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ORIGINAL ARTICLE

The Effect of Chemical Treatments on the Browning Prevention of Plantain (*Musa paradisiaca*) Products

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Abstract

Prevention of browning in plantain products using anti-browning agents was evaluated. Plantain pulps were sliced and treated with different concentrations of ascorbic acid and citric acid (1-5%) for 10 min and in 1.25% sodium metabisulphite for 15 min which was used as control 1. The slices were blanched in hot water for 15 min which served as control 2. Samples were drained and dried in an oven at 60°C for 24 h and milled to obtain plantain flour. The flour was reconstituted to obtain plantain "amala". Analysis were carried out on the browning index, polyphenol oxidase and peroxidase activity of fresh plantain, plantain flour and plantain "amala". Result revealed that control 2 samples had the highest level of browning index of 0.420 and the lowest value of 0.008 was obtained from control 1 samples. Control 1 samples had the lowest values of 0.026 (fresh), 0.023 (flour) and 0.003 "amala" for polyphenol oxidase activity and 0.016, 0.013 and 0.010 for fresh, flour and "amala" plantain products, respectively for peroxidase activity. Citric acid was also effective in inhibiting polyphenol oxidase activity from 0.157 and reduced to 0.046 for fresh plantain and 0.013 for plantain "amala" at 5% concentration. However, the lowest values of 0.026, 0.023 and 0.003 were observed when using 1.25% sodium metabisulphite for fresh plantain, flour and plantain "amala", respectively. This concentration (5%) was also found to reduce peroxidase activity to 0.033 for fresh plantain and the plantain products, whereas 1.25% sodium metabisulphite was able to reduce peroxidase activity to 0.016, 0.013 and 0.010 for fresh plantain, flour and plantain "amala", respectively. Blanching in hot water was not effective in preventing browning index, peroxidase activity and polyphenol oxidase. The results revealed that browning index, peroxidase and polyphenol oxidase activities were reduced as the concentration of ascorbic and citric acids increases.

Practical application

Producing plantain flour and plantain "amala" using the organic acids such as ascorbic and citric acids as anti-browning agents at different concentrations will help to prevent browning reactions associated with the activities of enzymes (polyphenol oxidase and peroxidase), thereby improving the colour and acceptability of the final products. Thus, providing recommendation to the manufacturers on the concentrations of these acids that will be comparable to the known standard of 1.25% sodium metabisulphite solutions.

Keywords: Browning Prevention, Chemical Treatments, Plantain Products.

1. Introduction

Plantain (*Musa paradisiaca*) is an important staple food that is grown throughout the tropics. It constitutes a major source of carbohydrates for millions of people in Africa, Latin America, Caribbean, Pacific and Asia. According to Treche (1997), 69.4% of plantains are used for human consumption and 8.0% are used for animal feeds. It also serves as a source of

nutrient and household income for many people around the world (Kawongolo, 2013).

Unripe mature plantain fruits can be processed into flour which can be mixed with boiled water to prepare an elastic pastry popularly known as "amala" in Nigeria (Oyesile, 1987). Flour from ripe plantain (stage 4 to 5 degree of ripeness) can be used in making bread, biscuit and instant flour (Ngalani & Crouzet, 1995). Plantain flour is industrially useful and can also be used in various dishes such as nursing porridge (Kiyingi, 1985).

Pretreatment have been used commercially to accelerate the drying of fruits. Dipping fruits for several seconds in pretreatment solutions such as sodium metabisulphite greatly reduces the drying time (Radler et al., 1964). They are applied to the surface of the fruits by dipping which results in a reduced resistance to moisture loss and this increases the drying rate (Ponting & McBean, 1970). Blanching is another pretreatment that had been used to prevent enzymatic browning. Different drying methods can be used for drying of plantain fruits (Arinola *et al.*, 2016). Microwave and freeze-drying had been used previously to dry plantain flour. However, these drying methods had been reported to affect the physical, proximate, rheological and functional properties of unripe plantain flour (Pacheco-Dalahaye *et al.*, 2008).

