zobo drink. It was observed in a study that the total reducing power of clove-spiced zobo increased from 1.674 to 1.717 for clove concentrations of 0.05 to 0.45%, ginger-spiced zobo increased from 1.655 to 1.674 for ginger concentrations of 0.05 to 0.45%, and for the mixture of ginger and clove spiced zobo, the total reducing power increased from 1.656 to 1.662 for concentrations of 0.05 to 0.45%, while the control had total reducing power of 1.628. All were observed on the first day of production.

**Effects of natural spices on sensory characteristics of zobo tea and drinks**

Various studies showed higher acceptance of zobo drinks produced with ginger, clove, and pineapple (Fasoyiro et al., 2005; Obi, 2015; Akujobi et al., 2018). The sensory evaluation was carried out
on zobo drinks produced with ginger, clove, orange juice, pineapple flavour, orange flavour, and pineapple flavour using 20 panellists. The panellists were aged between 18-30 years. The zobo drink was served at ambient temperature. The ratings by the panellists suggested that zobo drink was likely to be accepted by the public if prepared with pineapple or orange juice (Akujobi et al., 2018). This is most likely attributed to the fact that these natural additives are conventionally used in zobo tea and drink production, and also due to the fruity taste of pineapple. Sensory evaluation is significant in the production of novel products in order to gauge consumer acceptance (Akujobi et al., 2018).

Taste refers to a flavour sensation in the mouth and throat. Akujobi et al. (2018) reported better acceptance of the taste of conventional zobo produced with artificial flavour from sensory panellists (7.87) than zobo enriched with orange or pineapple juice, or a combination of both, which scored 7.33, 6.94, and 5.63, respectively. Fasoyiro et al. (2005) reported taste acceptance of 6.0, 7.0, and 6.2 for roselle-apple beverages in ratios of 1:1, 1:2, and 1:3; 8.0, 8.0, and 7.7 for roselle-pineapple beverages in ratios of 1:1, 1:2 and 1:3; and 6.1, 5.8, and 6.1 for roselle-orange beverages in ratios of 1:1, 1:2 and 1:3, respectively. Zobo enriched with ginger + pineapple juice, pepper + pineapple, and pepper had 6.4, 6.93, and 5.48 scores, respectively, for taste (Adelekan et al., 2014). Gbadegesin et al. (2017) produced four samples of zobo beverage with 100% roselle, 85% roselle and 15% pineapple, 80% roselle and 20% pineapple, and 75% roselle and 25% pineapple. The researchers reported better taste preference in zobo drinks with 25% pineapple, scoring 7.9, and the least preference in zobo drinks with 100% roselle, scoring 6.2. Obi (2015) spiced zobo with Nigerian indigenous spices, and reported taste preferences of 4.9, 6.5, 6.5, 5.4, 4.6, and 5.3 for zobo spiced with clove, ginger, uziza, ehu, uda, and ehuru, respectively.

The distinctive taste of food is referred to as flavour. Akujobi et al. (2018) reported better acceptance of the aroma / flavour of conventional zobo drinks produced with artificial flavours from sensory panellists (7.82), than zobo enriched with orange or pineapple juice, or a combination of both, which scored 7.75, 7.47, and 6.34, respectively. Fasoyiro et al. (2005) reported flavour acceptance of 6.1, 6.3, and 6.2 for roselle-apple beverages in ratios of 1:1, 1:2, and 1:3; 7.6, 7.8, and 7.8 for roselle-pineapple beverages in ratios of 1:1, 1:2 and 1:3; and 6.3, 6.1, and 6.2 for roselle-orange beverages in ratios of 1:1, 1:2, and 1:3, respectively. Zobo enriched with ginger and pineapple juice, pepper and pineapple, and pepper had 6.4, 6.4, and 5.06 scores, respectively, for aroma (Adelekan et al., 2014). Gbadegesin et al. (2017) reported better flavour acceptance in zobo drink with 25% pineapple juice, scoring 8.4, and the least preference in zobo drinks with 100% roselle scoring 5.8. Obi (2015) reported flavour preferences of 6.1, 6.4, 5.4, 5.3, 4.5, and 5.2 for zobo spiced with clove, ginger, uziza, ehu, uda, and ehuru, respectively.

