

Physicochemical Properties and Shelf-life Stability of Zobo Treated with Turmeric

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ABSTRACT

This study is aimed to evaluate the influence of turmeric addition on the quality and shelf stability of zobo drink under ambient and refrigerated temperatures. Four samples of Zobo drink preparations involving zobo petals, with added turmeric powder at different concentrations of 0%, 3%, 6% and 9 % w/w were labeled as samples TZ0, TZ3, TZ6 and TZ9, respectively. These were used to prepare zobo-turmeric drinks and stored at ambient and refrigeration condition, while zobo drink with 0% turmeric served as the control. The zobo-turmeric drinks were analysed using standard methods. Data obtained were subjected to analysis of variance, and means separated using Duncan multiple range test ($p < 0.05$). Result revealed that the proximate composition decreased in moisture content from 97.26 to 96.01%, while the carbohydrates increased from 2.13 to 3.22%, with increase in turmeric concentration and time of storage. The sensory scores of the zobo-turmeric drink showed decreased likeness in terms of colour, taste, aroma, and overall acceptability with the increased substitution of zobo with turmeric. The microbial count on zobo-turmeric drink during storage revealed that the bacterial and fungi load of the drink increased with storage time, although these were suppressed by the increased concentrations of turmeric, the microbial load was within permissible limits regarded as safe for ready to eat foods. It was therefore concluded that the addition of turmeric in combination of the use of refrigeration was effective in maintaining the quality of zobo drink.

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INTRODUCTION

Zobo drink (Sorrel, zoborodo) is a non-alcoholic local beverage prepared from many varieties of dried petals, and acid-succulent calyces of the flower *Hibiscus sabdariffa* L. It is an extract from hot water-treated *Hibiscus*, which is used to satisfy thirst in the tropics when it's hot. Zobo has a sour (vinegar) flavor and is popular throughout the country (Ağcam et al., 2019). It is usually produced on a small scale by traditional women at minimal cost because its ingredients are cheap and readily available. Zobo is mostly consumed by low-income individuals, but it is gaining widespread acceptance, with millions of people from various socioeconomic classes and backgrounds throughout the West African sub-region due to its expanding popularity, socio-economic potential, and ready source of protein, flavonoids, Vitamin C, and other minerals (Mohammad et al., 2018). Akdemir et al. (2016) reported that appropriately prepared and marketed zobo drink competes favourably with most foreign non-alcoholic beverages in Nigeria.

Hibiscus is an underutilized crop grown in Africa, Asia, Australia, Central America, and Europe. In English, it is commonly known as roselle and has various local names depending on the continent. In Nigeria, it is generally called zobo, or yakwua amongst the Hausas. Usually, it is utilized in the production of zobo drinks and often in combination with optional flavorings such as sugar and other spices like garlic, ginger, and fruit. Several herbs, such as garlic, ginger, and clove, have long been recognized and used for their flavour, and to a lesser extent for their preservative properties. Due to Zobo's popularity and nutritional benefits, any improvement of the drink can benefit many people in Nigeria, where malnutrition is a major concern.

The stability of zobo drink can be affected by factors including high moisture, nutrients, pH, microbial growth, and antioxidants. Microbial contamination is a significant concern in beverages like Zobo due to their high-water activity. Aghajanzadeh and Mohammad (2021) employed some chemical preservatives to improve the shelf life of the Zobo drink. They reported that only samples treated with benzoic acid remained organoleptically attractive after 14 days of storage. However, the problem with the use of chemical preservatives in food is that they tend to have adverse effects on the health of consumers (Ajanaku and Kolawole, 2022). An alternative approach to further augment the potential of zobo would be through food-to-food fortification, which is a solution for the population without radically changing food consumption patterns. Fortification of the zobo drink with another food ingredient that is rich in bioactive compounds could also improve the stability of the anthocyanin content, based on reports that the structure of the organic acid and food matrix in which it is combined would have a strong effect on the stability of the anthocyanins (Birsén et al., 2024). Therefore, naturally occurring plant extracts with proven antimicrobial properties will be preferred in food preservation. The use of natural preservatives has become more popular than synthetic antimicrobials and antioxidants (Erdal et al., 2023).

