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Characterization of spiced and malted maize supplemented orange-fleshed sweet potato beverage

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Abstract

Beverages made with spiced and malted maize (MM) and orange-fleshed sweet potato were characterized. The beverages were formulated by gradually adding 5 g of MM, ranging from 0 to 25 g, to OFSP extract containing a ginger-garlic (G-G) mixture and sugar. The samples were pasteurized, evaluated, and monitored for microbiological qualities for four weeks, after which the data were statistically assessed. With the exception of specific gravity and vitamin C, all physicochemical attributes increased as MM increased. The color and general acceptance evaluations of the beverages were improved with an increase in MM up to 20 g. Since G-G-spiced OFSP beverages containing 10, 15, and 20 g of MM demonstrated beneficial qualities, they may be added to the existing health-promoting beverages.

Keywords: Phytochemicals; Nutrients; Sensory attributes; Sweet potato beverage

Introduction

Sweet potato (*Ipomoea batata* L.) plays a pivotal role of ameliorating the challenges of food insecurity and poverty worldwide, especially, in the developing countries where is grown (Waseem *et al.* 2023). Among the different agronomic varieties of sweet potato available, orange fleshed sweet potato (OFSP) is identified to be rich in β-carotene which is the precursor of vitamin A (Adekambi *et al.* 2023). Consumption of foods rich in vitamin A is a sustainable and an effective tool for tackling such diseased conditions as measles, diarrhea and acute respiratory infections in children (National Bureau of Statistic, 2018). The high level (276.98 µg per g) of vitamin A in OFSP makes it suitable for tackling the challenge of vitamin A deficiency (VAD) in vulnerable populations (National Bureau of Statistic, 2018; Shwetha *et al.* 2020).

Beverages are a class of food that can be produced from different food materials such as milk, fruit and vegetable, legume and cereal grains, coffee beans, tea leaves and cocoa beans. However, beverages are also produced from non-conventional food materials such as roots and tubers and residues or what could be regarded as waste materials from root and tuber processing (Girard *et al.* 2021; Oyedokun *et al.* 2023). Such non-conventional food materials is OFSP.

However, there is little or no information available on the utilization of aqueous extract from OFSP for producing a beverage with health-promoting potentials. This would cater for the needs of beverage consumers who are now conscious of their health.

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Furthermore, there is a need for considering supplementation of the extract with a source of biological agents that may act on various components of OFSP for the enhancement of the properties of the resulting beverage. Therefore, this present study explored the possibility of supplementing OFSP beverage with malted maize (MM). The MM would serve as a source of external α- and β-amylase enzymes which would convert some of the starch in the sweet potato to sugars with a view of extracting more soluble solids. Apart from creating new OFSP-based beverages of enhanced quality, the supplementation would expand the utilization of both OFSP and maize. This will undoubtedly culminate in creating more jobs and wealth to achieving some sustainable development goals. Furthermore, the inclusion of ginger-garlic mix would also enhance the antioxidant properties of the formulated beverages (Lourenço *et al.* 2019).

Materials and methods

The OFSP (Mothers' delight) roots of varied sizes used in this study were obtained from an experimental farm whereas maize (yellow variety) grains, ginger, garlic and sugar (sucrose) were obtained from a local market. All the reagents used in this study were of analytical grade.

Preparation of malted maize

Malted maize (MM) was prepared as described by Dabija *et al.* (2021) with slight modification. Maize grains were steeped in water (1:3 w/v) for 24 h and moistened for 3 d to allow them to sprout. The sprouted grains were killed at 60 °C in a hot air oven and ground in an attrition mill to an MM fine meal.

Preparation of orange- fleshed sweetpotato extract

The method described by Oyedokun *et al.* (2023) with slight modifications, was used to prepare the orange-fleshed sweetpotato (OFSP) extract. The OFSP roots were trimmed and peeled followed by slicing to obtain pieces of about 10 mm in thickness. This was followed by cooking in water using the ratio 1:9 (w/v) for 15 min. The cooked potato was mashed in a blender and then subjected to filtration obtain OFSP extract.

