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Research article

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

Peggy Keamogetse Maakelo, Geremew Bultosa *, Rosemary Ikalafeng Kobue-Lekalake, John Gwamba, Kethabile Sonno

Department of Food Science and Technology, BUAN, P. Bag 0027, Gaborone, Botswana

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ABSTRACT

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 maize *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 ($p < 0.05$) more 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 compounds, 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. delbruckii, 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 *Motsena*. The same product in Swaziland is named *emahewu* (Simatende et al., 2015), *maxau* in Namibia (Misihairabgwi and Cheikhyoussef, 2017), *amahewu* by Zulus, *metogo* by Pedis, *machleu* by Sothos, *maphulo* by Vendas 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). Maize *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

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* Corresponding author.
E-mail addresses: geremewbultosa@gmail.com, gbultosa@buan.ac.bw (G. Bultosa).

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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; Tlili 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 (Boyiako et al., 2020), ferrous sulfate ($FeSO_4.7H_2O$) and ferrous fumarate ($C_4H_2FeO_4$) on cassava *mageu* at pre- and post-fermentation (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 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.

2.2. Preparation of mageu

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 Kayitesi 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.

2.3. Physicochemical analysis

Soluble solids content (SSC%, ^{o}Brix) was determined using a handheld 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, 2018).

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 digital balance and mixed on a mortar and pestle. For carotenoid extraction, successive additions of 20mL of acetone were made to obtain a paste, which was transferred into sintered funnel (5μm) coupled to a

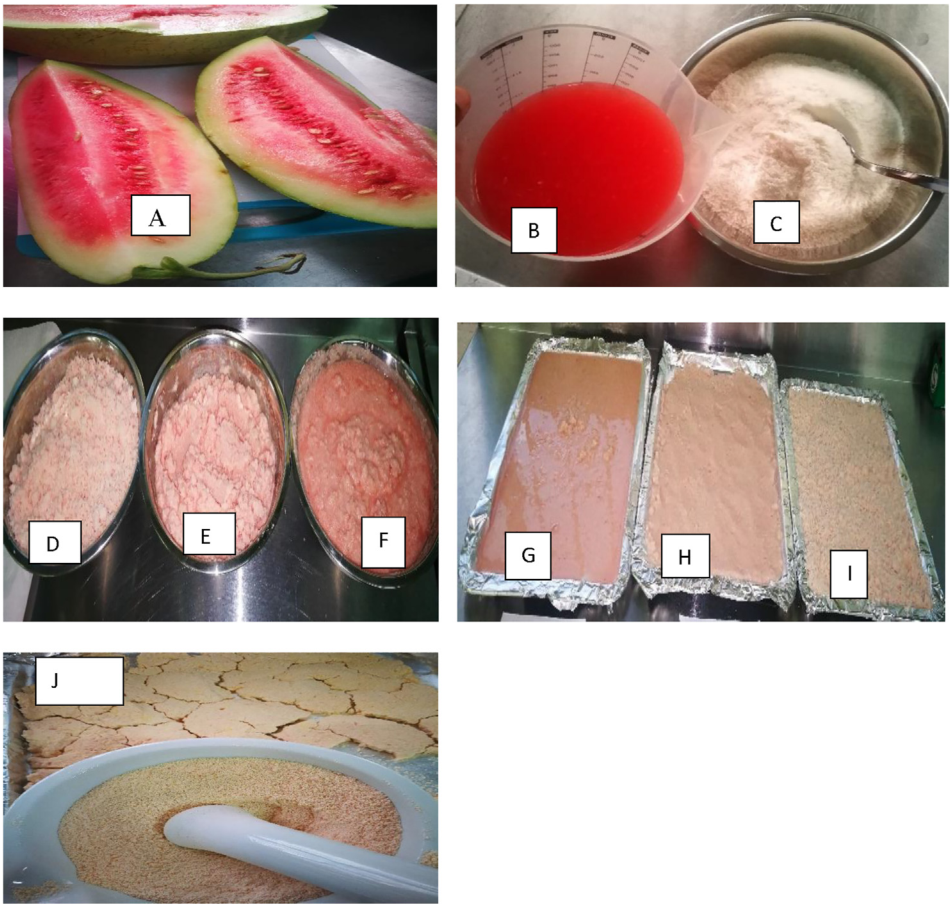

Figure 1. Where A = fresh watermelon cuts, B = watermelon pulp juice, C = maize meal flour, D = T1 (5g watermelon +100g maize meal flour), E = T2 (10g watermelon + 100g maize meal flour), F = T3 (15g watermelon +100g maize meal before drying), G = T3 before drying on a tray, H = T2 before drying on a tray, I = T1 before drying on a tray an J = typical dried sample (T2).

Table 1. Experimental design for the formulation of maize meal *mageu* fortified with watermelon pulp.

Formulations	Maize meal flour	Dried watermelon pulp	Bread wheat flour	Table sugar
1. Control	100g	0g	2g	2g
2. Treatment 1	100g	5g	2g	2g
3. Treatment 2	100g	10g	2g	2g
4. Treatment 3	100g	15g	2g	2g

Mixing was done on dry matter basis. Bread wheat flour was used as an inoculum and table sugar was added after fermentation.

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):

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

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

Weight; $A^{1\%}1cm = 2592$ (β-carotene extinction coefficient in petroleum ether).

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

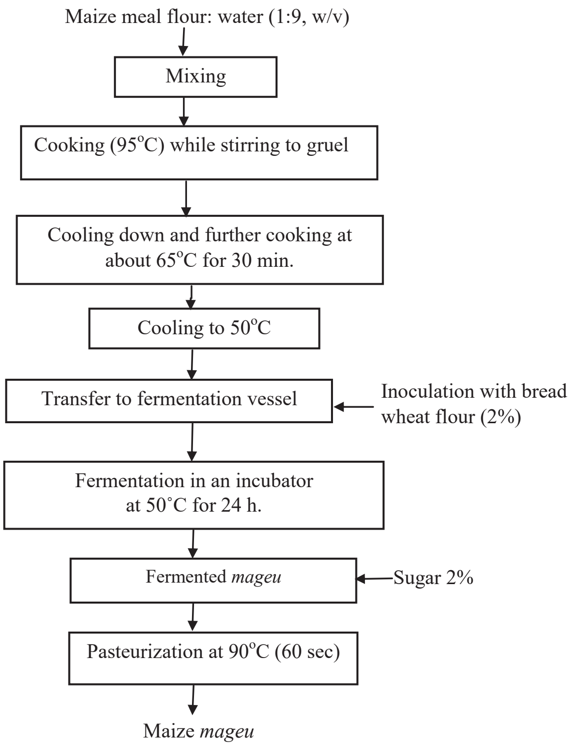

Figure 2. Processing flowchart for control maize *mageu* sample.