Turmeric (*Curcuma longa* L.) is a shallow-rooted crop, commonly grown throughout Nigeria, making its production and sales regionally and economically beneficial (Akyıldız et al., 2024). It is one of the common spices with natural phyto-constituents which have been reported to possess several health-promising effects such as; antioxidant, anti-protozoa, anti-tumour, anti-venom, and anti-inflammatory properties

that have been researched extensively. The key biologically effective substances of turmeric are curcuminoids, consisting of curcumin, bis- γ -desmethoxy curcumin, and demethoxy curcumin (Almeida et al., 2015). Curcumin is a yellow-coloured phenolic pigment and is an efficient antioxidant that can mitigate different free radicals, hence it has been utilized in various foodstuffs, such as bread, milk, parboiled rice, and street-vended drinks (Altemimi and Asaad-Rehman, 2021). In addition to curcumin, turmeric has been found to contain other antioxidants, such as ferulic acid (Munir and Abdullah, 2021). Ferulic acid exhibits anti-inflammatory, antidiabetic, and anticancer activity, with protective effects on organs, tissues, and cells of the cardiovascular system and skin de Oliveira. Therefore, turmeric could be used in zobo drink production to fortify and potentially improve the antioxidant, nutritional quality, and shelf life of the drinks (Andreou and George, 2023). The incorporation of turmeric into zobo drink presents a promising avenue for enhancing the nutritional quality, public health outcomes, and shelf life of this popular beverage (Cristina, 2024; Gulzar, 2024). Further research into optimal processing methods and concentrations will be essential for maximizing these benefits in commercial applications. Overall, this research aims to evaluate the proximate, Microbial and sensory composition of zobo-turmeric drink during storage.

MATERIALS AND METHODS

Materials

Dried zobo (*H. sabdariffa*) calyces and turmeric roots were purchased from Wednesday market Dutsin-ma, Katsina state, Nigeria. All the reagents and equipment used were of analytical grade and was sorted from the Department of Food Science and Technology, Federal university Dutsin Ma, Nigeria.

Sample preparation

The zobo calyces and turmeric roots were manually cleaned by handpicking to remove all extraneous materials. The samples were thoroughly washed separately using potable water to remove adhering dirt and allowed to air dry under the sun.

Preparation of turmeric paste

Turmeric paste was made by combining 40 g of finely chopped turmeric root with 80 ml of potable water. The two components were blended, using a Waring Commercial blender, for appropriately 4 minutes at the highest speed, until smooth, the final product was obtained and kept for further processing.

Formulation of Zobo-turmeric drink

Four samples which involve turmeric at different concentrations of 0%, 3%, 6% and 9 % w/w and labeled as samples TZ0, TZ3, TZ6 and TZ9 respectively as presented in Table 3.1,

Table 1: Formulation of Zobo-Turmeric Drink

Samples	ZT0	ZT3	ZT6	ZT9
Zobo	100	97	94	91
Turmeric	0	3	6	9

Production of Zobo-turmeric Drink

The zobo-turmeric drink was produced by boiling about 400g of the washed calyces zobo leaves and turmeric paste in 2000 mL of water for 15 minutes as described by Izah et al. (2016) after which it was left to cool for 15 minutes before removing the calyces-turmeric cake using a white muslin cloth to get the Zobo-turmeric drink and then stored in a vessel for further analysis. The 100 % zobo drink served as the control.

Storage of Zobo-turmeric Drink

The prepared Zobo-turmeric drinks with different concentrations of turmeric were store in a cool dry place at ambient temperature and in the refrigerator for 9 days and were analyzed for its various properties.

Turmeric rhizomes



Figure 1: Turmeric Powder Production
Source: (El-Saadony et al. 2023)

Methods

Proximate Composition

Moisture content

The moisture content was determined by the following FQD protocol number 1 'Determination dry matter content'. Analysis was done in triplicate with three independent batches for the samples with zobo only and the samples with zobo and turmeric paste.