Preparation of ginger- garlic extract

Fresh ginger roots and garlic cloves at a ratio of 4:1 were blended and mixed with potable water at a ratio of 1:9 (w/v), and muslin cloth was used for filtration to obtain ginger-garlic (G-G) extract.

Formulation and production of ginger-garlic spiced and malted maize supplemented orange-fleshed sweetpotato beverage samples

Beverage samples were formulated as summarized in Table I. Varied quantities (5, 10, 15, 20, and 25 g) of MM ground to fine meal using attrition mill were mixed with 100 ml OFSP filtrate containing 1 ml of G-G extract. The mixture was cooled to ambient temperature (30 ± 2°C), filtered using a muslin cloth, and packaged in sterile bottles. The mixture was pasteurized at 75°C for 30 min and cooled to ambient temperature (30 ± 2°C). Some of the beverage samples were analyzed for physical and chemical properties and phytochemical constituents, while others were stored at ambient temperature (30 ± 2°C) for 4 weeks for microbiological stability studies.

Table I. Formulation of beverage sample

Sample	Malted maize (g)	OFSP extract (ml)	Ginger-garlic (ml)	Sugar (g)
BWMM	0	100	1	10
B5MM	5	100	1	10
B10MM	10	100	1	10
B15MM	15	100	1	10
B20MM	20	100	1	10
B25MM	25	100	1	10

BWMM = Beverage without malted maize; B5MM = Beverage with 5g malted maize; B10MM = Beverage with 10g malted maize; B15MM = Beverage with 15g malted maize; B20MM = Beverage with 20g malted maize; B25MM = Beverage with 25g malted maize.

Specific gravity determination

The specific gravity of the samples was determined using a specific gravity bottle (AOAC, 2023). The bottles were

washed, rinsed, and dried. The empty bottle was weighed and the mass was recorded as M_1. The bottle was filled with either distilled water or the beverage sample, weighed, and the mass was recorded as M_2 or M_3. The specific gravity was calculated using Equation (1):

$$\text{Specific gravity} = \frac{M3 - M1}{M2 - M1} \quad (1)$$

Determination of total soluble solids

Handheld refractometer was used to determine the total soluble solids (TSS) of the beverage samples (AOAC, 2023).

pH determination

The pH of the beverage was determined using a pH meter (AOAC, 2023). The pH meter was calibrated using pH 4 and 7 standard buffer solutions. A 100 ml was placed in a 250 ml beaker, and the pH electrode was immersed in the sample to determine its pH.

Determination of sedimentation rate

The sedimentation rate (SR) was determined using the Westergen method, with minor modifications. The sample was poured into a Westergren-Katz tube to a 200 mm mark and allowed to stand in a strictly vertical position for 1 h at 30 ± 2°C (ambient temperature). Then the distance from the lowest point of the surface meniscus to the upper limit of the sediment was measured and SR was expressed in millimeters per 1 h (mm/h).

Mineral analyses

The method described by AOAC (2023) was used for mineral analysis. The beverage samples were ashed at temperature of about 550 °C followed by boiling of the ash with 20% HCl (10 mL). The boiled mixture was subjected to filtration into a standard flask (10 mL) and then made up to the mark with deionized water. The resulting solution was used for the analysis. The determination of phosphorus (P) was done colorimetrically using monobasic potassium phosphate as the standard, while atomic absorption spectrophotometer was used to determine the amount of calcium (Ca) in the beverage samples. For the determination of sodium (Na) and potassium (K), flame photometer was used, with potassium chloride as the standard. The mineral ratios of Ca/P and Na/K were calculated and compared with acceptable ranges, as described by Oyedokun *et al.* (2021).

Determination of beta-carotene

Beta-carotene content of the beverage samples was determined as described by Oyedokun *et al.* (2023). The beverage sample (40 mL) was thoroughly stirred with acetone (20 mL) to the point of saturation. The sample was left in a refrigerator for 12 h and the aqueous layer was extracted while the remaining content was weighed and about 20 ml of acetone was added. The mixed sample (15 ml) was placed in a funnel and acetone (2 mL) and followed by the addition of 2 mL of acetone and 15 mL of methylene chloride for solubility and easy filterability. After the mixture was subjected to filtration, methylene chloride was removed and few drops of calcium chloride were added for complexation of organic compounds. The resulting sample was heated moderately in a vial and then mixed with petroleum ether (1 mL) and then subjected to column chromatographic purification. The column chromatography was fitted with cotton by placing it on a layer of sand, a layer of mixture of silicone gel, and hexane in a glass pipette. The hexane, sand and petroleum ether were sealed off. Beta-carotene and hexane were collected. Absorbance at 450 nm was read off in a UV-VIS spectrophotometer. The reading was performed quickly because of the volatility nature of petroleum ether. The beta-carotene concentration was determined by using Beer-Lambert law as shown in Equation (2) from the measured absorbance data:

$$C = \frac{10 \times M \times A}{L\epsilon} \quad (1)$$

Where: C = β-carotene concentration, ϵ = β-carotene molar extinction coefficient in petroleum ether (138900 $Lmol^{-1}$ cm^{-1}), M = β-carotene molecular weight (536.88 $gmol^{-1}$), A = absorbance at 450 nm and L = path length (1 cm).

Determination of flavonoids

The flavonoid content was determined as described by Aparna and Hema (2022), with slight modifications. The samples (0.5 ml) were weighed and mixed with 10 ml of 80% methanol for 2 h. A 0.4 ml of the resulting mixture was measured into a 10 ml standard flask and 1.2 ml of 10% NaOH, 1.2 ml of 0.2 M sulphuric acid and 3 ml of 3 M of sodium nitrite were added and made up to the mark with distilled water. The mixture was read at 395 nm using a Shimadzu 1800 double-beam UV-visible spectrophotometer.

Determination of vitamin C content

The vitamin C contents of the samples were determined using the method described by AOAC (2023). Ten (10) ml of the sample was measured in a 100 ml volumetric flask and diluted to 100 ml with 3% metaphosphoric acid solution

0.0033M EDTA. The diluted samples were filtered using a Whatman filter paper. Ten milliliters of the filtrate was pipetted into a small flask and titrated immediately with a standard solution of 2, 6-dichlorophenol indophenols to a faint pink end point. The ascorbic acid content of each sample was then calculated.

Determination of phytates

Phytate content of the beverages was determined using the method described by AOAC (2023). About 0.1 ml each beverage sample was extracted with 10 ml of 2.4% HCl on a mechanical shaker for 1 h at ambient temperature and centrifuged at 3000 rpm for 30 min. About 1 ml of Wade reagent (containing 0.03% solution of $FeCl_3.6H_2O$ and 0.3% of sulfosalicilic acid in water) was added to 3 ml of sample solutions (supernatant from the centrifuge) and the mixture was mixed on a vortex mixer for 5 s. Four different concentration of standard sodium salt of phytates (0.025 mg/l, 0.05 mg/l, 0.075 mg/l and 0.1 mg/l) were prepared to obtain the calibration curve and 0.15 g of standard solution was added into 15 ml of centrifuge tubes with 3 ml of water which was used as a zero level (blank). Wade reagent (1 ml) was added to each test tube, and the solution was mixed using a vortex mixer for 5 s. The mixture was centrifuged for 10 min, and the absorbance of the solutions (both sample and standard) was measured at 500 nm using deionized water as a blank in a UV-Vis spectrophotometer. The concentration of phytate in the beverage was determined using a calibration curve.

Determination of oxalates

The method employed for determination was described by AOAC (2023) with little modification. A sample of 2 ml was digested with 10 ml 6 M HCl for 1 h and made up to 250 ml in a volumetric flask. The pH of the filtrate was adjusted to conc. NH_4OH solution until the color of the solution changed from salmon pink to faint yellow. Thereafter, the filtrate was treated with 10 ml of a 5% $CaCl_2$ solution to precipitate insoluble oxalate. The suspension was then centrifuged at 2500 rpm, after which the supernatant was decanted and completely dissolved in 10 ml of 20% (v/v) H_2SO_4. The total filtrate resulting from the dissolution in H_2SO_4 was made up to 300 ml. An aliquot of 125 ml of the filtrate was heated to near the boiling point and then titrated against 0.05 M of standardized $KMnO_4$ solution to a faint pink color that persisted for about 30 s after which the burette reading was taken. Oxalate content was evaluated using the titer value.

Evaluation of sensory properties

The sensory properties of the beverage samples were evaluated by following the procedure of Akinwande *et al.* (2024) with slight modifications. Sensory panelists (50) evaluated the samples for mouthfeel, aroma, colour and overall acceptability on a hedonic scale ranging from 1, dislike extremely to 7, like extremely.

Statistical analysis

The Analysis of Variance (ANOVA) was performed on the data that were generated with significant differences deter-

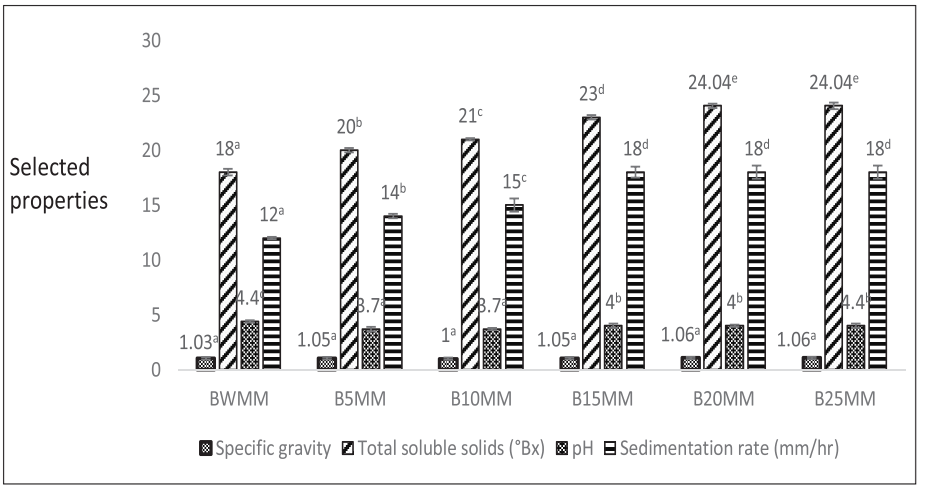

Fig. 1. Selected properties of beverage sample

BWMM = Beverage without malted maize; B5MM = Beverage with 5 g malted maize; B10MM = Beverage with 10 g malted maize; B15MM = Beverage with 15 g malted maize; B20MM Beverage with 20 g malted maize; B25MM Beverage with 25 g malted maize. Different superscript letters on values above the bars of the same colour fill are significantly different ($p \leq 0.05$).

mined at $p<0.05$ using Minitab Software (Minitab Ltd. Coventry, UK).

Results and discussion

Selected properties of the beverage samples

The selected properties of the orange-fleshed sweet potato (OFSP) based beverages are presented in Figure 1. There was no significant difference ($p>0.05$) in the values of specific gravity (SG) of the beverage samples, which ranged from 1.00 to 1.06. The total soluble solids (TSS) ranged from 18 °Brix for the beverage without MM (BWMM) to 24.20 °Brix for beverages with 25 g MM (B25MM). It increased significantly ($p<0.05$) with an increase in the MM level in the samples. With the inclusion of MM in the OFSP beverage, the pH decreased significantly, regardless of the quantity of MM. However, the pH values (3.70) of beverages with 5 g of malted maize (B5MM) and beverages with 10 g of MM (B10MM) were not significantly different. The SR of the beverage samples ranged from 12.00 mm/h for BWMM to 18.00 mm/h for B15MM, B20MM and B25MM. It increased with the inclusion of MM in beverage samples.