The end use of plantain flour in food depends on the attractiveness of the colour. Enzymatic browning reaction is one of the factors that affect plantain during processing and the reaction often affects the colour of the flour. This browning reaction occurs during processing due to the activities of polyphenol oxidase (PPO), also known as tyrosinase (Carbonaro & Mattera, 2002). It is a copper containing enzyme that is widely found in plants. During enzymatic browning, polyphenol oxidase catalysis the hydroxylation of monophenol to diphenol and diphenol is then oxidized to quinones, which will undergo polymerization to form brown pigments (Saper & Hicks, 1989). It is therefore essential to pretreat plantain slices during processing to arrest or prevent the browning, which may affect the final product colour. Pretreatments such as blanching the plantain pulp, soaking in a sodium metabisulphite solutions or in citric acid solution followed by draining and drying can result in the production of more or less whitish flour (Ngalani, 1989). Thus, the aim of this study was to evaluate the effects of different chemical solutions such as ascorbic acid, citric acids and sodium metabisulphite used for blanching of sliced plantain pulp on the browning prevention of plantain products.

2. Materials and Methods

2.1. Materials

Two bunches of unripe mature green plantain was purchased from Omudioga Market in Emohua Local Government Area of Rivers State, Nigeria. Chemicals such as polyvinylpyrrolidone, potassium citrate buffer pH 4, 4- methylcatechol, 3% hydrogen peroxide, 4% guaiacol, sodium metabisulphite, citric acid and ascorbic acid were all obtained from the Department of Food Science and Technology Laboratory, Rivers State University, Port Harcourt, all in Nigeria. The obtained chemicals and reagents used for the research were of analytical grade.

2.2. Methods

2.2.1. Preparation of plantain flour

The plantain fingers were washed, hand peeled and sliced into 3 mm thickness using a stainless steel knife. Five hundred gram of the sliced plantain was blanched in 1.25% sodium metabisulphite for 15 min and another 500 g of the sliced plantain pulp was blanched each in different concentrations of citric acid and ascorbic acid (1-5%) for 10 min and the final blanching was done using only warm water for 15 min. The samples were drained and then dried using hot air oven for 24 h at 60^{o}C. The dried samples were cooled and milled, after which they were sieved to obtain smooth flour as shown in Figure 1. The flour obtained were sealed in polyethylene bags and stored for further analysis.

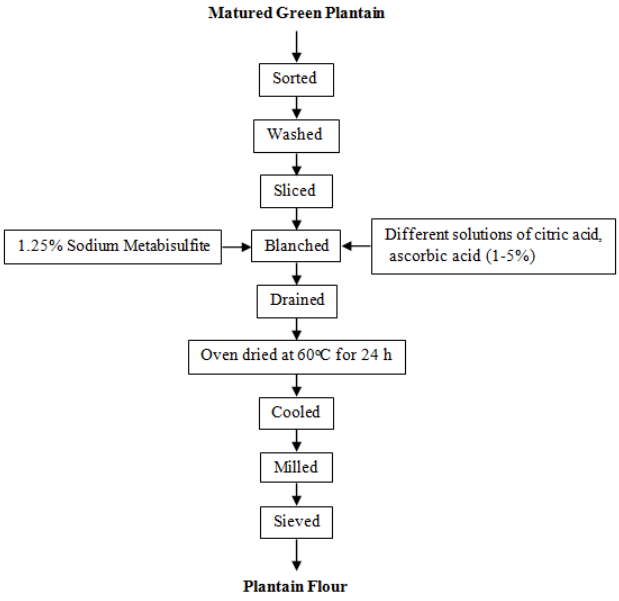

Figure 1: Preparation of plantain flour

2.2.2. Production of plantain "amala"

Twenty gram (20 g) of plantain flour was gradually turned into 25 ml of boiling distilled water and stirred continuously in a gas burner flame for approximately 2-3 min with a wooden spatula until the mixture become thick and formed a paste called "Amala".