Ash content

The ash content was measured by heating the sample in a Carbolite CSF1100 ashing oven at 550 °C for 6 h, using the method of (Ekanem et al., 2018). Then the ash content was calculated using the formula below. Analysis was done in triplicate with three independent batches

Ash Content = (Weight of the sample after ashing x 100)/ (Weight of the sample transferred before ashing)

Fat content

The fat content was determined by a Soxhlet fat extraction. FQD protocol 38 'The Soxhlet extraction' was followed. Extraction was done for four hours to ensure extraction of all lipids. Analysis was done in triplicate with three independent batches.

Crude protein content

The protein fraction was determined by the DUMAS method, coupled with a protein analyzer. Protocol number 39 by FQD 'Use Dumas at Chemistry Group' was used, with the method described for wet samples. Because of a low expected protein concentration, a small adjustment to the protocol was made. The sample was pipetted in tin cups (200 µL), dried overnight, and then more sample was added (200 µL) and dried. The standard nitrogen to protein conversion factor, 6.25, was used to calculate the protein concentration (Sáyago-Ayerdi et al., 2007). Analysis was done in triplicate with three independent batches.

Carbohydrate content

As all food fractions should add up to 100%, the carbohydrate content was calculated by difference, using the formula below (Ekanem, et al., 2018).

Carbohydrate content = 100% - (Moisture content + ash content + fat content + crude protein content)

Microbial analysis of zobo-turmeric drink

The various zobo drink samples were serially diluted in sterile distilled water and appropriate dilutions were plated on nutrient agar and potato dextrose agar (PDA) for total viable and fungal counts, respectively. The nutrient agar plate was incubated at 35°C for 24 h, while the PDA was incubated at 28°C for 72 h and was supplemented with streptomycin to inhibit the growth of bacteria (Adesokan, 2005).

Statistical Analysis

The data obtained was subjected to analysis of variance (ANOVA) using Statistical Package for the social sciences (SPSS) version 20.0 at 5% level of significance and the means were separated using Duncan multiple range test (DMRT).

RESULTS AND DISCUSSION

Proximate Composition of Zobo-turmeric During Storage

Table 4.1 shows the result of the proximate composition of zobo-turmeric drink stored under ambient and refrigeration conditions for 9 days.

Moisture Content

After storage for 9 days, the moisture content of the zobo turmeric drink decreased from 97.26% in the control to a range of 96.04 to 96.72%. Drink with 3% turmeric stored at refrigeration temperature had the lowest moisture content while that with 9% turmeric stored at ambient temperature had the highest. There was however, no significant differences ($P < 0.05$) among samples with the different concentrations of turmeric in the various storage conditions. The proximate composition show that the zobo-turmeric drinks contain high water content which is helpful in thirst-quenching and may be beneficial in rehydrating individuals who consume the drink. The moisture content in this study was slightly higher than the 94.5 to 95.1% reported by Adeniji (2017) and this could be attributed to the differences in the methods of processing. The high moisture content indicates that zobo drinks are susceptible to microbial growth and have a shorter shelf life. This result is consistent with previous findings by Gbadegesin and Gbadamosi (2017), Adeniji (2017), Koopman (2019), and Akujobi et al. (2018), who all reported moisture content in zobo drinks to be greater than 80%.

Table 2: Proximate Composition of Zobo-Turmeric during Storage

Sample	Moisture (%)	Ash (%)	Fats (%)	Protein (%)	Carbohydrate (%)
Control	97.26±0.19 ^a	0.45±0.00 ^f	0.0035±0.00071 ^b	0.17±0.01 ^d	2.13±0.21 ^c
ZTR3	96.76±0.19 ^b	0.48±0.00 ^e	0.0055±0.00071 ^{ab}	0.19±0.01 ^c	2.57±0.17 ^b
ZTF3	96.77±0.04 ^b	0.53±0.01 ^d	0.0060±0.00000 ^a	0.21±0.00 ^{bc}	2.49±0.04 ^b
ZTR6	96.01±0.01 ^c	0.55±0.01 ^c	0.0065±0.00071 ^a	0.22±0.01 ^{ab}	3.22±0.01 ^a
ZTF6	96.08±0.08 ^c	0.58±0.01 ^b	0.0050±0.00141 ^{ab}	0.23±0.01 ^{ab}	3.12±0.06 ^a
ZTR9	96.04±0.05 ^c	0.59±0.01 ^{ab}	0.0055±0.00071 ^{ab}	0.22±0.01 ^{ab}	3.15±0.07 ^a
ZTF9	96.13±0.09 ^c	0.61±0.01 ^a	0.0060±0.00141 ^a	0.24±0.01 ^a	3.03±0.12 ^a

