Effects of watermelon pulp fortification on maize mageu physicochemical and sensory acceptability

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A B S T R A C T

Mageu is a non-alcoholic fermented gruel processed from cereal grains, mostly maize and is widely consumed in the Southern African region. The refined maize meal used for mageu processing is limited in dietary fiber, B-vitamins, vitamin C, carotenoids, omega-3 fatty acids and minerals because of bran removal during milling. Fortification with plant carotenoid sources may be an effective method to supply potent antioxidants such as lycopene and beta-carotene that help preventing vitamin A deficiency related diseases. The objective of this study was to investigate the effects of three levels of watermelon pulp powder fortifications (5g, 10g, and 15g) on the physicochemical and sensory acceptability of mageu. Significant difference (p < 0.05) was found for crude protein, ash, titratable acidity, and total carotenoid contents among the mageu samples. The percentage protein, ash, titratable acidity (TA), vitamin C (mg/100g) and total carotenoids (TC) (μg/g) contents for the mageu samples ranged between 10.60–13.70, 0.53–0.86, 0.08–0.15, 8.81–17.60 and 0.00–51.60, respectively. There was an increase in the protein, ash, TA, vitamin C and TC contents with an increasing level of watermelon pulp fortification. When watermelon pulp fortification increased to 15g, total carotenoids content increased significantly which shows the potential to fortify mageu with lycopene, the major carotenoid in the watermelon pulp, as well beta-carotene a pro-vitamin A carotenoid. Furthermore, the sensory attributes of the mageu sample fortified with 15g watermelon pulp was liked significantly more (p < 0.05) by a consumer panel. The study showed the potential of an acceptable maize mageu fortification with watermelon pulp powder to increase its nutritional and bioactive contents, particularly lycopene.

1. Introduction

Mageu/mahewu is a Southern African maize (Zea mays L.) meal based lactic acid bacteria (Lactobacillus species: L. fermentum, L. plantarum, L. bulgaricus, L. brevis, L. delbruekii, L. rossiae; Weissella spp, Pediococcus pentosaceus, Lactococcus lactis, Leuconostoc lactis) fermented (Pswarayi and Gänzle, 2019; Simango, 2002), non-alcoholic gruel beverage of pH 3.6 to 4.0 widely consumed by Bantu people in the Southern African region (Kayitesi et al., 2017). Mageu is also processed from sorghum, grain malts (sorghum and millet) and cassava (Salvador et al., 2016). Even though, the end fermentation is dominantly carried out by metabolic activities of lactic acid bacteria, the involvement of yeasts: Saccharomyces cerevisiae and Candida glabrata (Pswarayi and Gänzle, 2019), Candida haemuloni, Candida sorbophila, Debaryomyces Hansenii and Saccharomyces capsularis were also recorded (Chelule et al., 2010; Solange et al., 2014; Simango, 2002). In some culture in Botswana, mageu is known by the name Motse. The same product in Swaziland is named emahewu (Simatende et al., 2015), maxau in Namibia (Mishairabgwi and Cheikhhoussif, 2017), amahewu by Zulus, metogo by Pedis, machele by Sothos, naphulu by Vendus and amarehwu by Xhosas (Solange et al., 2014). The traditional maize mageu is processed by spontaneous lactic acid bacterial fermentation of cooked maize meal (i.e., gelatinized starches and sterilized substrate) in water (8–12% solid), cooled (25–40 °C), and followed by inoculum of wheat flour (3–5%) or grain malt at ambient temperature (25–35 °C) for 1–3 days (Kayitesi et al., 2017). In its industrial production, starter cultures (Lactobacillus bulgaricus var delbrueckii and Lactobacillus brevis) are used (Nyanzi et al., 2010). Magei mageu is mostly starch and proteins with low fat content; and is mostly consumed as an energy giving, thirst-quenching beverage by all age groups including by weaning infants. However, maize mageu is limited in dietary fiber, bioactive compounds, mineral nutrients, omega-3 fatty acids and vitamin C among others. This is because dry milling of the...
maize grain to the maize meal, results in the anatomical parts (pericarp, aleurone layer and germ) which are rich in most of such nutrients and bioactive compounds being removed as part of the bran (Suri and Tanumihardjo, 2016; Gwirtz and Garcia-Casal, 2014). The maize mageu nutrients and bioactive compounds can be improved through fortification with plant food sources such as watermelon pulp. Lately, the intake of adequate dietary fiber and other bioactive compounds, such as phenolic and carotenoid compounds, through diet as functional foods, are recognized as protective towards different metabolic syndrome diseases like obesity, diabetes mellitus type two, various cardiovascular diseases, and cancers (Senkus et al., 2019; Venkatakrishnan et al., 2019).

Watermelon (Citrullus lanatus) is a fruit that belongs to the family Cucurbitaceae (Pennington, and Fisher, 2009; Edwards et al., 2003). Watermelon per 100g contains 92.0% water, 7.6% carbohydrates out of which 6.2% are sugars, 0.4% dietary fiber, 112mg potassium, 10mg magnesium, 8.1mg vitamin C, 4.5mg lycopene, 0.3mg beta-carotene (precursor of vitamin A) and provides 30 kcal (USDA, 2015). Other nutrients found in the watermelon include thiamine (B1), niacin (B3), pantothenate (B5) and B6 vitamins (USDA, 2015). Watermelon fruit is a valuable source of natural antioxidants such as carotenoids (lycopene, beta-carotene), phenolic compounds (phenolic acids, flavonoids, iridoids, coumarins and lignans), vitamin C, amino acids citrulline and arginine (Abu-Reidah et al., 2013; Tili et al., 2011). These functional ingredients, particularly lycopene, are protective against some cancers (prostate, colorectal, ovarian, lung and pancreatic) and various cardiovascular disorders (Caseiro et al., 2020; Senkus et al., 2019; Perkins-VEazie et al., 2007). Antioxidants protect DNA, lipids, proteins, and cell integrity from reactive oxidative damage. The lycopene content in the watermelon was reported to be higher than that in the tomatoes (Suwanaruang, 2016; Edwards et al., 2003). This shows the potential of watermelon pulp in the fortification of cereal foods like maize mageu with lycopene. The lycopene stability is favoured by the acidic pH (3.6–4.0) of maize mageu, maximum stability of lycopene found at pH 3.5 to 4.5 (Caseiro et al., 2020). Thus, enriching mageu with watermelon pulp has a potential to improve the carotenoids, dietary fibers (such as pectin), vitamin C, and phenolic compounds.

In the past, mageu fortification with Moringa oleifera leaf powder (MOLP) (Olusanya et al., 2020), Aloe vera (Aloe barbadensis) powder (Mashau et al., 2020), beetroot (Beta vulgaris L) on cassava mageu at post fermentation (Boyikao et al., 2020), ferrous sulfate (FeSO4·7H2O) and ferrous fumarate (C4H2FeO4) on cassava mageu at pre- and post-fortification (Salvador et al., 2016) and processing from provitamin A-biofortified maize (Awobusuyi et al., 2016) were reported. However, mageu fortification with other edible plant nutrients and bioactive compounds such as watermelon pulp is not available. In this work, the effects of fortifying maize mageu with three levels (5g, 10g and 15g) of dried watermelon pulp powder on the proximate composition, pH, titratable acidity, total carotenoids, and sensory acceptability of mageu are reported.

2. Materials and methods

2.1. Sampling

The watermelon intended for fortifying the mageu was washed and the rind and seeds were removed. The pulp was cut into small pieces, blended in a food blender for better dispersion of particles (Figures 1A, B). The watermelon pulp (92% water) and the maize meal flour (Figure 1C) were mixed on a dry matter basis and oven dried at air temperature of 60 °C for 24 h (Figure 1D–F). Pre-mixing of watermelon pulp with maize meal flour facilitated the drying of watermelon pulp presumably by osmotic drying effect and prevented the formation of caking. The dried mixture after cooling was ground using mortar and pestle and then stored in a labelled zip-lock plastic bag at refrigeration temperature (4 °C) until used. The experimental design for the formulations was as shown in Table 1.