Since there was no significant difference ($p>0.05$) in the values of specific gravity (SG) of the beverage samples, which ranged from 1.00 to 1.06, the degree of cloudiness of the beverage samples may be similar (Ndife *et al.* 2020). However, the beverage samples supplemented with malted maize (MM) may be slightly denser than those supplemented with water, as the SG of water is 1.00. This could be a result of the extraction of soluble solids from the MM into the beverage. The values of SG from this study compares well with the SG value (1.01) obtained for fermented beverage produced from boiled dasheen (Arebo *et al.* 2023) and the values, 1.09, 1.00, 1.01, 1.07, 1.02 and 1.04 for pineapple juice, pineapple wine, dealcoholized pineapple wine, sorghum wort, sorghum beer and dealcoholized sorghum beer, respectively (Iwouno *et al.* 2019). The increase in TSS may be due to an increase in the quantity of MM used to supplement the beverage, as a larger quantity of MM may yield more amylolytic enzymes that are necessary for the degradation of starch to sugars. The range of TSS values from this study is higher than the range (4.95 – 8.25%) reported for sorghum-based *kunu-zaki* supplemented with orange-fleshed sweet potato (Ibrahim *et al.* 2022) and comparable to the 20.91% reported by Mamo *et al.* (2014) for OFSP juice that produced 100% OFSP. High TSS values may be an indication of the high sugar content of the beverage, which may increase the acceptance level of the beverage, especially by children. The decrease in pH with the inclusion of MM could be due to the low level of organic acids in MM. The pH values of the beverage samples are comparable with the pH values (3.97 – 4.10) reported for sorghum-based *kunun-zaki* supplemented with sweet potato (Ibrahim et al., 2022) but lower than the values (4.65 – 4.90) for Beauregard sweetpotato beer (Humia *et al.* 2020) and the value (5.5) obtained for sweet potato wine (20). The high pH values of the beverage samples supplemented with MM could make them preferable to drinks with low pH values by consumers living with ulcers or those who are allergic to drinks that are high in acid. SR is a physical property related to the settling

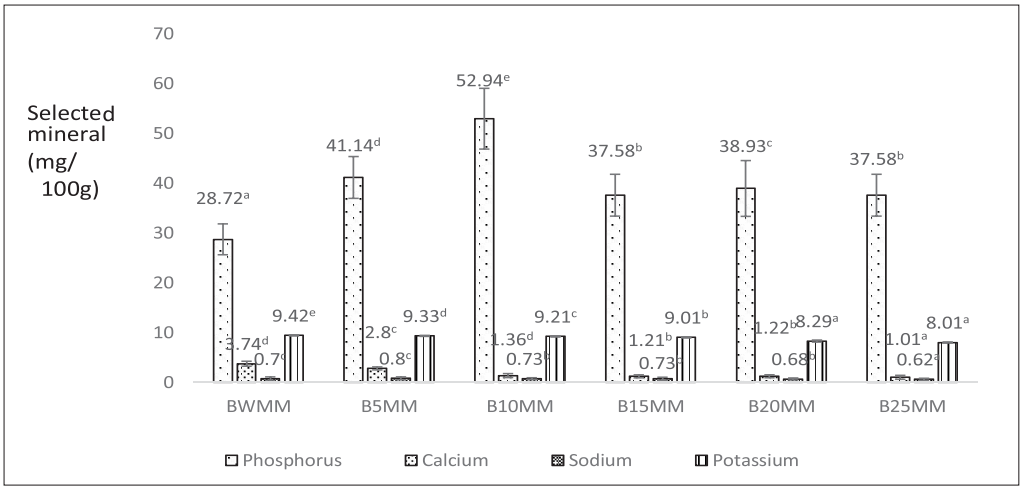

Fig. 2. Mineral composition of beverage sample

BWMM = Beverage without malted maize; B5MM = Beverage with 5 g malted maize; B10MM = Beverage with 10 g malted maize; B15MM = Beverage with 15 g malted maize; B20MM Beverage with 20 g malted maize; B25MM Beverage with 25 g malted maize. Different superscript letters on numbers on bars of the same colour fill are significantly different ($p \leq 0.05$).

of solids in a beverage (Paul *et al.* 2014). The higher values of SR in the beverages with MM may be due to the solid particles comprising fibers from MM. This was similar to the sedimentation observed in fermented millet sprout milk beverages (Sudha *et al.* 2021). A suitable stabilizing agent may be incorporated into the sample containing MM to decrease SR.

Mineral composition of the beverage samples

The mineral compositions of the beverages are shown in Figure 2. The inclusion of MM in the beverage samples increased effect on phosphorus (P) but decreased calcium (Ca), sodium (Na), and potassium (K). The mineral ratios are shown in Figure 3. The Ca/P ratios of the samples ranged from 0.03 in all BWMM samples that contain MM to 0.13 in BWMM (control sample). However, the Na/K ratios of all samples (0.08) were the same, regardless of the amount of MM in the beverage samples.

The increase in phosphorus from 28.72 mg/100 ml for BWMM to 52.94 mg/100 ml could be as a result of MM added to the beverage samples since the amount of P in maize (210 mg/100 g) is higher than that of OFSP 15 – 51 mg/100 g (Neela and Fanta, 2019). This could also be due to the increasing effect of the malting process on the mineral content, especially phosphorus. Beverage samples containing MM may play a crucial role in metabolic processes such as energy metabolism and bone mineralization (Neela and Fanta, 2019). A 100 ml of the beverage samples would contribute between 3.01 to 4.24% of Recommended Daily Allowance (RDA) for the adult (Zamberlin *et al.* 2012). The decreased values of Ca, Na, and K observed for the beverage samples containing MM could have stemmed from the low levels of the minerals in MM occasioned by steeping during malting (Nkhata *et al.* 2018). This is similar to the observation of Ofoedu *et al.* (2020), who reported lower values of Ca and Mg for syrup from malted rice than for non-malted rice. Olaoye *et al.* (2015) also reported a decrease in ash content as MM increased in composite flour formulated from wheat flour and MM. A 100 ml of the beverage samples could only contribute 0.08 – 0.31%, 0.04 – 0.05% and 0.17 – 0.20% of RDA for the adult for Ca, Na and K, respectively (Nkhata *et al.* 2018). Therefore, the beverages could be fortified with key minerals, especially Ca, to boost their nutritional quality. The decreased Na in the beverage sample implies its suitability for consumers living with high blood pressure or who are sensitive to high sodium (Grillo *et al.* 2019). The values of Ca/P of all the beverage samples were less than the value (1.5 - 1.67) of calcium/phosphorus compound deemed to be calcium-deficient (Nikolendo *et al.* 2020). The low Ca/P values of the samples imply that the beverage samples may not facilitate the absorption of calcium in the small intestine; therefore, there is a need to fortify samples with Ca. The Na/K ratios obtained in this study are comparable to the range of Na/K reported by Sanoussi *et al.* (2016) for ten elite sweet potato landraces in Benin. Na/K values of less than 1 in beverage samples are desirable for lowering blood pressure.

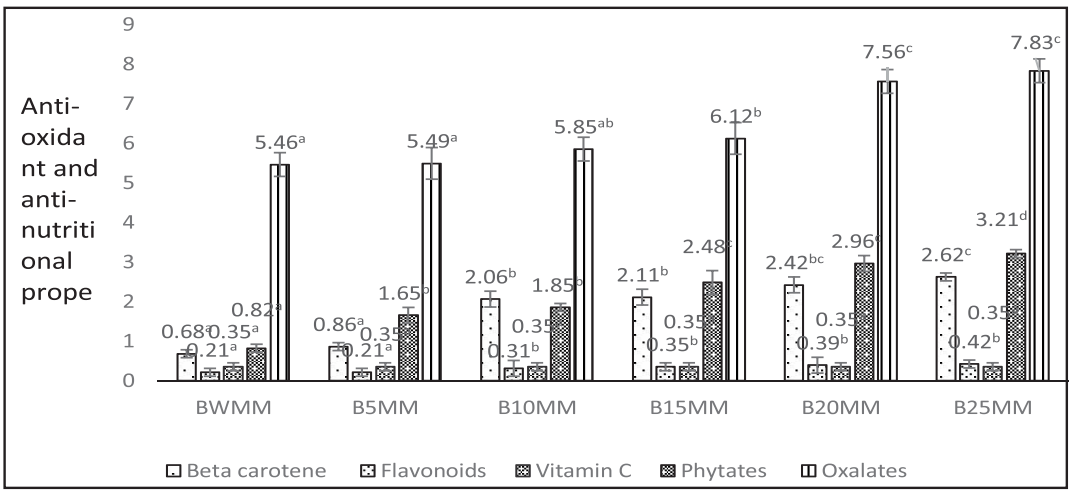

Fig. 3. Antioxidant and anti-nutritional properties of beverage samples

BWMM = Beverage without malted maize; B5MM = Beverage with 5 g malted maize; B10MM = Beverage with 10 g malted maize; B15MM = Beverage with 15 g malted maize; B20MM Beverage with 20 g malted maize; B25MM Beverage with 25 g malted maize. Different superscript letters on numbers on bars of the same colour fill are significantly different ($p \leq 0.05$).

Antioxidant and anti-nutritional properties of the beverage samples

The antioxidant and anti-nutritional properties of the OFSP-based beverage samples are shown in Figure 3. The concentration of beta-carotene ranged between 0.68 and 2.62 mg/100 ml. BWMM (control sample) had the lowest value (0.68 mg/100 ml while B25MM had the highest value (2.62 mg/100 ml. Beta-carotene content increased as MM increased in the beverage samples. The flavonoids values of the beverage samples ranged between 0.21 and 0.42 mg/100 ml with the control (BWMM) and B5MM samples having the lowest values. However, there was an increase in flavonoid content as MM increased to 10 g in the beverage samples, above which there was no change in the flavonoid content. Beverage samples supplemented with up to 10 g of MM would be a good source of phenolic compounds, which may confer antioxidative properties to the beverages. There was no significant difference ($p>0.05$) in the vitamin C content of the control sample (BWMM) and beverage samples containing MM. The phytates and oxalates of the beverage samples increased with a stepwise increase in MM up to 10 g in the beverage samples. The ranges of phytates and oxalates were 0.82 - 3.21 mg/100 ml and 5.46 – 7.83 mg/100 ml, respectively.

The increase in beta-carotene with the inclusion of MM could be a result of high beta-carotene in the maize used for producing MM (Ndife *et al.* 2020; Arebo *et al.* 2023). However, the values of beta carotene of all the beverage samples are higher than the range (0.00092 – 1.92 mg/100 ml) reported for beverages developed from OFSP supplemented with mango and spices (Mamo *et al.* 2014). Beverage samples containing MM may be preferable for consumption due to their high beta-carotene content. The increase in flavonoids could be due to the variety of maize (yellow maize) utilized for the production of MM used to supplement the beverage samples, as maize contains a considerable amount of flavonoids. The range of flavonoid contents of the beverage samples are within the range (0 to 191.50 mg/100 g) obtained for sorghum-based *kunun-zaki* supplemented with orange fleshed sweetpotato (Ibrahim *et al.* 2022). Beverage samples supplemented with up to 10 g of MM would be a good source of phenolic compounds, which may confer anti-oxidative properties to the beverages. There was an indication that MM could not contribute to the vitamin C content of the beverage samples. The amount of vitamin C (0.35 mg/100 ml) observed for the beverage samples in this study is lower than the value (2.33 mg/100 g) reported for ready to drink beverage from sweetpotato (Sohail *et al.* 2013) and the value (2.43 - 3.99 mg/100 g) observed for non-alcoholic beverage from cassava-sweetpotato (Wireko-Manu *et al.* 2016). Vitamin C is vital for preventing molecular changes and scurvy (Wireko-Manu *et al.* 2016), and the vitamin C content of beverage samples could be increased through fortification to contribute to the recommended daily allowance (RDA) of the vitamin.

The increase in phytates with an increase in MM could be a result of the MM in the beverage samples. Meanwhile, OFSP has little or no phytates, as they could not be detected in juice produced from 100% OFSP compared to juice samples that