Values are expressed as means ±SD of triplicate determinations. Means with different superscripts in the same column indicate significant differences ($P < 0.05$)

Keys:

Control: freshly prepared zobo drink without turmeric or storage

ZTR3: drink produced with 97% zobo and 3% turmeric, stored at ambient conditions

ZTF3: drink produced with 97% zobo and 3% turmeric, stored at refrigeration temperature

ZTR6: drink produced with 94% zobo and 6% turmeric, stored at ambient conditions

ZTF6: drink produced with 94% zobo and 6% turmeric, stored at refrigeration temperature

ZTR9: drink produced with 91% zobo and 9% turmeric, stored at ambient conditions

ZTF9: drink produced with 91% zobo and 9% turmeric, stored at refrigeration temperature

Ash Content

Ash content increased from 0.45% in the control to between 0.48 to 0.61%. drink with 3% turmeric stored at room temperature had the lowest ash content, while that produced with 9% turmeric and stored in the refrigerator had the highest and values varied significantly ($P < 0.05$) among samples. The ash content is a representation of the total inorganic matter, and the presence of ash in the various drinks sample is an indication of a possible supply of minerals by these drinks. Zobo drink's ash contents of between 0.6-1.8% were found by Adeniji (2017) and Ekanem (2018), 0.56%, 0.52% and 0.50% were reported by Onabanjo and Airaodion (2022), Gbadegesin and Gbadamosi (2017) and Koopman (2019), respectively, and the ash content measured in this study (0.45 to 0.61%) was close to these reported values. higher ash content as observed in this study with increase in storage time. This increase was further intensify by the concentration of turmeric and/or could be due to the loss of moisture which led to concentration of the drink during storage.

Fat Content

The fat content increased from 0.0035% in the control to a range of 0.005% in drink produced from 6% turmeric stored in the refrigerator to 0.0065% in drink produced from 6% turmeric content stored in the refrigerator. All samples showed an extremely low fat percentage, close to zero. This could be so, as the zobo leaves contain only around 3% fat before preparation and the fat does not dissolve well in the water in which the leaves are boiled, and as such, not much fat is to be expected in the finished zobo (Babalola et al., 2001). This could be of benefit to the drink as low-fat containing foods will not easily go rancid during storage (Airaodion et al., 2019). Because of the low fat content in this study, it suggests that the zobo drink could be stored for a long time without discoloring or developing an off-odor. Also, the low-fat content of zobo drink makes it an ideal drink for obese people as high fat containing foods has been linked with increased deposition of adipose tissues which gives superficial weight gains to individuals.

Protein Content

The protein content of Zobo drink increased from 0.17% in the control to between 0.19 to 0.24%. Drink with 3% turmeric stored at room temperature had the lowest value, while that produced with 9% turmeric, stored at refrigeration temperature had the highest. There were no significant differences ($P < 0.05$) among drinks produced from 6% turmeric stored in the room or refrigerator, and 9% turmeric stored in the room. Protein has been highlighted as a nutrient in short supply in poor countries; protein deficiency is a severe problem on the African continent, particularly in Nigeria (Okudu et al., 2017). This study's proximate analysis revealed that Zobo drinks with higher concentration of turmeric contain significantly more nutrients than 100% Zobo drinks, and results were slightly lower than the 0.36% and 0.28 % was reported by Fasoyiro et al. (2005) and Gbadegesin and Gbadamosi (2017) respectively. High crude protein contents of 0.76% and 0.73% had been reported by Akujobi et al. (2018) and Onabanjo and Airaodion (2022), respectively. However, the variabilities of results in these researches with that of this study could be attributed to the method of processing and the level of supplementations made on the Zobo drinks as some have been nutrient dense fruits such as pineapples, mangoes, oranges, etc., as similar findings were observed in this study as the concentrations of turmeric increased. Proteins are the building blocks of life, they are

needed to repair worn out tissues, and however, with the low supply of proteins from Zobo drink, it is indicative that this drink needs to be consumed with protein rich sources.

