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Effect of organic acid pretreatment on some physical, functional and antioxidant properties of flour obtained from three unripe banana cultivars

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ABSTRACT

Unripe banana flour (UBF) obtained from organic acid pretreatment of pulp from three non-commercial cultivars were profiled for physical, functional and antioxidant properties. UBF showed marked significant differences ($p < 0.05$) in colour (CIEL*a^*b^* and CIELCH) and water holding capacity with no significant difference in oil holding capacity. The total polyphenol content (TPC) and 1,1-diphenyl-2-picrylhydrazyl (DPPH) differed significantly with M-red UBF recording high TPC (1130.39 ± 27.26 mg GAE/100 g d.w.) at 10 g/L citric acid pretreatment. Correlation analysis between TPC and DPPH showed very strong positive correlation for Mabonde UBF in citric and lactic acid pretreatment ($r = 0.999$, $p < 0.01$; $r = 0.985$, $p < 0.01$), while inverse correlation was recorded in M-red UBF for ascorbic and lactic acid pretreatment ($r = -0.031$; $r = -0.137$). Organic acid pretreatment enhances the physical and antioxidant properties of UBF hitherto absent in composite food formulations.

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1. Introduction

Presently, there are ongoing efforts and research to mitigate postharvest losses of banana through postharvest utilization and processing of the fruit. The onset of ripening due to the climacteric nature of the fruit makes banana susceptible to spoilage and short storage period. Several authors have reported the nutraceutical, nutritional, medicinal and other beneficial use of banana fruit both in its ripe and unripe form (Aurore, Parfait, & Fahrasmane, 2009; Juarez-Garcia, Agama-Acevedo, Sayago-Ayerdi, Rodriguez-Ambriz, & Bello-Perez, 2006; Rodriguez-Ambriz, Islas-Hernández, Agama-Acevedo, Tovar, & Bello-Perez, 2008; Sarawong, Schoenlechner, Sekiguchi, Berghofer, & Ng, 2014). Banana non-digestible carbohydrates, high starch (resistant starch), dietary fibre and polyphenol content in its unripe form makes the fruit a suitable material for the production of flour with great application in glycemic index reduction, diabetes and colon cancer prevention (Anyasi, Jideani, & Mchau, 2013). Thus the prospect of utilizing unripe banana flour for the production of ready-to-eat consumer products provides a great opportunity of combining bioactive compounds otherwise missing nutrients in these products (Aurore et al., 2009). Banana readily availability and low cost processing into flour also places the fruit at an advantageous position as a substitute for wheat flour (Rebello et al., 2014; Zandonadi et al., 2012).

Flour obtained from unripe banana cultivars is growing rapidly in its usage and application worldwide. Various methods however have been employed in the development of this flour. One of such methods is the use of organic acids as pretreatment in the prevention of enzymatic browning, biochemical and microbial activities that occur during flour production. The increased emphasis on use of naturally derived preservatives has further encouraged the application of organic acids for processing and preservation of food products. Organic acids play some vital roles of inhibition of enzymatic browning and other activities in foods (Theron & Lues, 2011) and are defined as carbon containing compounds with weak acidic properties sometimes synthesized by plants. The use of ethylenediaminetetraacetic acid (EDTA), ascorbic, citric (Alkarkhi, Bin Ramli, Yong, & Easa, 2011; Bezerra, Amante, de Oliveira, Rodrigues, & da Silva, 2013; Rodriguez-Ambriz et al., 2008; Wang et al., 2014) acetic, benzoic, fumaric and sorbic acid (Couto & Sanroman, 2006; Nielsen & Arneborg, 2007; Theron & Lues, 2011) generally regarded as safe (GRAS) have been employed either singly or in combination as an acidulant in pretreatment against enzymatic browning during unripe banana flour processing as well as in the shelf life extension of food produce. Among the GRAS organic acids, the influence of ascorbic and citric acid have been widely examined (Son, Moon,

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& Lee, 2001; Wang et al., 2014), although their effect comparatively with lactic acid on banana flour properties are yet to be highlighted.

The action of polyphenol oxidase (PPO) has been implicated in the degradation of anthocyanins and other phenolic compounds in plant produce (Jiang, 2000). Cultivar variation among fruit has been attributed to the degree of PPO activity during enzymatic browning and degradation of fruit pulp (Ducamp-Collin, Ramarson, Lebrun, Self, & Reynes, 2008). Most literature however reported the effect of two or more organic acid and in combination during inhibition of enzymatic activities. There is scarce information on the activity of individual organic acid treatment and at various concentration levels on unripe banana flour properties. This study therefore reports the effect of ascorbic, citric and lactic acid pretreatment at concentration levels of 10, 15 and 20 g/L on the physical and antioxidant properties of flour of some banana cultivars in South Africa.

2. Materials and methods

2.1. Plant materials and pretreatment

Non-commercial banana cultivars: Luvhele (*Musa* ABB), Mabonde (*Musa* AAA) and M-red (*Musa balbisiana* cv Muomva-red) obtained at unripe stage of maturity from household banana farms in Thohoyandou, South Africa were used for the conduct of this research. Fruit pulp from all three non-commercial cultivars was cut to 4 mm size and pretreated with organic acids: ascorbic, citric and lactic acid at concentrations of 10, 15 and 20 g/L for 10 min. The mixture containing pretreated and sliced pulp was allowed to drain for 2 min after which sliced banana fruit pulp was vacuum dried in an oven at a temperature of 70 °C for 12 h.

