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Effect of Steam Blanching and Storage Durations on the Physicochemical Properties of White Yam *(Dioscorea rotundata)* Slices

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

White yam (*Dioscorea rotundata*) is a vital crop in many tropical regions, and its preservation and quality retention are of paramount importance for ensuring food security. This study investigated the impact of steam blanching and different storage durations on the physicochemical properties of white yam slices. White yam slices were subjected to varying steam blanching durations of 1 min, 3 min and 5 min, followed by oven drying at 60℃ for 72 hours and storage at room conditions for 7 days. Physicochemical properties such as proximate composition, total soluble solids, titrable acidity, moisture content, color and pH were measured before and after blanching. The results showed that the steam blanching durations significantly ($p < 0.05$) affected all the physicochemical properties measured. The proximate results showed the non-blanched (control) samples had higher

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moisture (65.04±0.35), crude protein (4.55±0.04), fat (0.53±0.01), fibre (1.42±0.02) and ash contents (2.25±0.02) than the blanched samples with exception of the carbohydrate content (26.22±0.29) where the control samples had lower values. Proximate components decreased with blanching duration, except for carbohydrate content, while storage duration did not significantly affect the measured attributes, despite slight changes in moisture content, color, and pH. However, the duration of blanching and storage significantly impacted the physicochemical attributes. These findings have significant implications in the food processing industry, promoting the development of improved storage and preservation strategies for white yam and also ensure food security and reduced post-harvest losses.

Keywords: Chemical composition; heat pretreatment; postharvest handling; shelf life; antioxidant capacity.

1. INTRODUCTION

Yam (*Dioscorea spp*.) is a multispecies tuber crop cultivated widely in the tropics and sub-tropics [1], with significant economic and socio-cultural importance especially in Ghana, where millions of people consume it as a mainstay [2]. White yam is a significant nutritional source of energy, mostly include starch but also contain small amounts of proteins, lipids, vitamin C, vital minerals, anti-aging benefits, and fertility-enhancing characteristics [3]. It has a significant impact role in the economic and nutritional value in Ghana; from food security and nutrition to culture, environmental benefits and the economy.

The production and marketing of yam, however, face significant difficulties due to the yam's high moisture content (50-80%) [4], high rates of respiration [5], lack of a cuticle, decay caused by fungus when stored, microbial growth, weight loss, mechanical damage, natural aging, and sprouting. Postharvest losses significantly impact the sharp decline in yam quality and quantity, resulting in financial losses [6]. Therefore, after harvest, yams must be eaten immediately or modified into yam slides by peeling, slicing, blanching and drying.

Blanching, specifically steam blanching has been identified as a promising method for controlling microbial growth and reducing spoilage in yam. Blanching is a quick and gentle heat treatment done before the main process to inactivate enzymes, change texture, maintain color and flavor providing nutritious value as well as freeing up air. Hot water and steam are the most used heating media for blanching in the food industry [7]. