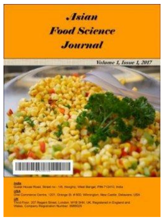

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Browning Prevention and Sensory Evaluation of Frozen Yam Slices (*Dioscorea cayenensis-rotundata* Cv Kponan) of Côte D'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. Author AC designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors SD and NGA managed the analyses of the study. Author KCD managed the literature searches. Authors APMB and YKE performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To prevent enzymatic browning during the freezing of yam slices of the Kponan variety *(Dioscorea cayenensis-rotundata)*.
Study Design: The experimental set-up was of a completely randomized design.
Place and Duration of Study: Department of Food Science and Technology, Food Biochemistry and Tropical Products Technology Laboratory (BATPTL), University of Nangui Abrogoua, Abidjan, Côte d'Ivoire, between August and December 2018.

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Methodology: For this purpose, yam slices were either pretreated with a natural agent (lemon juice solution at different pH) or pretreated and blanched (85 °C for 2 min) and then packed in plastic bags and kept in the freezer at -18°C over a period of 4 weeks. Polyphenoloxidase and Peroxidase activities, Dry matter, rate of browning and sensory attributes of yam slices were determined.
Results: The results showed a decrease in polyphenoloxidase and peroxidase activities regardless of the treatment. The largest decreases in activity were observed in yam slices that were both pretreated and blanched compared to the control (about 53.49% decrease in the specific activity of the PPOs and 51.46% of POD). The combination of pretreatment and blanching also resulted in lower dry matter yam slices compared to pretreated slices only. After 1 month of storage in the freezer, the lower rates of loss (browning) were recorded for the slices of yams that were both pretreated and blanched compared to the other methods which had very high losses. The pretreated and blanched slices had high dry matter content. The sensory profile of slices processed by the combined technique after one month of freezing had a good appreciation for all sensory characteristics of yam.
Conclusion: In order to have a good product, the combined method is recommended for better freezer storage of yam slices.

Keywords: Yam; Kponan; enzymatic browning; freezing, blanching; lemon juice; sensory analysis.

1. INTRODUCTION

Yam is a staple of many tropical countries particularly in West Africa, South Pacific and Asia, Central and Southern America and Caribbean [1]. The global distribution of yam species varies greatly from African to Asian regions in a genotype, wild and cultivated specie [2]. There are more than 600 species of the tuber but only a such as white yam *(Dioscorea rotundata)*, yellow yam *(D. cayenensis)*, water yam *(D. alata)*, trifoliate yam *(D. dumetorum)*, and Chinese yam *(D. esculenta)* are edible [3]. They are widely cultivated in the savannah region of West Africa. Global yam production in 2016 amounted to 66 million tons, of which 97% was produced in Africa. Most of the world's production comes from West Africa representing 94% [1,4].

Yam is one of the most important dietary sources of energy composed mainly of starch, with some proteins, lipids, vitamins and minerals [5,6]. Yams are highly perishable because of its relatively high moisture content (50–80%) and high respiration rates. It is estimated that postharvest losses of yam are more than 20% and are mainly due to rot caused by fungus during storage. Postharvest losses significantly affect farmers' and traders' income and threaten food security and livelihood.

Côte d'Ivoire is the third yam producer in West Africa with an annual production of about 5.9 million tones [4]. In Côte d'Ivoire, Yam is mostly consumed as fresh tubers thus the culinary preparations of fresh yam are pounded yam, boiled yam, yam stew, roasted yam and fried yam [7].

Nethertheless, because of their very perishable nature harvested yams must be consumed within a few weeks or processed adequately [8]. To overcome the storage problems, more and more studies are being conducted on frozen food because of the increased desire for convenience in terms of time and energy required for final food preparation for the consumer [9]. In addition, cold storage has many advantages. Freezing is a fast, convenient and popular method of preserving food. If freezing is done properly, it retains food without causing changes in size, shape, texture, aroma and nutrients. This technology has already proven its effectiveness in the industrial field and is used for the conservation of fruits, vegetables, meats, fish and milks [10]. A method of conservation over a long period of time would be a catalyst for rural development leading to increased income for producers, processors and traders. It can contribute to household food security. However, yam is rich in polyphenol oxidase and peroxidase, which catalyses browning during processing (peeling) and also during freezing in the presence of oxygen [11]. However, the edible quality of food is significantly affected by color, which is the primary attribute used by consumers in assessing the quality of a food. Maintaining the natural color in processed and stored foods has been a major challenge in the treatment of any food because of oxidation processes such as enzymatic browning [11,12]. To overcome this phenomenon, blanching and pretreatment could be used and adapted to the conservation of yam slices.

The aim of this study was to control enzymatic browning during the freezing process of yam slices.

2. MATERIALS AND METHODS

2.1 Sourcing of the Materials

Yam tubers of Kponan variety of the species *Dioscorea cayenesis-rotundata* were purchased from wholesalers at the local market of Abobo in Abidjan, Côte d'Ivoire. The analysis was carried out at the Food Biochemistry and Tropical Products Technology Laboratory (BATPTL) of the University of Nangui Abrogoua. The laboratory equipment and reagents that were used for the experiment were of analytical grades and standards.

2.2 Sample Preparation

The yam tubers were thoroughly washed with tap water, peeled and then cut into sticks about 1cm thick and 10 cm long with a stainless-steel knife.

The yam sticks obtained after slicing were divided into four batches of which three batches were pretreated in a pure solution of lemon juice diluted at different pH (pH = 2.5, pH = 3 and pH = 3.5) and the last batch to serve as a control. Yams slices were pretreated by soaking for 30 min in different lemon juice [13]; which were used as natural anti-browning agent The yam slices pretreated at pH 1 = 2.5; pH 2 = 3 and pH 3 = 3.5 were respectively noted **YSPL** 2.5; **YSPL** 3 and **YSPL** 3,5. These batches were then blanched (85°C for 2 min) [14]. Thus, the batches from these two technologies (pretreatment in a pure solution of lemon juice and blanching) were noted **YSPLB** 2.5; **YSPLB** 3 and **YSPLB** 3.5. The six batches formed as well as the control (slice without any treatment) were dewatered and packaged in freezer bags ensuring the bags are void of air. The batches were kept in a freezer at -18°C for one month (Fig. 1).

2.3 Methods of Analysis

2.3.1 Determination of dry matter

The Association of Official Analytical Chemists (AOAC) methods were used to determine the moisture and dry matter of the flours [15]. The moisture content and the dry matter were determined by the direct oven drying method with 1 g of the sample at 105°C for 24 h to constant weight.