2.2.3. Determination of browning index

Browning index was determined using the method described by Walter & Purcell (1980) as modified by Omauru *et al*. (1990). One gram (1g) of sample was weighed; 20 ml of distilled water was added and homogenized for 20 min in a shaker vigorously. The sample was centrifuged for 30 min at 3500 rpm, filtered using Whatman paper no.4 and the filtrate read initially at 450 nm and after 180 min at room temperature in a spectrophotometer (CE 1021, UK). The change in absorbance (Δ450 nm) within the time interval was used as a measure of browning index.

2.2.4. Determination polyphenol oxidase activity

Polyphenol oxidase was determined spectrophotometrically using the method described by Munoz *et al*. (2006) with some modifications. Five grams (5 g) of sample was weighed into a beaker and 25 ml of potassium citrate buffer pH 4 and 0.5 g of polyvinylpyrrolidone was added. Then brought to ice and centrifuge for 30 min at 3500 rpm. After centrifugation, tubes were kept in ice until polyphenol oxidase assay and peroxidase were performed. Half (0.5) millimeter of 4-methylcatechol was added to 2 ml of the extract and incubated for 3 min, absorbance was read at 412 nm at 0 min and after 3 min.

$$\text{Activity u/ml} = \frac{ABS\ at\ 3\ min - ABS\ at\ 0\ \text{min}\ x\ total\ reaction\ volume}{Time\ interval\ x\ 0.2}$$

Where;

u/ml = Enzyme activity
ABS = Absorbance at 3 min and zero minute
0.2 = Volume of enzyme taken in reaction mixture
Time interval = 3 min.

2.2.5. Determination of peroxidase activity

Peroxidase activity was determined using spectrophotometrical method as described by Zhang *et al.* (2005) with some modifications. Half (0.1) millimeter of 3% hydrogen peroxide and 0.15 ml of 4% guaiacol was added to 2 ml of the extract, incubated for 3 min and read absorbance at 470 nm after 3 min, final absorbance was read.

$$\text{Activity u/ml} = \frac{ABS\ at\ 3\ min - ABS\ at\ 0\ \text{min}\ x\ total\ reaction\ volume}{Time\ interval\ x\ 0.2}$$

Where;

u/ml = Enzyme activity
ABS = Absorbance at 3 min and zero minute
0.2 = Volume of enzyme taken in reaction mixture
Time interval = 3 min.

2.2.6. Statistical analysis

The obtained data were subjected to Analysis of Variance (ANOVA) using statistical package in Minitab 16 computer program. Mean values were separated using Turkey's multiple comparison test and significance accepted at $p \leq 0.05$ probability level. All experiments and analysis were carried out in duplicates.

3. Results and Discussions

3.1. Browning index

Browning index indicates the proportions of oxidized phenols present in a food sample (Jeong *et al.*, 2008). The results showed that 1% ascorbic acid (0.165) and 1% citric acid (0.157) had high levels of browning which significantly ($p > 0.05$) reduced with increase in the concentrations as shown in Figures 2a and 2b. It was also observed that there was no significant ($p > 0.05$) difference between 5% ascorbic acid and 5% citric acid compared with control 1 (1.25% sodium metabisulphite) for the products. The treatment was more effective in plantain "amala" as compared to other products - fresh and plantain flour. Blanching with water alone (control 2) could not effectively control browning reactions in the products; sodium metabisulphite appeared to be a potent inhibitor for preventing browning in plantain paste (amala). However, physical examination showed that ascorbic acid was not very effective with respect to the colour of the product (amala) because it is more readily oxidized with heat and tends to form brown colour than phenols (Vamos-Vigyazo, 1981).

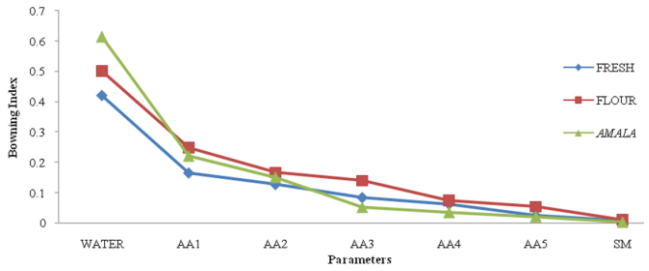

Figure 2a: Graphical View of the Effect of Ascorbic Acid on Browning Index.