The control maize mageu was processed from 100g maize meal flour and water (1:9, w/w) as described in Kayitse et al. (2017) with some modification (Figure 2). The three levels dried watermelon pulp fortified maize flour (Table 1) were prepared into mageu as indicated in Figure 3. The mixture was cooked with boiling water (1:9, w/w, 95 °C) in a pot to make a gruel with occasional stirring to avoid formation of lumps. After mixing well, the heat was reduced, and the gruel was left to simmer for 30 min at 65 °C with occasional stirring until cooked. After cooking, the gruel was cooled to about 50 °C and transferred to a fermentation container and 2% of wheat flour was added as an inoculum. The mixture was placed in an incubator (Panasonic Healthcare Co., Ltd, Japan) set at 50 °C to ferment for 24 h. After fermentation, 2% sugar was added, and the mageu products were pasteurized at 90 °C for 60 s and packaged in a clean glass bottle with a lid (Figure 4). Physicochemical analysis and sensory evaluations were done on the products.

2.2. Preparation of mageu

The watermelon used in this study was obtained from Kanye, Botswana and transported to the Department of Food Science and Technology (FST) of Botswana University of Agriculture (BUAN), in Gaborone in a cooler box. Other ingredients, maize meal (flour), wheat flour and sugar, for mageu production were bought from the supermarket in Gaborone and transported to the FST Department for the product formulation. All the raw material ingredients were kept at room temperature and used immediately as per the mageu formulation protocol.

2.3. Physicochemical analysis

Soluble solids content (SSC%, °Brix) was determined using a hand-held refractometer as described in AOAC (2000) method 932.14. This instrument measures the refractive index which automatically converts to percent soluble solids from its calibration. The moisture content was determined by using approx. 3 g mageu sample in a two stages oven drying. Initial drying at 60 °C to reduce water content for about 24 h in an oven and final drying at 130 °C for 5 min using fast halogen moisture analyzer (Adam PMB202 Moisture Analyser, Milton Keynes, UK) (AOAC, 2000 method 925.10). The crude protein content was determined by using approx. 0.1g sample by Kjeldahl system (DKL 20 block digester, and UDK 149 semi-automated distillation, VELP Scientifica Srl, Italy) method of nitrogen content analysis (AOAC 2000, method 920.87). Crude protein (%) = %N x 6.25. The ash content was determined after carbonization of approx. 3g sample over a blue Bunsen burner and ignition in a muffle furnace (Carbolite, Derbyshire, United Kingdom) at 550 °C until ashing completed (AOAC, 2000 method 923.03).

The pH was determined by pre-calibrated (buffer solution pH 4.0, 7.0 and 9.0) glass electrode attached to the digital pH meter. The titratable acidity as equivalent of percentage lactic acid was determined by diluting 6ml of sample with 12ml distilled water and titrating with standard NaOH (0.1N) using 0.5% phenolphthalein as an indicator (AOAC, 2000 method 947.05). Vitamin C content was determined by iodometric redox titration using standard potassium iodate (0.005M) in the presence of potassium iodide (0.6M) and soluble starch (0.5%) as an indicator (Canterbury.ac.nz, 2019). The total carotenoid content was determined after extraction from approx. 5g sample with acetone and petroleum ether and measuring the absorbance of the extract at 450 nm using UV-Vis spectrophotometer (Spectronic 20D+, Thermo Fisher Scientific, USA), as described in Jaeger de Carvalho (2012). Sample of 5g and 2g of celite were weighed on a Thermo Fisher Scienti
250mL Buchner filtration flask and filtered under vacuum. The procedure was repeated five times until the sample became colorless. The extract obtained was transferred to a 500 mL separatory funnel containing 40 mL of petroleum ether. The acetone was removed through the slow addition of distilled water to prevent emulsion formation. The aqueous phase was then discarded. This procedure was repeated four times until no residual solvent remained. Then, the extract was transferred through a funnel to a 50 mL volumetric flask containing 15g of anhydrous sodium sulfate and the volume was made up by petroleum ether, and the sample absorbance was read at 450nm using UV-Vis spectrophotometer. The total carotenoid content was calculated using Eq. (1):

$$\text{Carotenoids content} (\mu g/g) = \frac{A \times V(\text{mL}) \times 10^4}{A_{1\%}^\text{cm} \times P(\text{g})} \tag{1}$$

where $A$ = absorbance; $V$ = total extract volume; $P$ = sample.