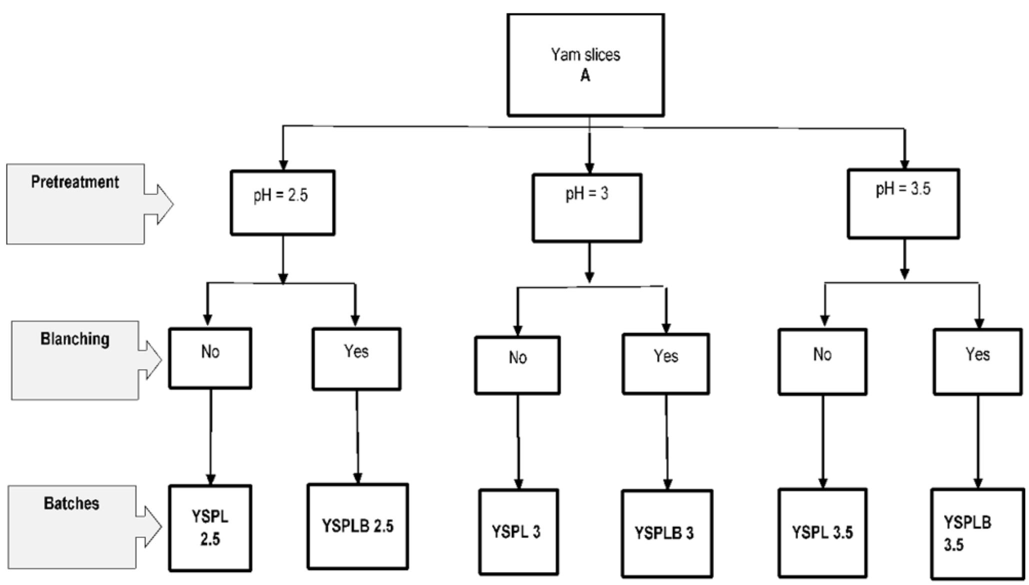

Fig. 1. Distribution of yam slices into batches within each treatment
A: control; YSPL 2.5: Yam slices pretreated in lemon solution at pH = 2.5; YSPLB 2,5: Yam slices pretreated in lemon solution at pH = 2.5 and blanched; YSPL 3: Yam slices pretreated in lemon solution at pH = 3; YSPLB 3: Yam slices pretreated in lemon solution at pH = 3 and blanched; YSPL 3.5: Yam slices pretreated in lemon solution at pH = 3.5; YSPLB 3.5: Yam slices pretreated in lemon solution at pH = 3.5 and blanched

2.3.2 Determination of enzymatic activity

2.3.2.1 Preparation of raw yam tuber extracts

About 150 g of yam tuber were crushed in 300 mL of sodium chloride (0.9%, w/v) using a Moulinex mixer. The crushed material was subjected to sonication (4°C) at 50-60 Hz frequency using a TRANSSONIC T420 for 10 min and then centrifuged at 10,000 x g for 30 min at 4°C. The supernatant filtered through cotton wool was kept refrigerated (4°C) and used as the enzymatic crude extract of the yam tuber.

2.3.2.2 Measurement of polyphenol oxidase (PPO) activity

Under the standard test conditions, PPO activity was measured spectrophotometrically using a modified method of Wong et al. [16]. The reaction mixture (2 mL) containing 0.8 mL of 8 mM dopamine solution, 1.1 mL of a 100 mM phosphate buffer (pH 6.6) and 0.1 mL of the enzyme solution was incubated at 25°C for 10 min. After incubation, the activity was determined by measuring the absorbance of the reaction mixture at 480 nm. One unit of enzymatic activity was defined as an increase in absorbance of 0.001 per minute [17]. Experiments were performed in triplicate, and the results expressed as units of enzymatic activity per mg of protein.

2.3.2.3 Measurement of peroxidase (POD) activity

POD activity was measured spectrophotometrically and using guaiacol as substrate. The reaction mixture (2.3 mL) containing 0.2 mL of 10mM guaiacol solution, 1.9 mL of a 100 mM phosphate buffer (pH 6.6), 0, 1 mL of hydrogen peroxide of 5mM and 0.1 mL of the enzyme solution was incubated at 25°C for 10 min. After incubation, the activity was determined by measuring the absorbance of the reaction mixture at 480 nm. One unit of enzymatic activity was defined as an increase in absorbance of 0.001 per minute. Experiments were performed in triplicate, and the results expressed as units of enzymatic activity per mg of protein.

2.3.2.4 Protein quantification

The protein content was measured according to the method of Lowry et al. [18] using bovine serum albumin as standard.

2.3.3 Estimation of browning rate

The rate of browning was estimated by visual observation. Thus, the browning rate is the ratio of the number of browned slices to the total number of slices.

2.4 Sensory Analysis

The evaluation of the organoleptic characteristics was done on frozen fries' yam slices by 15 usual tasters-consumers. The characteristics retained were visual appearance and color, friability and firmness with the fingers; the firmness with the fork, the crisp effect and the taste in the mouth. The marks awarded were between 1 and 5 and correspond to the following assessments: 1 = poor; 2 = bad; 3 = medium; 4 = good; 5 = very good.

2.5 Statistical Analysis

Physicochemical analyses were performed in triplicates and the results were expressed by means ± standard deviation (SD). Statistical significance was established using analysis of variance (ANOVA) models to estimate the main effects and their interaction effects. Means were separated according to turkey's multiple range analysis (P = .05), with the help of the software XLSTAT (Version 19.6). Sensory data were expressed according to the preservation time.