Colour of food is the first attraction to the food. A study carried out by Akujobi et al. (2018) showed better acceptance of pineapple juice enriched zobo colour (7.34), followed by zobo enriched with orange juice (7.28), conventional zobo produced with artificial flavours (7.08), and zobo enriched with a combination of orange and pineapple (6.15). Fasoyiro et al. (2005) reported colour acceptance of 6.99, 6.60, and 7.2 for roselle-apple beverage in ratios 1:1, 1:2, and 1:3; 8.1, 7.8, and 7.9 for roselle-pineapple beverage in ratios 1:1, 1:2, and 1:3; 6.7, 7.7, and 7.4 for roselle-orange beverages in ratios of 1:1, 1:2, and 1:3, respectively. Zobo enriched with ginger and pineapple juice, pepper and pineapple, and pepper scored 5.93, 7.66, and 7.53, respectively, for colour (Adelekan et al., 2014). Gbadegesin et al. (2017) reported the most colour preference in zobo drinks with 25% and 20% pineapple scoring 7.8, and the least preference in zobo drinks with 100% roselle scoring 7.5. Obi (2015) reported colour preferences of 7.9, 8.1, 7.6, 7.6, 7.6, and 7.3 for zobo spiced with clove, finger, uziza, ehu, and ehuru, respectively.

Overall acceptance of zobo in the study of Akujobi et al. (2018) in descending order is: zobo enriched with orange juice (8.04), pineapple-enriched zobo (7.94), conventional zobo produced with flavours (7.88), and finally, combination of orange and pineapple in zobo (6.03). Fasoyiro et al. (2005) reported overall acceptability of 6.5, 6.7, and 6.7 for roselle-apple beverages in ratios of 1:1, 1:2, and 1:3; 7.9, 7.2, and 7.9 for roselle-pineapple beverages in ratios of 1:1, 1:2, and 1:3, respectively. Adelekan et al., 2014 reported that zobo enriched with ginger and pineapple juice, pepper and pineapple, and pepper had 6.86, 7.2, and 6.53 overall scores, respectively, for acceptability. Gbadegesin et al. (2017) reported better overall acceptability in zobo drinks with 25% pineapple, scoring 8.5, and the least...
preference in zobo drink with 100% roselle, scoring 6.3. Obi (2015) reported overall acceptance scores of 5.9, 7.1, 6.6, 5.8, 5.5, and 5.9 for zobo spiced with clove, finger, uziza, ehu, uda, and ehuru, respectively.

**Discussion**

In the quest to overcome the hurdles associated with the short life span of zobo, and the potential incidence of disease conditions attributed to the zobo drink / tea spoilage microorganisms, studies have discovered several natural preservatives / spices of organic / natural origin that could improve the quality attributes of zobo tea and drinks, and also reduce both the microbial diversity and the density of zobo spoilage microorganisms.

Antioxidant contents of five local Nigerian drinks, namely: “kunu”, palmwine, plantain, soybean, and zobo were analysed for flavonoids, phenolics, and vitamin C (Oboh and Okhai, 2012). The antioxidant scavenging abilities were evaluated using four different in vitro methods. Zobo drink with sugar had the highest phenolic content (16.00 ± 0.26 mg/mL), while zobo drink with ginger recorded the highest flavonoids and vitamin C (3.91 ± 0.02 and 2.31 ± 0.01 mg/mL), respectively. The roselle calyces of Hibiscus sabdariffa used in preparing zobo drink are rich in vitamin C and flavonoids (Wong et al., 2002). This is responsible for the high antioxidant content seen in the zobo drinks which correlates with the high ability of the drinks to scavenge free radicals. Furthermore, the ferric reducing ability of the drinks was highest in the zobo drinks possibly due to its high phenolic or flavonoid contents (r = 0.952 and 0.970, respectively). However, the total phenolic content was significantly different (p ≤ 0.05) in all the zobo drinks. This showed that sugar and ginger affected the total phenolic of the drinks. Zobo enriched with ginger had a significantly (p ≤ 0.05) higher flavonoid and vitamin C content as compared to the other zobo drinks (Oboh and Okhai, 2012).