2.4. Sensory analysis

For the consumer acceptability, twenty ($n=20$) panelists who were selected randomly from BUAN students and were regular consumers of mageu were used. Before enrolling the panelists, informed consent was received from each for their willingness to participate. The Panelists were presented with four three-digit coded mageu samples including the control sample in a randomized order. They were asked to evaluate their level of liking of the color, appearance, aroma, flavor, texture, and overall liking of the samples using the 9-point hedonic scale ($1 =$ dislike extremely, $2 =$ dislike very much, $3 =$ dislike moderately, $4 =$ dislike slightly, $5 =$ neither like nor dislike, $6 =$ like slightly, $7 =$ like moderately, $8 =$ like very much and $9 =$ like extremely). Water was
provided to the Panelists for palate cleansing before and after tasting each sample.

2.5. Statistical analysis

A triplicate data generated (except pH where duplicate data used) was analyzed using One-way Analysis of Variance (ANOVA) by IBM Corporation (2017) SPSS® Statistics Version 25 (USA). Mean separation was done using Duncan’s Multiple Range Test and significant differences was declared at 5% level.

3. Results and discussion

3.1. Physicochemical analysis

The effect of watermelon pulp fortification on maize mageu physicochemical properties are given in Table 2. Watermelon pulp fortification into maize meal flour had a significant effect (p < 0.05) among the treatment levels on maize mageu physicochemical properties evaluated except for the total soluble solids. There was an increase in the protein, ash, TA, vitamin C and TC contents with an increasing level of watermelon pulp fortification. As compared to the content found in the control mageu, with the 15 g watermelon pulp fortification, there was a significant increase (p < 0.05) in the protein, ash, titratable acidity, vitamin C and total carotenoid contents.

3.2. Moisture content

The moisture content of the mageu samples before drying ranged between 84.4-88.6% (Table 2). Similar moisture content of 85.5% by Fadahunsi and Soremekun (2017), 88.4–90.7% in Moringa oleifera leaf powder fortified (0%, 2%, 4% and 6%) mageu (Olusanya, 2018), and higher moisture content (91.7–92.9%) by Idowu et al. (2016) were reported for fresh fermented mageu samples. After the mageu gruel slurry drying at 60 °C for 24 h, the moisture content was reduced to between 3.38-5.07%. Similar reduction in the moisture content to 4.53% for the control maize mageu and for Moringa oleifera leaf powder (2%, 4% and 6%) fortified mageu 2.07-5.02% were reported (Olusanya et al., 2020). Drying can favor the mageu storage for a long time which can be re-constituted with water on later use. The high moisture content in foods reduces their storage stability period and favors microbial proliferation of the mageu constituents. Whereas dried products are stable and can be stored for long durations because of reduced water activity that limits microbial proliferation and chemical reactions among the mageu constituents (Gouw et al., 2017).
Table 2. The effect of watermelon pulp fortification on maize mageu proximate composition, pH, total soluble solids, titratable acidity, vitamin C and total carotenoid contents (dry matter basis).

| Treatment          | M (%) M (%) dried mageu | Protein (%) | Ash (%) | pH     | TA (%) | TS (%) | Vit C (mg/100 g) | TC (µg/g) |
|--------------------|--------------------------|-------------|---------|--------|--------|--------|-----------------|-----------|
| Control            | 84.4 ± 2.4b              | 3.38 ± 0.2c | 10.6 ± 1.2b | 0.53 ± 0.02d | 5.59 ± 0.1a | 0.08 ± 0.10d | 10.0a | 8.81 ± 0.0b | 0.00 ± 0.0c |
| T1                 | 87.8 ± 0.1ab              | 5.07 ± 0.1a | 13.0 ± 0.2a | 0.65 ± 0.02c | 5.26 ± 0.04b | 0.10 ± 0.00c | 10.0a | 11.7 ± 5.1ab | 12.5 ± 0.4b |
| T2                 | 86.9 ± 0.2ab              | 4.42 ± 0.1c | 13.6 ± 0.4a | 0.72 ± 0.01b | 5.24 ± 0.01b | 0.13 ± 0.01b | 11.0a | 14.7 ± 5.1ab | 16.1 ± 2.8b |
| T3                 | 88.6 ± 3.1a               | 4.73 ± 0.1b | 13.7 ± 0.3a | 0.86 ± 0.00a | 5.64 ± 0.02a | 0.15 ± 0.00a | 11.0a | 17.6 ± 0.0a | 51.9 ± 3.5a |
| Range              | 84.4–88.6                | 3.38–5.07   | 10.6–13.7 | 0.53–0.86 | 5.24–5.64 | 0.08–0.15 | 10–11 | 8.81–17.6 | 0.00–51.6 |