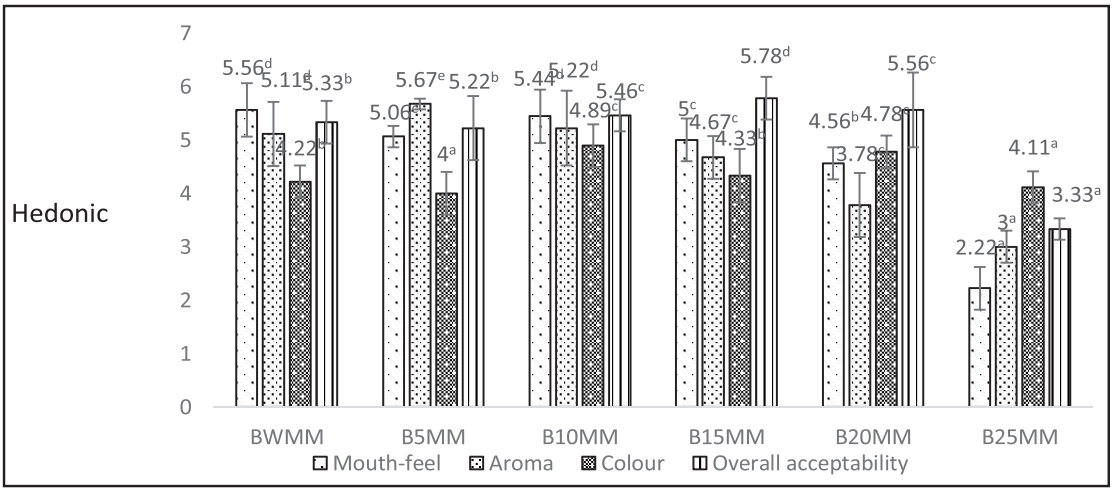

Fig. 4. Sensory attributes of beverage samples

BWMM = Beverage without malted maize; B5MM = Beverage with 5 g malted maize; B10MM = Beverage with 10 g malted maize; B15MM = Beverage with 15 g malted maize; B20MM Beverage with 20 g malted maize; B25MM Beverage with 25 g malted maize. Different superscript letters on numbers on bars of the same colour fill are significantly different ($p \leq 0.05$).

contain other food materials along with OFSP (Tariku *et al.* 2014). Beverage samples containing MM could contribute to the physiological functions and health benefits of consumers due to their phytates (Xiong *et al.* 2022). The increase in oxalate content could be due to the inclusion of MM in the beverage samples. However, the quantities of oxalates which ranged from 5.46 to 7.83 mg/100 ml is lower than the values reported by Siener *et al.* (2016) for rhubarb (198.3 mg/100 ml), beetroot juice (60.1 – 70.0 mg/100 ml) and other juices (<10 mg/100 ml). Consequently, beverage samples may be a choice of drink for consumers prone to certain conditions, such as kidney stones. The bioactive compounds may play a vital role in lowering the glucose and cholesterol levels of consumers, as they are present in low concentrations in beverage samples (Pathaw *et al.* 2022).

Sensory scores of the beverage samples

The sensory attributes of OFSP beverage samples are shown in Fig. 4. The mouthfeel scores decreased with the inclusion of MM. There was no significant difference ($p>0.05$) between the mouthfeel scores for BWMM (control sample) and B10MM. For aroma, the score increased as MM increased to 10 g and then decreased beyond this quantity. Meanwhile, the color score increased with increasing MM in the samples with B10MM, B15MM, and B20MM, which had higher values than BWMM. The same trend was observed for the overall acceptability score in that B10MM, B15MM, and B20MM were preferred to BWMM. The sample containing 25 g of MM (B25MM) had the lowest score among all the attributes studied.

Sensory scores indicated that consumers had a higher preference for B10MM, B15MM, and B20MM than for BWMM in terms of colour and overall acceptability. With low scores for all attributes studied for B25MM, which could be due to the high level of polyphenols extracted into the beverage occasioned by a relatively large quantity of MM in the beverage (Suriano *et al.* (2021), the amount of MM should never reach 25 g in a formulated 100 ml OFSP beverage sample.

Conclusions

The study showed that the inclusion of MM in OFSP beverages led to the enhancement of TSS, phosphorus, and beta-carotene contents, whereas the vitamin C content of the beverages remained unchanged. Meanwhile, beverages containing MM were rich in phytochemicals compared to those without MM. Sensory scores indicated that consumers had a higher preference for B10MM, B15MM, and B20MM than for BWMM in terms of color and overall acceptability. Therefore, up to 20 g of MM could be incorporated into OFSP-based beverages at a ratio of 1:5 (w/v). The beverage developed in this study could be added to the existing health-promoting beverages.

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