2.2. Unripe banana flour (UBF) production

Vacuum dried pretreated pulp was used to obtain UBF through milling (Retsch ZM 200 miller, Haan, Germany) of dried pulp at 16,000 rpm for 30 s. Flour obtained from homogenized unripe banana pulp was characterized for colour, water and oil holding capacities, total polyphenol content and antioxidant capacity.

2.3. Colour profile of unripe banana flour

Colour attributes of unripe banana flour was measured with a Hunterlab LabScan XE Spectrophotometer CIELAB and CIELCH colour scale with the parameters $L^*a^*b^*$ and $L^*C^*H^*$. L^* indicates lightness, 0–100 with 0 representing black and 100 representing white. Coordinate a^* corresponds to red (+) and green (−) while b^* corresponds to yellow (+) and blue (−). C^* coordinate is the chroma (Eq. (1)) and H^* coordinate the hue (Eq. (2)) (Wrolstad & Smith, 2010). The $L^*a^*b^*$ values obtained from samples were used for the determination of whiteness and yellowness index.

$$\text{Chroma } C^* = \sqrt{(a^*)^2 + (b^*)^2} \tag{1}$$

$$\text{Hue angle } H^\circ = \tan^{-1}\left\{\frac{b^*}{a^*}\right\} \tag{2}$$

The methods of Rodriguez-Aguilera, Oliveira, Montanez, and Mahajan (2011) and Pathare, Opara, and Al-Said (2013) were used in the determination of whiteness index (WI) and yellowness index (YI) of UBF samples (Eqs. (3) and (4)).

$$\text{WI} = 100 - \sqrt{(100 - L) + a^2 + b^2} \tag{3}$$

$$\text{YI} = \frac{142.86b^*}{L^*} \tag{4}$$

2.4. Water holding capacity

Approximately 1 g of banana flour was weighed into pre-weighed 15 mL centrifuged tubes. To each sample, 10 mL of distilled water was added and mixed for 2 min. Samples were thoroughly wetted and allowed to stand at room temperature for 30 min after which they were centrifuged at 3000 rpm for 20 min. The resulting supernatant was decanted and the centrifuge tube containing sediment was weighed. Water holding capacity; gram of water per gram of protein was calculated thus:

$$\text{WHC} = \frac{(W2 - W1)}{W0} \tag{5}$$

2.5. Oil holding capacity

The oil holding capacity (OHC) of unripe banana flour was determined according to the methods of Larrauri, Ruperez, Borroto, and Saura-Calixto (1996). Approximately 1 g of banana flour was weighed into 15 mL centrifuge tubes and thoroughly mixed with 10 mL of cooking oil. Samples were allowed to stand for 30 min and centrifuged at 3000 rpm for 20 min. After centrifuging, the supernatant was poured into a 10 mL graduated cylinder and the volume recorded. Final OHC values were calculated thus:

$$\text{OHC} = \frac{(V1 - V2)}{W0} \tag{6}$$

2.6. Total polyphenol

Total polyphenols of flour obtained from three non-commercial banana cultivars was determined using the Folin–Ciocalteu colorimetric methods. The method is based on the reduction of MoO^{4+} to MoO^{3+} that is detected by colour change from yellow to blue; measured at 760 nm. Approximately 0.2 g of milled sample was weight and 2 mL of acetone was added to the milled sample. The mixture was incubated for 1 h at room temperature, shaking occasionally and centrifuged at 6000 rpm for 5 min at 4 °C. To 9 μL of centrifuged sample in a microplate, 109 μL of Folin Ciocalteu solution was added. About 180 μL of 7.5% Na_2CO_3 was added to the mixture, covered with aluminium foil and incubated at 50 °C for 5 min. Absorbance of samples was then read at 760 nm using a UV spectrophotometer microplate reader (Zenyth 200rt Biochrom, UK). Gallic acid was used as the standard phenol compound and acetone used as the extraction solvent. The results were expressed as equivalents of gallic acid (mg GAE/100 g d.w.) from the calibration curve.

2.7. Determination of antioxidant capacity (DPPH Assay)

The ability of UBF samples to scavenge the unstable free radical 1,1-diphenyl-2-picrylhydrazyl was determined using the methods of Ribeiro, Barbosa, Queiroz, Knodler, and Schieber (2008). Methanol was used as the extraction solvent and gallic acid used as standard with result of analysis measured in mg GA/g (d.w.). To 0.2 g of milled banana flour, 2 mL of methanol was added to the sample, incubated for 30 min at room temperature and centrifuged at 6000 rpm for 10 min at 4 °C. Dilution of different concentrations of 10, 20, 30, 40 and 50 mg/mL of the sample was used to determine the IC_{50} of the sample. IC_{50} is the amount of antioxidant necessary to decrease the initial DPPH absorbance by 50%. Final values of IC_{50} were obtained by plotting the percentage disappearance of

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