Carbohydrate Content

The carbohydrate content also increased with storage from 2.13% in the control, to between 2.49% in the drink with 3% turmeric stored in the refrigerator to 3.22% in the drink produced from 6% turmeric stored at ambient conditions. There was however, no significant differences ($P < 0.05$) among these drinks in terms of their storage condition, however, drinks with 3% turmeric were significantly lower than those with higher turmeric concentrations in the different storage methods. At rest and during daily activities, the human body requires a lot of energy. The carbohydrate content from this finding is much lower than the 6.31% and 5.34% reported by Fasoyiro et al. (2005) and Akujobi et al. (2018), respectively. This variation in the carbohydrate content between those of this study and those of previous researchers could be as a result of the differences in the processing methods. The low carbohydrate in all the Zobo drink samples will suggest low calorific values and low energy supply to the body.

Microbial Load on Zobo-turmeric Drink

Microbial contamination is a significant concern in beverages like zobo due to their high water activity. Aghajanzadeh and Mohammad (2021) employed some chemical preservatives to improve the shelf life of zobo drink. They reported that only samples treated with benzoic acid remained organoleptically attractive after 14 days of storage. However, the problem with the use of chemical preservatives in food is that they tend to have adverse effects on the health of consumers (Ajanaku and Kolawole, 2022).

Several microorganisms are known to cause spoilage of zobo drink during storage. The microbial quality is used to assess the microbial density and diversity found in the nutritive drink. The microbial population of the drink seldom exceeds acceptable/level and tolerant level for ready-to-eat food. Also, coliforms in the zobo exceeding the permissible recommended limit of 0 in ready-to-eat food are an indication of contamination (Risiquat, 2013). The microbial counts in the zobo drinks sold in the markets and hawked in streets ranged from 10^2 – 10^8 cfu/ml. These values depend on the type of flavor, preservatives used and storage duration. For instance, bacteria counts of 8.1×10^4 cfu/ml, 1.21×10^5 cfu/ml, 2.6×10^5 cfu/ml, 3.2×10^5 cfu/ml and 2.5×10^6 cfu/ml for zobo drink prepared without sugar, with sugar, no sugary spices, with sugary spices, sugary spices with pineapple flavor respectively (Ekanem, 2019). Majority of the microbes found in the samples cause spoilage. Typically, microorganisms invade food products from several perspectives ranging from exposure, handling and storage. The microbial diversity found in zobo drink is mainly bacteria and fungi/yeast.

Bacterial Load on Zobo-turmeric Drink

After 3 days of storage, the bacterial load on the zobo turmeric drink (Table 4.6) showed that the values ranged from 2.9×10^2 cfu/ml to 1.3×10^3 cfu/ml. The drink prepared with 91% zobo and 9% turmeric, and stored in the refrigerator had the lowest bacterial load, while that prepared from 100% zobo, and stored under ambient condition had the highest. The zobo turmeric drink prepared with 3% and 6% turmeric inclusion and stored in the refrigerator were not significantly different $p < 0.05$. By 6 days of storage, drink prepared with 100% zobo, and stored under ambient conditions had the highest microbial load (2.4×10^4 cfu/ml), while that prepared with

9% turmeric, and stored in the refrigerator had the lowest (4.2×10^2 cfu/ml). By day 9 of storage, the bacterial load ranged from 4.4×10^3 to 1.8×10^5 cfu/ml. The zobo turmeric drink prepared with 100% zobo, and stored at room temperature had the highest bacterial load, while that prepared with 9% turmeric, and stored in the refrigerator had the lowest. There was significant differences ($P < 0.05$) among samples on day 6 and 9 of storage.