3. RESULTS AND DISCUSSION

3.1 PPO and POD Activities in Treated Yam Slices before Freezing

The evolution of the enzymatic activity of the PPOs and PODs after treatment is presented in Figs. 2 and 3 respectively. The results show a significant decrease (P = .0001) in the activity of PPOs and PODs, regardless of the type of treatment. There is no significant difference in the specific activity of PPOs and PODs according to the pH of yam slices pretreated with lemon juice only.

The activities of polyphenol oxidases and peroxidases after different treatments are lower on all yam slices that have been pretreated with lemon juice and blanched. This would be due to the combined action of lemon acid pH and blanching temperature (85°C) which are different from the stability conditions of PPOs and PODs (Temperature 30°C and pH 6.0-7) [19]. Indeed, several studies have shown that PPO and POD obtained from various sources are thermally inactivated [20,21]. The short-term heat treatments at temperatures between 70-90°C, of the PPO are in most cases sufficient for the irreversible destruction, partial or total of its catalytic function [19,21]. In the case of PODs, they are also sensitive to heat, which reduces their activities [11]. The citric acid and ascorbic acid contained in the lemon are capable of inactivating PPOs by occupying their catalytic sites [19,22]. According to Oluwole et al. [23], the combination of blanching at 95°C for 7 min and chemical treatment with 0.5% sodium meta-bisulfite and 0.5% ascorbic acid resulted in significant decrease in the activity of polyphenol oxidase on the variety of white yam *Dioscorea cayenensis*. It is important to emphasize that this study was conducted with a natural agent which meets the needs of the consumer. A similar observation was obtained by Severini et al. [24]. The activity of the POD as evaluated by Bahçeci et al. [25] found blanching green beans at 95°C for 2 min resulted in 90% inactivation of POD.

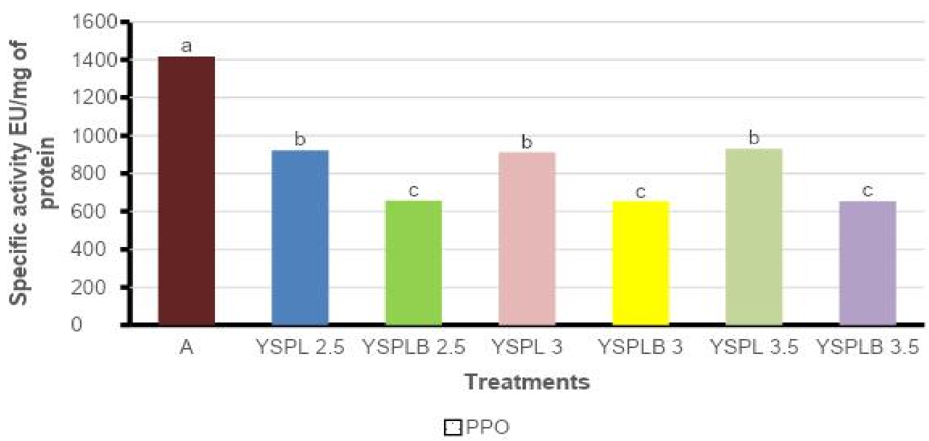

Fig. 2. Specific activity of polyphenoloxidase after treatment

A: control; YSPL 2.5: Yam slices pretreated in lemon solution at pH = 2.5; YSPLB 2,5: Yam slices pretreated in lemon solution at pH = 2.5 and blanched; YSPL 3: Yam slices pretreated in lemon solution at pH = 3; YSPLB 3: Yam slices pretreated in lemon solution at pH = 3 and blanched; YSPL 3.5: Yam slices pretreated in lemon solution at pH = 3.5;YSPLB 3.5: Yam slices pretreated in lemon solution at pH = 3.5 and blanched