Where M = moisture, TA = titratable acidity, TS = total soluble solids, TC = titratable acidity, T1 = 100 g maize meal + 5 g watermelon pulp, T2 = 100 g maize meal + 10 g watermelon pulp and T3 = 100g maize meal + 15 g watermelon pulp. Mean values in a column followed by different letters are significantly different at p < 0.05.

3.3. Protein content

The protein content in the mageu samples ranged between 10.6-13.7% (dry matter basis, db). The lowest protein content was recorded in the control maize meal mageu (10.6%). Blending with watermelon pulp powder increased the protein content significantly (p < 0.05). The higher the watermelon fortification level, the higher increase in the protein contents (i.e., in samples fortified with 10 g and 15 g watermelon pulp powder an increase in the protein content of 29% was observed). Similar protein contents in the maize meal mageu in the range 10.4-14.8% were reported (Idowu et al., 2016). On the fermentation to maize mageu by Idowu et al. (2016) and (1.66–2.27%) by Olusanya et al. (2020). This is because in both these studies, whole grain maize dry milled at laboratory was used. Whereas, in this study the refined maize meal was used; from which bran where most minerals are concentrated was removed on milling. The ash content is an indicator of the mineral nutrient content. In this regard, this shows the potential for watermelon pulp powder to increase the mineral nutrient contents of refined maize meal mageu. Fermentation action was also reported to increase the ash, mineral nutrients (iron, zinc, and calcium) content and their bioavailability because of the destruction of phytic acid by phytase enzymes of the fermenting microorganisms (Sharma et al., 2020; Fadahunsi and Soremekun, 2017; Chelule et al., 2010).

3.4. Ash content

The ash content in the mageu samples ranged between 0.53-0.86% (db). As the fortification level with watermelon pulp powder increased, a significant increase (p < 0.05) in the ash content was found. With 15 g watermelon pulp powder fortification, an increase in the ash content of 62% from the control mageu was observed. The result shows that watermelon pulp powder may have contributed some minerals accounting for the ash content increase. Similar increase in the ash contents of maize mageu fortification with 2, 4 and 6% Morinda oleifera leaf powder (Olusanya et al., 2020) and beetroot fortification on cassava mageu (Boyako et al., 2020) were reported. However, the ash content found in this work was lower than the ash content (1.34–1.50%) reported for maize mageu by Idowu et al. (2016) and (1.66–2.27%) by Olusanya et al. (2020). This is because in both these studies, whole grain maize dry milled at laboratory was used. Whereas, in this study the refined maize meal was used; from which bran where most minerals are concentrated was removed on milling. The ash content is an indicator of the mineral nutrient content. In this regard, this shows the potential for watermelon pulp powder to increase the mineral nutrient contents of refined maize meal mageu. Fermentation action was also reported to increase the ash, mineral nutrients (iron, zinc, and calcium) content and their bioavailability because of the destruction of phytic acid by phytase enzymes of the fermenting microorganisms (Sharma et al., 2020; Fadahunsi and Soremekun, 2017; Chelule et al., 2010).