Keys: AA1 = 1% Ascorbic Acid, AA2 = 2% Ascorbic Acid, AA3 = 3% Ascorbic Acid, AA4 = 4% Ascorbic Acid, AA5 = 5% Ascorbic Acid, SM = Sodium Metabisuphate

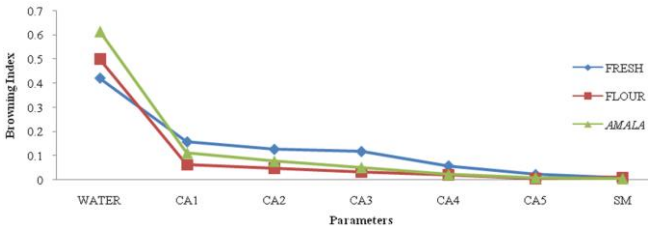

Figure 2b: Graphical View of the Effect of Citric Acid on Browning Index

Keys: AA1 = 1% Citric Acid, AA2 = 2% Citric Acid, AA3 = 3% citric Acid, AA4 = 4% Citric Acid, AA5 = 5% Citric Acid, SM = Sodium Metabisuphate

3.2. Polyphenol oxidase activity (PPO)

The results of PPO activity for fresh, plantain flour and plantain "amala" treated with different concentration of ascorbic acid, citric acid and sodium metabisulphite are shown in Figures 3a and 3b.

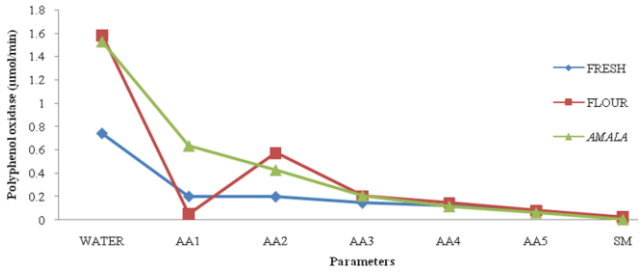

Figure 3a: Graphical View of the Effect of Ascorbic Acid on Polyphenol Oxidase

Keys: AA1 = 1% Ascorbic Acid, AA2 = 2% Ascorbic Acid, AA3 = 3% Ascorbic Acid, AA4 = 4% Ascorbic Acid, AA5 = 5% Ascorbic Acid, SM = Sodium Metabisuphite.

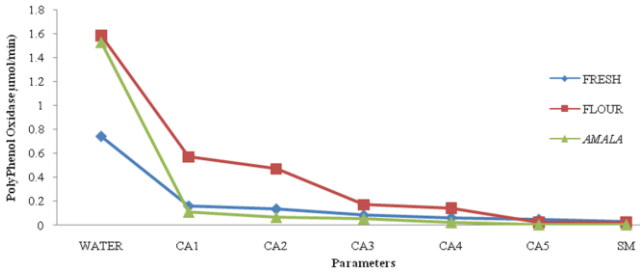

Figure 3b: Graphical View of the Effect of Citric Acid on Polyphenol Oxidase

Keys: AA1 = 1% Citric Acid, AA2 = 2% Citric Acid, AA3 = 3% citric Acid, AA4 = 4% Citric Acid, AA5 = 5% Citric Acid, SM = Sodium Metabisulphite

It was observed that samples blanched with water had an increased level of PPO activity between fresh plantain, plantain flour and "amala". This increase in PPO is caused by the fact that PPO requires molecular oxygen as a surface phenomenon and specific phenolic substrates as reputed by Macheix *et al.* (1991) and confirmed by Nicholas *et al.* (1994). The polyphenol oxidase activity decreased significantly ($p < 0.05$) with increase in the concentration of both ascorbic and citric acids. However, 5% solution of citric acid compared favourably in inhibiting PPO activity on all plantain products when compared to 1.25% solution of sodium metabisulphite. The inhibiting effect of citric acid may be due to the chelation of copper located at the active site of PPO and lowering of pH as reported by Holzwarth *et al.* (2012). The effect of ascorbic acid may be temporary because it can be oxidized irreversibly by the reaction of pigment intermediates, endogenous enzymes and metals (Torte *et al.*, 2007). Also, Voleroet *et al.* (1991) had reported this inhibiting effect by combining irreversibly with copper at the active site of the enzyme. Sodium metabisulphite had been used as inhibitor of enzymatic browning because of the formation of quinone sulphite complexes which prevents quinone polymerization (Embs & Makakis, 1985).