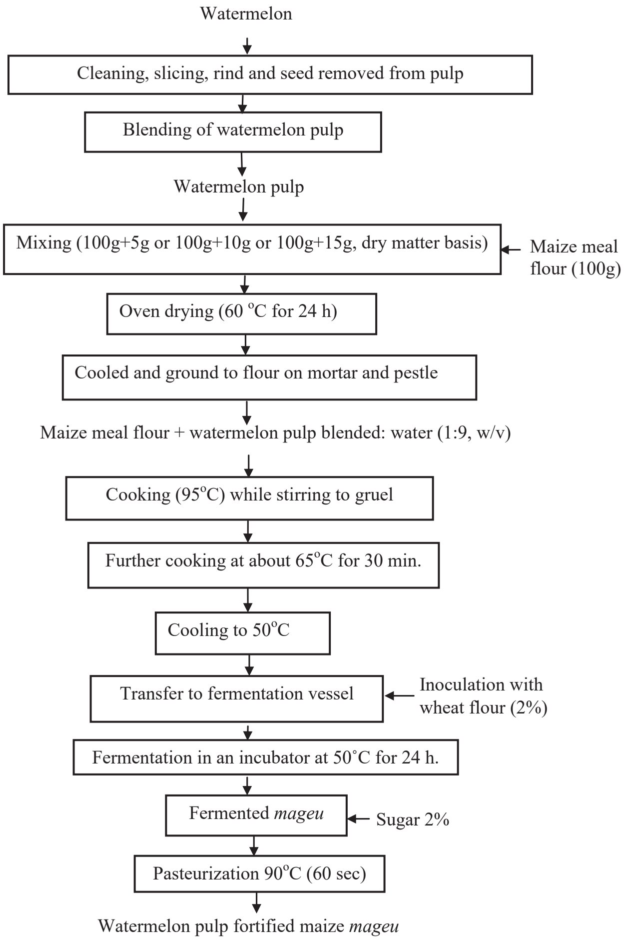

Figure 3. Processing flowchart of watermelon pulp fortified maize *mageu*

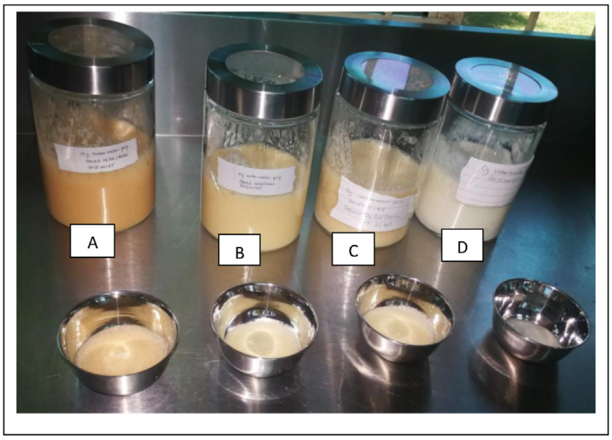

Figure 4. Maize *mageu* processed with watermelon pulp powder (WPP) fortification (A = 100g maize meal + 15 g WPP, B = 100g maize meal + 10 g WPP, C = 100g maize meal + 5 g WPP and D = 100g maize meal).

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 powder fortification on maize *mageu* physicochemical properties are given in Table 2. Watermelon pulp powder 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 reduce their storage stability period and favors the microbial proliferation and chemical reactions among 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 ± 0.01d	10.0^{a}	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 mater 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/amahewu*, when bread wheat flour as one substrate and yeast as fermenting microorganisms were involved, in addition to lactic acid bacteria, an increase in the protein content in the range 12–17% to the extent of 149% protein content increase from the control maize mageu protein content was reported (Chelule et al., 2010). Fermentation was found to significantly improve nutritive value such as essential amino acids (lysine, methionine, and tryptophan) because of the microbial enzyme proteases proteolytic activity on proteins (Chelule et al., 2010) and phytases enzyme activities (Sharma et al., 2020) that degrade the antinutrient phytates binding to proteins. In this study, the protein content increase with an increase in the watermelon pulp powder fortification is likely because of the contribution to nitrogen and carbon sources from watermelon pulp powder and unlike subtle increase in protein content was noticed when only sucrose supplementation was used (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 15g 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% *Moringa oleifera* leaf powder (Olusanya et al., 2020) and beetroot fortification on cassava *mageu* (Boyiako 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 0.08–0.15%. 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 °C (Olusanya et al., 2020), 3.9–4.0 after fermentation for 72 h at 37± 5 °C (Mashau et al., 2020), 3.6–4.6 after fermentation for 24–36 h at 37 °C (Idowu et al., 2016), 3.0–4.0 after fermentation for 2–4 days at 22–25 °C (Chelule et al., 2010), 3.0–3.5 after fermentation for 24–48 h at 25 °C (Simango, 2002) and about <4.0 after 24 h fermentation at 35 °C (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 (Simango, 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 °C. The fermentation temperature 50 °C used in this work was beyond the optimum temperature (30–32 °C) for lactic acid bacteria and is toward the maximum temperature tolerated (55 °C) 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 °C for maize meal substrate for production of *mageu* was indicated (Kayitesi et al., 2017). The temperature range 45–65 °C 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 °C 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 10-11% 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 increase the vitamin C contents (Nkhata et al., 2018; Jagannath et al., 2012). Probably the watermelon pulp powder also contributed to the availability of glucose which is a precursor for the biosynthesis of vitamin C on fermentation by fermenting microorganisms (Nkhata et al., 2018). The dried watermelon pulp powder produced by pre-mixing watermelon pulp with maize meal flour at reduced temperature (60 °C) might also contributed to the reduction of vitamin C loss in the watermelon pulp powder. Also, the stability of vitamin C in the heated viscous medium were known to be high (Caritá et al., 2020) and in this case the substrate used was a maize meal flour and watermelon pulp mixture gelatinized gruel which is viscous that may probably also reduce the destruction of vitamin C contributed from watermelon pulp powder.

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 (Tlili 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 carotenoid 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.

Geremew 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 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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