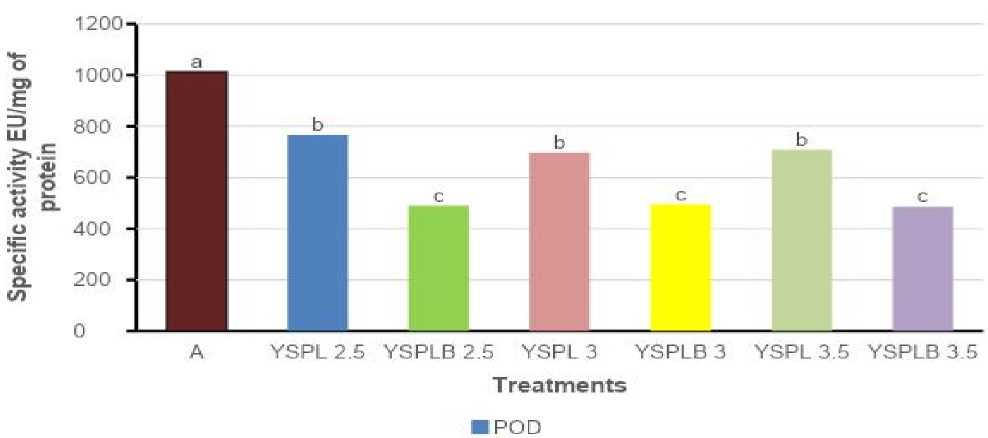

Fig. 3. Specific activity of peroxidase after treatment

A: control; YSPL 2.5: Yam slices pretreated in lemon solution at pH = 2.5; YSPLB 2,5: Yam slices pretreated in lemon solution at pH = 2.5 and blanched; YSPL 3: Yam slices pretreated in lemon solution at pH=3; YSPLB3: Yam slices pretreated in lemon solution at pH = 3 and blanched; YSPL 3.5: Yam slices pretreated in lemon solution at pH = 3.5;YSPLB 3.5: Yam slices pretreated in lemon solution at pH = 3.5 and blanched

3.2 Dry Matter of Treated Yam Slices before and after One Month of Freezing

The dry matter content of the yam slices after the different treatments and before the freezing is presented in Table 1. There is no significant difference between the dry matter of yam slices pretreated with lemon juice and the control compared to yams that were both pretreated with lemon juice and blanched. There is a significant decrease in dry matter, and this is independent of the ph. The drop in dry matter after heat treatments could be explained by the effect of temperature on the pore diameter of yam slices. This diameter increases with temperature thus facilitating the massive inflow of water into the cell. The ability to absorb water is a property related to the hydrophilic nature of the starch. Indeed, yam is rich in starch and during the blanching there is a swelling phenomenon of starch grains which increases the absorption of water. These results correlate with that of Taiwo et al. [26] study on plantain slices which recorded a decrease in the dry matter content after blanching at 60°C for 10 min.

The dry matter content of the samples after one month of freezing is shown in Table 2. Statistical analysis of the data showed that, there is a significant difference between the dry matter of the selected batches before and after freezing. There is generally an increase in dry matter after one month of freezing.

The increase in the dry matter of treated yam slices after 1 month of storage could be due to the existence of temperature gradients which causes a migration of the water contained in the slices of yam to the outside. Kowalska et al. [27] observed a greater loss of water and an increase in solids gain, after pretreatment of the pumpkin by blanching at 80°C for 1 min and frozen at -18°C for 16 h. This is a consequence of the dependence of the water vapor pressure on the temperature. In effect, the water moves in the empty spaces around the product and accumulates on the surface of the product and on the inner surface of the package. Moisture migration causes ice to form inside the package [10].

3.3 Browning Rate

Fig. 4 shows the rate of browning of yam slices after one month of freezer storage. After one month in the freezer, the rate of browning varied depending on the treatments. The rate of browning was very high in yams slices treated only with lemon juice, regardless the pH. Thus, the rate was in the order of 80 ± 1.91% for the control and 75.73 ± 1.42% for YSPL 2.5; 74.45 ± 0.03% for YSPL 3 and 75.12 ± 4.54% for YSPL 3.5. The lowest rates of browning were recorded in pretreated and blanched yams. The browning rates were in the order of 0.66 ±1.15% for YSPLB 2.5; 1.00 ± 1.00% for YSPLB 3 and 5 ± 1.03% for YSPLB 3.5. The losses recorded after one month of storage are mainly due to enzymatic browning. The lowest rates of loss (browning) were recorded in pretreated and blanched yams. Indeed, this low level could be due to a strong inactivation of the enzymatic activity of PPOs and PODs. This is demonstrated by Cano et al. [28] who observed a reduction in losses after heat treatment and freezing of banana slices at different stages of maturity. In addition, high losses were recorded in the slices of yams pretreated only with lemon juice and the control. Indeed, the pretreated slices which were initially of acceptable color changed to an undesirable coloring. In addition, the strong enzymatic activities observed in these slices and ice crystals formed during freezing could be the basis of enzymatic browning. The formation of ice crystals damages the cell walls. The initially separated oxidizing enzymes and phenolic substrates mix as soon as the cells are broken, resulting in the formation of undesirable colors in the products [29]. This stain is observed during freezing when enzymes responsible for enzymatic browning are not completely inactivated before freezing.