3.3. Peroxidase activity

The results for peroxidase activity of plantain treated with different chemical concentrations are shown in Figures 4a and 4b. Plantain treated with sodium metabisulphite (0.016) and 5% citric acid (0.033) had the least peroxidase activity whereas plantain treated with water (control 2) had the highest activity (0.536). Results also revealed that 1% ascorbic acid and 2% ascorbic acid had the same level of peroxidase activity. In the plantain flour, 4% ascorbic acid (0.250) and 5% ascorbic acid (0.233) had differed levels of activity but not significantly ($p < 0.05$). Whereas plantain treated with sodium metabisulphite and 5% citric acid recorded lowest activity levels. It was also observed that plantain treated with ascorbic acid

had more peroxidase activities than plantain treated with citric acid in the plantain "amala" which indicated that ascorbic acid did not inhibit peroxidase activity in the "amala". This may be due to heat treatment given to plantain "amala" that oxidizes ascorbic acid making it unstable. This observation in agreement with the report of Tortoe *et al.* (2007). It had also been reported that chemical treatment can be used to bleach the intermediate oxidation products formed (quinones) thereby preventing browning reaction leading to an improved colour (Holderbaum *et al.*, 2010). Results of the study revealed that there were significant ($p < 0.05$) difference in peroxidase activity of plantain treated with inhibitors and those treated with water (control 2). It also revealed that 1.25% sodium metabisulphite completely inhibited peroxidase activity followed by 5% citric acid.

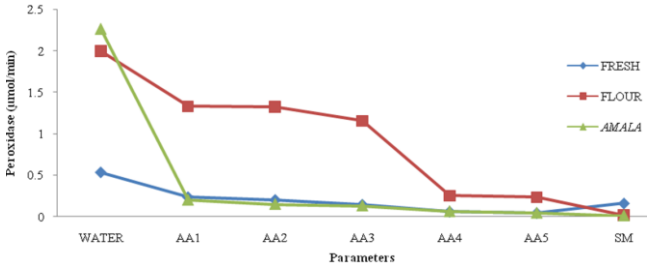

Figure 4a: Effect of Ascorbic Acid on Peroxidase Activity

Keys: AA1 = 1% Ascorbic Acid, AA2 = 2% Ascorbic Acid, AA3 = 3% Ascorbic Acid, AA4 = 4% Ascorbic Acid, AA5 = 5% Ascorbic Acid, SM = Sodium Metabisuphite

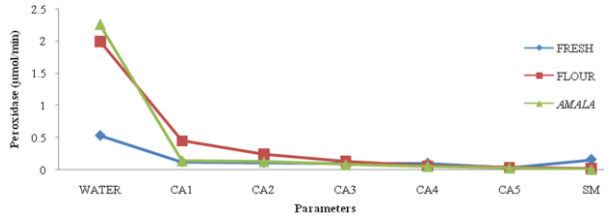

Figure 4b: Effect of Citric Acid on Peroxidase Activity

Keys: AA1 = 1% Citric Acid, AA2 = 2% Citric Acid, AA3 = 3% citric Acid, AA4 = 4% Citric Acid, AA5 = 5% Citric Acid, SM = Sodium Metabisuphite

4. Conclusion

Polyphenol oxidase (PPO) and peroxidase activity were effectively inhibited in processed plantain flour (amala) by sodium metabisulphite and citric acid which also resulted in prevention of browning and successfully led to the production of white "amala". Ascorbic acid was not effective in the inhibition of PPO, peroxidase activity and browning in plantain flour (amala). Hence, apart from sodium metabisulphite, citric acid can also be used commercially as a cheap source of anti-browning agent to prevent enzymatic browning in plantain products.

Conflict of interest

The authors declare that there are not conflicts of interest.

Ethics

This Study does not involve Human or Animal Testing.

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