3.5. pH and titratable acidity (TTA) contents

The pH of the mageu samples ranged between 5.24-5.64. There was a significant difference (p < 0.05) in the pH among the control mageu and mageu samples fortified with 5g and 10g watermelon pulp powder (p < 0.05). The titratable acidity was significantly (p < 0.05) varied across all the samples within the range of 0.08–1.5%. There was a progressive increase in the titratable acidity with an increasing fortification levels with watermelon pulp powder. The pH values recorded in this work were high as compared to the pH values recorded for mageu samples reported in the previous studies. For example, a pH value of 4.2–4.5 after 24 h fermentation at about 27 ºC (Olusanya et al., 2020), 3.9–4.0 after fermentation for 72 h at 37 ± 5 ºC (Mashau et al., 2020), 3.6–4.6 after fermentation for 24–36 h at 37 ºC (Idowu et al., 2016), 3.0–4.0 after fermentation for 2–4 days at 22–25 ºC (Chelule et al., 2010), 3.0–3.5 after fermentation for 24–48 h at 25 ºC (Simang et al., 2002) and about <4.0 after 24 h fermentation at 35 ºC (Byaruhanga et al., 1999) were reported. The titratable acidity of 0.2–0.6% for 72 h fermentation (Mashau et al., 2020), 0.23–1.50% for 24–36 h fermentation (Idowu et al., 2016), ca. 0.9% after fermentation for 48 h (Simang, 2002) and about 0.10% after 24 h fermentation (Byaruhanga et al., 1999) were reported. The pH condition of <4.0 and titratable acidity of about 0.1% were reported to be inhibitory for the survival of Bacillus cereus (pathogen prevalent in cereal products) in mageu (Byaruhanga et al., 1999).

The pH for the unfermented maize meal base for mageu processing was reported to be 6.5 (Byaruhanga et al., 1999). The acidification and decrease in the pH recorded in this work shows production of lactic acid and other organic acids. However, on the pH and acidity basis alone, it may not be sufficient for the prevention of Bacillus cereus. The high pH and low acidification recorded was most probably because the fermentation was done only for 24 h at 50 ºC. The fermentation temperature 50 ºC used in this work was beyond the optimum temperature (30–32 ºC) for lactic acid bacteria and is toward the maximum temperature tolerated (55 ºC) for the lactic acid bacteria (family Lactobacillaceae) (Sharma et al., 2020; Holzapfel and Wood, 2014). For pure cultures of Lactobacillus acidophilus, L. bulgaricus, and Streptococcus lactis, the temperature of adaptation 51 ºC for maize meal substrate for production of magen was indicated (Kayitesi et al., 2017). The temperature range 45–65 ºC and pH 5.0–7.0 were found to be optimum for most lactic acid bacteria phytases enzyme activity to degrade phytic acid that can lead to improved mineral bioavailability and protein digestibility (Sharma et al., 2020). In this work, fermentation longer than 24 h to bring the pH below 4.0 is required as well as the temperature of 50 ºC could result in the degradation of phytic acid by phytases enzyme activity.

3.6. Total soluble solids (TSS) content

The total soluble solids (TSS) content for the mageu samples ranged from 10.1-11% and showed no significant difference (p > 0.05) among treatment samples even though there was a trend of increase with an increase of watermelon pulp powder fortification in the blend. In other studies, with 10g addition of Aloe vera powder fortification, the TSS in the range 4.7–5.4% (Mashau et al., 2020) and 1.9–4.0% for mageu.
prepared from provitamin A-biofortified maize grains (Awobusuyi, 2015) were reported. The TSS value reflects soluble sugars content. The high %TSS recorded in this work is because after fermentation, 2% of table sugar was added. In addition, the mageu samples were only fermented for 24 h and hence the sugars from the base maize meal starch hydrolysis and sugars from watermelon pulp powder were most probably not completely utilized by the fermenting microorganisms as is also observed from the high pH and low titratable acidity recorded in the mageu samples (Table 1).