3.4 Sensory Evaluations

Assessments of the different organoleptic characteristics of yams are shown in Fig. 5. The analysis of the sensory test data revealed a good general appreciation of slices of fried yams after one month of freezing. All slices of fried yams had a good appearance, color, firmness with the fork, friability and taste. The grades obtained show no significant difference between frozen yams and controls for parameters such as appearance, color, firmness at the fork, friability at the fingers, crispness, firmness to the fingers, firmness in the mouth and taste.

Organoleptic characteristics such as appearance, color, fork firmness, finger friability, and crispness were retained in fried yam slices that had the combined methods. Freezing and blanching would have had no influence on the organoleptic characteristics. These results could be correlated with those of the study of Dima et al., [30] on cold storage at -18°C peas previously blanched at 95°C for 4min. The study revealed a good overall sensory appreciation of sensory parameters such as color, appearance, taste, consistency and smell.

Table 1. Dry matter of treated Yam Slices

Sample	Dry matter (%)
A	36.44 ± 0.28[a]
YSPL 2.5	36.52 ± 0.33[a]
YSPLB 2.5	32.51 ± 0.58[b]
YSPL 3	36.54 ± 0.47[a]
YSPLB 3	33.16 ± 0.67[ab]
YSPL 3.5	36.31 ± 0.39[a]
YSPLB 3.5	32.87 ± 0.05[b]

Mean ± standard deviation, n = 3. Values in the same column with different alphabetic letters are significantly different at the 5% level according to Tukey's variance analysis test. A: control; YSPL 2.5: Yam slices pretreated in lemon solution at pH = 2.5;YSPLB 2,5: Yam slices pretreated in lemon solution at pH = 2.5 and blanched;;YSPL 3: Yam slices pretreated in lemon solution at pH=3 ;YSPLB 3 : Yam slices pretreated in lemon solution at pH = 3 and blanched; YSPL 3.5: Yam slices pretreated in lemon solution at pH=3.5 ;YSPLB 3.5: Yam slices pretreated in lemon solution at pH=3.5 and blanched

Table 2. Evolution of dry matter of yam slices after one month of freezing

	Dry matter content of yam slices (%)	
Sample	Before freezing	After 1 month of freezing
YSPLB 2.5	32.51 ± 0.58[b]	33.35 ± 1.77[a]
YSPLB 3	33.16 ± 0.67[b]	35.46 ± 1.15[a]
YSPLB 3.5	32.87 ± 0.05[b]	34.97 ± 0.84[a]

Mean ± standard deviation, n = 3. Values in the same row with different alphabetic letters are significantly different at the 5% level according to Tukey's variance analysis test. YSPLB 2.5: Yam slices pretreated in lemon solution at pH = 2.5 and blanched; YSPLB 3: Yam slices pretreated in lemon solution at pH = 3 and blanched. YSPLB 3.5: Yam slices pretreated in lemon solution at pH = 3.5 and blanched