Fungal Load on Zobo-turmeric Drink

Table 4.7 shows the result of fungal load on zobo tumetic drink stored under ambient and refrigeration conditions. After 3 days of storage, the fungal load on the zobo turmeric drink ranged from 3.1×10^2 cfu/ml to 8.3×10^2 cfu/ml. The drink prepared with 91% zobo and 9% turmeric, and stored in the refrigerator had the lowest fungal load, while that prepared from 100% zobo, and stored under ambient condition had the highest. The zobo turmeric drink prepared with 100% zobo, and stored in the refrigerator and that produced with 9% turmeric inclusion

Table 3: Bacterial Load on Zobo-Turmeric Drink during Storage (Cfu/ml)

Sample	Day 3	Day 6	Day 9
Control	1.3×10^{3a}	2.4×10^{4a}	1.8×10^{5a}
ZTR3	8.4×10^{2b}	6.2×10^{3b}	1.2×10^{5b}
ZTF3	3.8×10^{2ef}	9.1×10^{2f}	8.3×10^{3f}
ZTR6	8.0×10^{2b}	2.8×10^{3c}	9.2×10^{4c}
ZTF6	3.5×10^{2f}	6.5×10^{2g}	5.9×10^{3g}
ZTR9	7.6×10^{2c}	1.9×10^{3d}	7.8×10^{4d}
ZTF9	2.9×10^{2g}	4.2×10^{2h}	4.4×10^{3h}

Values are expressed as means $\pm$ SD of triplicate determinations. Means with different superscripts in the same column indicate significant differences ($P < 0.05$)

Key

Control: freshly prepared zobo drink without turmeric or storage

ZTR3: drink produced with 97% zobo and 3% turmeric, stored at ambient conditions

ZTF3: drink produced with 97% zobo and 3% turmeric, stored at refrigeration temperature

ZTR6: drink produced with 94% zobo and 6% turmeric, stored at ambient conditions

ZTF6: drink produced with 94% zobo and 6% turmeric, stored at refrigeration temperature

ZTR9: drink produced with 91% zobo and 9% turmeric, stored at ambient conditions

ZTF9: drink produced with 91% zobo and 9% turmeric, stored at refrigeration temperature

Table 4: Fungal Load on Zobo Turmeric Drink during Storage

Sample	Day 3	Day 6	Day 9
Control	8.3×10^{2a}	7.4×10^{3a}	1.4×10^{5a}
ZTR3	6.7×10^{2b}	5.8×10^{3b}	7.3×10^{4b}
ZTF3	3.6×10^{2e}	1.1×10^{3d}	9.1×10^{3f}
ZTR6	5.2×10^{2c}	3.0×10^{3c}	5.1×10^{4c}
ZTF6	3.4×10^{2e}	6.2×10^{2e}	8.4×10^{3fg}
ZTR9	4.6×10^{2d}	1.4×10^{3d}	4.3×10^{4d}
ZTF9	3.1×10^{2e}	4.8×10^{2f}	5.2×10^{3h}

Values are expressed as means $\pm$ SD of triplicate determinations. Means with different superscripts in the same column indicate significant differences ($P < 0.05$)

Key

Control: freshly prepared zobo drink without turmeric or storage

ZTR3: drink produced with 97% zobo and 3% turmeric, stored at ambient conditions

ZTF3: drink produced with 97% zobo and 3% turmeric, stored at refrigeration temperature

ZTR6: drink produced with 94% zobo and 6% turmeric, stored at ambient conditions

ZTF6: drink produced with 94% zobo and 6% turmeric, stored at refrigeration temperature

ZTR9: drink produced with 91% zobo and 9% turmeric, stored at ambient conditions

ZTF9: drink produced with 91% zobo and 9% turmeric, stored at refrigeration temperature

Stored in the room were not significantly different $p < 0.05$. By 6 days of storage, drink prepared with 100% zobo, and stored under ambient conditions had the highest fungal load (7.4×10^3 cfu/ml), while that prepared with 9% turmeric, and stored in the refrigerator had the lowest (4.8×10^2 cfu/ml). By day 9 of storage, the fungal load ranged from 5.2×10^3 to 1.4×10^5 cfu/ml. The zobo turmeric drink prepared with 100% zobo, and stored at room temperature had the highest bacterial load, while that prepared with 9% turmeric, and stored in the refrigerator had the lowest. There were significant differences among samples $p < 0.05$ on day 6 and 9 of storage.

These results from this study, therefore, revealed that the bacterial and fungal load on the Zobo drink during storage was within the tolerable levels of $< 10^6$ and a combination of low temperature storage and increased concentration of

turmeric was effective in lowering the microbial load, suggesting a possible extension in the shelf life of zobo drink. Similar results were also obtained for the total fungal count.