3.7. Vitamin C content

A significant difference (p < 0.05) in the vitamin C (L-ascorbic acid) contents between the control mageu and mageu processed with 15g watermelon pulp powder fortification was observed. The vitamin C contents showed an increasing trend in the range 8.81–17.6 mg/100g with an increase in the addition of watermelon pulp powder as compared to the base mageu processed from 100g maize meal. With 15g watermelon pulp powder fortification, as compared found in the control mageu, an increase in the vitamin C content of 99.8% was observed. Watermelon is a good source of vitamin C (9.7mg/100g, fresh weight basis) (Lee and Kader, 2000). However, processing that involves heat will lead to the destruction of vitamin C even though heat can also inactivate the enzyme ascorbic acid oxidase, an agent that catalyzes the destruction of vitamin C. The vitamin C found in the fermented mageu samples was at large most probably contributed from the fermentation process since some lactic acid bacterial and yeast fermentations were known to in

large most probably contributed from the fermentation process since such as lycopene (14.4mg/100g) (Suwanaruang, 2016). Lycopene is

than all the other samples. This signi

ficantly (p < 0.05) increased with an increased level of watermelon pulp powder fortification. The effects of watermelon pulp powder forti

cation on maize meal mageu on sensory acceptability was evaluated using a 9-point hedonic scale are given in Table 3. Significant differences (p < 0.05) were observed on the sensory parameters evaluated (color, appearance, aroma, taste, texture and overall liking) among the treatments and control mageu samples.

3.8. Total carotenoid content

The total carotenoid content ranged from 0.00-51.6 µg/g for the mageu samples. Control mageu sample was significantly different (p < 0.05) from all the treatments with no traces of carotenoid content recorded. Mageu processed by fortification of 15g watermelon powder showed a significantly (p < 0.05) higher carotenoid content (51.9 µg/g) than all the other samples. This signifies that watermelon pulp powder fortification increased the carotenoids in the mageu samples processed because watermelon is a good source of potent antioxidant carotenoids such as lycopene (14.4mg/100g) (Suwanaruang, 2016). Lycopene is regarded as highly preventive bioactive compound against various metabolic syndrome diseases such as cardiovascular diseases, hypertension, atherosclerosis, neurodegenerative disorder, diabetes mellitus, certain cancers (prostate cancer), and ocular diseases because of its antioxidant activities of preventing cells integrity (DNA, proteins, and lipids) from the oxidative stress (Senkus et al., 2019 and Caseiro et al., 2020). The lycopene content among watermelon varieties was reported high in red-fleshed genotypes but minimal in yellow, orange, and pink-fleshed ones (Tilli et al., 2011). In this work, the red-fleshed genotypes (Figure 1) were used and hence there is a high potential to enrich maize mageu with the carotenoid lycopene from watermelon pulp powder. Recommendation on daily adequate intake for total carotenoids is debatable and as such there is no clear recommendation. But after a review of different sources, Böhm et al. (2020) based on individual carotenoid daily recommendations (0.7 mg alpha-carotene, 4.1 mg beta-carotene, 2.2 mg lutein/zeaxanthin, 0.3 mg beta-cryptoxanthin and 4.6 mg lycopene) described the estimated normal daily intake for total carotenoids as 11.8 mg. Based on this, consumption of 100 g of mageu processed from fortification by 15 g watermelon pulp powder can supply total carotenoids of 44.1% (51.9 µg/g = 5.19 mg/100g) toward daily intake. However, the bioavailability of carotenoids is influenced by nature of foods (i.e., foods structural matrix, high fiber can limit whereas lipids/fats promote bioavailability) and individual factors (disease conditions, e.g., colitis, lifestyle behavior e.g., smoking, and variations in age, gender and genetics) (Böhm et al., 2020; Bohn et al., 2017). Given this, the potential bioavailability of carotenoids may be promoted by dispersed nature of mageu gruel and low fiber content but limited by low-fat content in the mageu. Fortification with watermelon pulp powder also offers an alternative color to mageu samples which could be attractive toward consumers. Such value addition could contribute also toward a reduction in the watermelon postharvest losses since it would increase watermelon usage.

3.9. Sensory analysis

The effects of watermelon pulp powder fortification on maize meal mageu on sensory acceptability was evaluated using a 9-point hedonic scale are given in Table 3. Significant differences (p < 0.05) were observed on the sensory parameters evaluated (color, appearance, aroma, taste, texture and overall liking) among the treatments and control mageu samples.