Adesokan et al. (2013) demonstrated that the vitamin C contents of zobo drinks supplemented with garlic and ginger were higher than those of ordinary zobo juice. This means that the vitamin C status of zobo beverages can be improved by blending them with these spices. The crude protein content of non-spiced zobo juice was 9.1%, but higher values were obtained for the samples containing spices. Adesokan et al. (2013) reported that spices were able to reduce the microbial loads of zobo samples during 7 days storage. Ogiehor et al. (2008) extended the shelf life of zobo for 42 days by using 0.2% ginger extract and refrigeration. This method of storage under refrigeration is not practicable because of epileptic public power supply, and the use of power generators is not economical in Sub-Saharan African countries (Adesokan et al., 2013). The sensory attributes of the zobo samples containing spices were also enhanced. The use of extracts of ginger and garlic in zobo preparation should therefore be encouraged as the sensory properties and shelf life of the resulting product will be enhanced (Adesokan et al., 2013). Adesokan et al. (2013) and Popoola et al. (2019) concluded that the incorporation of ginger, garlic, and their extracts into zobo drink could be an effective means of improving the quality attributes of this drink.

Hibiscus sabdariffa leaves were extracted by hot water extraction using different local spices namely Piper guineense (uziza), Zingiber officinale (ginger), Xylopia aethiopica (uda), Monodora myristica (ehuru), Syzygium aromaticum (clove), and Aistonei boonei (ehu) (Obi, 2015). The drinks were then dispensed into six (2 L) cans, which were cooled in a refrigerator for sensory evaluation, and into six (150 mL) plastic bottles which were stored on the shelf for six days. All samples were pasteurised and allowed to cool before storage. The sensory evaluation results showed the drink with Zingiber officinale had the highest overall acceptability, followed by Piper guineense, while that with Xylopia aethiopica had the lowest acceptability. Results of the microbial counts showed that the Monodora myristica sample had the highest preservative effect, showing no visible growth after 48 h, while the Xylopia aethiopica sample had the highest microbial count, thus indicating the least preservative effect.

Apart from the spices reported by Obi (2015), other widely utilised and potential spices include garlic, a mixture of garlic and ginger, lime, cinnamon, nutmeg, kola nut, and pepper (Izah et al. 2016). These spices, along with the dried calyces of Hibiscus sabdariffa, have antimicrobial properties and are rich in phytonutrients, including vitamins and minerals. Hence, their ability to improve the shelf life of zobo mostly depends on the concentration added. Izah et al. (2016) reported that the ability of the natural preservatives to wade off microorganisms appears to be in this order; lime, mixture of garlic and ginger, ginger, garlic, clove, kola nut, cinnamon, and nutmeg. The activities of the spices were due to differences in the biochemistry, nutrition, physiology, and
metabolism of the microorganisms. Therefore, attention should be focused on the carbonation of the drink after treatment with natural spices (Ogiehor et al., 2008; Izah et al., 2016). Zobo can equally be processed in dry form with natural spices, and packaged in tea bags, which could be preserved for longer periods due to low moisture content, and it will still retain its nutritive value and attract acceptance (Mohammed et al., 2017).

Conclusion

Zobo is rich in carbohydrates, vitamins C and A, phenols, potassium, sodium, phosphorus, and antioxidants. Consuming and drinking zobo tea daily would help to provide the recommended daily allowance of vitamins, and aid in proper health functioning. Due to the adverse effects of chemical additives, the use of plants and natural spices as potential flavour, antimicrobials, and preservatives should be fully adopted. The use of natural additives in zobo production would go a long way in enriching zobo tea and drink, and supplementing nutrients that may be lacking in health drink, thereby making it a super food. In a bid to extend shelf life, zobo tea, which is a formulation of dehydrated zobo extract, should be investigated. The use of tea bags in zobo tea packaging would reduce loss of quality, and yield maximum retention of nutrients.

References


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