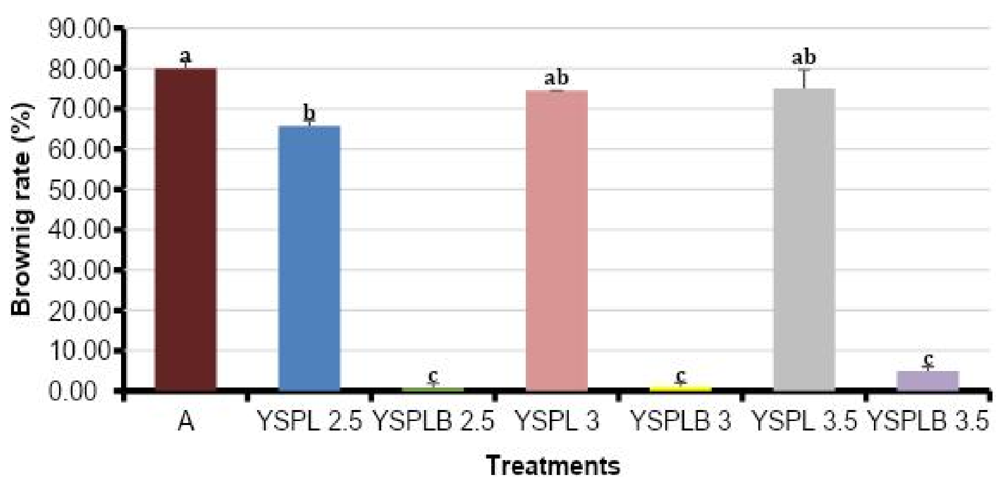

Fig. 4. Browning rate after one month of freezing

A: control ; YSPL 2.5 : Yam slices pretreated in lemon solution at pH = 2.5; YSPLB 2,5: Yam slices pretreated in lemon solution at pH=2.5 and blanched; YSPL 3: Yam slices pretreated in lemon solution at pH = 3; YSPLB 3: Yam slices pretreated in lemon solution at pH = 3 and blanched; YSPL 3.5: Yam slices pretreated in lemon solution at pH = 3.5; YSPLB 3.5: Yam slices pretreated in lemon solution at pH = 3.5 and blanched

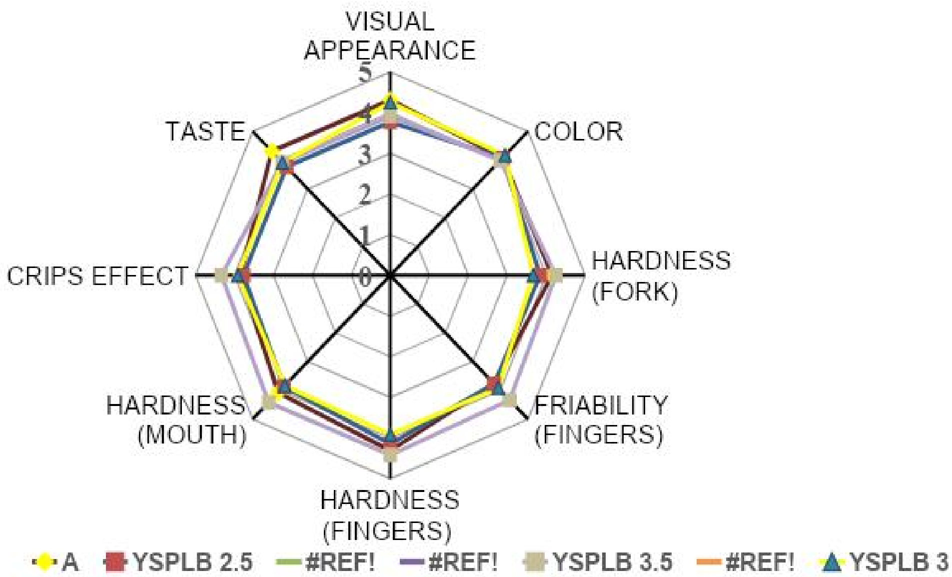

Fig. 5. Sensory profile of yam slices after one month of freezing

A: control; YSPLB 2,5: Yam slices pretreated in lemon solution at pH = 2.5 and blanched.; YSPLB 3: Yam slices pretreated in lemon solution at pH = 3 and blanched; YSPLB 3.5: Yam slices pretreated in lemon solution at pH = 3.5 and blanched

4. CONCLUSION

The different treatment methods have an influence on the preservation of yam slices during freezing. In general, the combined treatment method involving pretreatment in lemon juice and blanching is found to be more effective for freezer storage than pretreatment with lemon solution alone. In order to have a good product, the combined method is recommended for better freezer storage of yam slices.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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