Sensory Evaluation of Zobo-turmeric Drink during Storage

Sensory assessment is an essential factor for determining quality in the creation of new goods and satisfying consumer demands (Munoz, 2013). Table 4.5: shows the result of sensory attributes of Zobo-turmeric drink stored under ambient and refrigeration conditions. After 9 days of storage, the preference for the colour of Zobo drink ranged from 5.80 to 7.60, and sample with 9% turmeric, stored under ambient condition had the lowest acceptable colour, while the control had the highest. In terms of taste, the control was the most

preferred (7.20), while that prepared with 9% turmeric and stored in the room had the lowest ratings (5.20). The Zobo-turmeric drink with 9% turmeric, and stored in either the refrigerator or under ambient conditions was significantly different from all the other samples. For aroma, the control was the most accepted, while the drink prepared with 9% turmeric and stored in the room had the lowest acceptance with scores of 7.40 and 4.60, respectively. For the overall acceptability, the control ranked the highest (7.20) and this was not significantly different ($P < 0.05$) from all the other

samples except for that which was made from 9% turmeric and stored under ambient conditions.

While the health benefits of turmeric are well-documented, consumer acceptance is crucial for successful product development. Educating consumers about the advantages of turmeric-fortified zobo can help increase its popularity in the market. The addition of turmeric to zobo drink has shown that turmeric can significantly enhance the freshness, sensory attributes (taste and aroma), and safety of zobo while providing consumers with a health-boosting option (Takayuki et al 2021; Wibowo and Esther 2019).

Table 5: Sensory Attributes Of Zobo-Turmeric during Storage

Sample	Colour	Taste	Aroma	Overall Acceptability
Control	7.60±0.55 ^a	7.20±0.45 ^a	7.40±0.55 ^a	7.20±0.45 ^a
ZTR3	7.00±0.71 ^{ab}	6.60±0.55 ^a	6.40±0.55 ^b	6.40±0.55 ^a
ZTF3	7.40±0.55 ^{ab}	7.00±0.00 ^a	6.20±0.45 ^b	7.00±0.71 ^a
ZTR6	6.60±0.55 ^{bc}	6.60±0.55 ^a	5.80±0.84 ^b	6.40±0.55 ^a
ZTF6	7.00±0.71 ^{ab}	6.60±0.55 ^a	6.40±0.55 ^b	6.60±0.55 ^a
ZTR9	5.80±0.84 ^c	5.20±0.45 ^b	4.60±0.55 ^c	5.40±0.55 ^b
ZTF9	6.60±0.55 ^{bc}	5.80±0.84 ^b	6.00±0.71 ^b	6.40±0.55 ^a

Values are expressed as means ±SD of triplicate determinations. Means with different superscripts in the same column indicate significant differences ($P < 0.05$)

Key

Control: freshly prepared zobo drink without turmeric or storage

ZTR3: drink produced with 97% zobo and 3% turmeric, stored at ambient conditions

ZTF3: drink produced with 97% zobo and 3% turmeric, stored at refrigeration temperature

ZTR6: drink produced with 94% zobo and 6% turmeric, stored at ambient conditions

ZTF6: drink produced with 94% zobo and 6% turmeric, stored at refrigeration temperature

ZTR9: drink produced with 91% zobo and 9% turmeric, stored at ambient conditions

ZTF9: drink produced with 91% zobo and 9% turmeric, stored at refrigeration temperature

CONCLUSION

This research has shown that fortifying Zobo with turmeric significantly increased the ash, fats, proteins, and carbohydrate contents of Zobo-turmeric drink, with decrease in the moisture content during storage under ambient conditions and in refrigeration temperature, during storage. This was attributed to the concentration of these nutrients as a consequence of moisture loss. There was significant increase in the bacterial and fungal load with increase in storage time in the Zobo-turmeric drink, the increase in turmeric concentration and storage in refrigerated temperature has shown a significant suppression of microbial growth.

The study recommends the use of turmeric in combination with refrigeration to preserve the quality of zobo drink. It also suggests fortifying zobo drink with mineral-rich ingredients to improve its nutritional value. Furthermore, future research should investigate higher concentrations of turmeric and other natural preservatives to enhance the shelf life and quality of the beverage.

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