The consumer acceptability for color and appearance of the samples significantly (p < 0.05) increased with an increased level of watermelon pulp powder fortification. The color and appearance of the mageu with 15g watermelon pulp powder fortification was most preferred and rated “like very much”. The control (0g watermelon pulp powder) mageu sample was the least acceptable. The same trend was observed for aroma, taste, and texture in that acceptability of mageu sample increased with the increased level of watermelon pulp powder fortification. The aroma of mageu sample processed by 15g watermelon pulp powder fortification was more preferred (evaluated as liked moderately) than that of the 10g and 5g watermelon pulp powder fortified mageu samples and the control mageu sample. The acceptability of the taste of the mageu samples showed

| Table 3. Effect of watermelon pulp fortification on the sensory acceptability of maize mageu. |
|-------------------------------------------------|--------|--------|--------|--------|--------|--------|--------|
| Treatment                                      | Color  | Appearance | Aroma | Taste | Texture | Overall liking |
| Control                                        | 5.45 ± 1.6c | 5.45 ± 1.3c | 3.95 ± 1.3c | 3.40 ± 1.4c | 4.85 ± 1.6b | 4.70 ± 1.5c |
| T1                                             | 5.85 ± 2.0cb | 6.10 ± 1.6cb | 5.25 ± 1.9b | 5.15 ± 2.1b | 5.35 ± 1.8b | 6.30 ± 1.3b |
| T2                                             | 6.50 ± 1.4b | 6.75 ± 1.5b | 6.05 ± 1.1b | 6.50 ± 1.3a | 6.40 ± 1.5a | 6.55 ± 1.1b |
| T3                                             | 7.95 ± 0.8a | 7.70 ± 1.2a | 7.30 ± 1.0a | 7.20 ± 1.2a | 6.40 ± 1.4a | 7.60 ± 0.8a |
| Range                                          | 5.45-7.95 | 5.45-7.70 | 3.95-7.30 | 3.40-7.20 | 4.85-6.40 | 4.70-7.60 |

Where T1 = 100g maize meal + 5 g watermelon pulp, T2 = 100 g maize meal + 10 g watermelon pulp and T3 = 100g maize meal + 15 g watermelon pulp. Mean values in a column followed by different letters are significantly different at p < 0.05, 9-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely).
significant difference between 5g and 15g watermelon pulp powder fortification and the control mageu samples. The mageu samples taste processed by 10g and 15g watermelon pulp powder fortification was evaluated as most preferred (liked moderately). Texture of the mageu samples processed by watermelon pulp powder fortification of 10g and 15g showed no significant difference (p < 0.05) as they were both more preferred than the 5g watermelon pulp powder fortification and the control mageu samples. The rating for overall liking of the mageu fortified with 15g watermelon pulp powder was significantly higher and evaluated as “liked very much” than the other samples. Overall, the consumer acceptability increased with higher level of watermelon pulp powder fortification. However, one limitation of the study is that the number of consumer panelist was low. Future studies need to use more panelists.

4. Conclusions

The maize meal was processed into mageu by fortification with three levels of watermelon pulp powder (5g, 10g and 15g) using mageu processed from 100g maize meal as a base control to improve the nutrients, total carotenoids contents and sensory acceptability of the product. Fortification of maize meal with watermelon pulp powder produced positive effects with respect to protein, ash, vitamin C and total carotenoids contents and sensory acceptability of the mageu samples. The results showed fortification with 15g watermelon pulp powder has a better potential of improving the protein, ash mineral, total carotenoids and sensory (color, appearance, aroma, taste, texture and overall) acceptability of the mageu products. The study showed there is a potential to improve the maize mageu to be more functional in addition to its probiotic effects by fortification with watermelon pulp powder particularly with the watermelon carotenoid lycopene antioxidant as the red-fleshed genotypes watermelon was known to have high lycopene contents than the tomato fruits.

Declarations

Author contribution statement

Peggy Keamogetse Maakelo: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Gerewem Bultosa, Rosemary Ikalafeng Kobue-Lekalake: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

John Gwamba, Kethabile Sonno: Performed the experiments.

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Data availability statement

Data included in article supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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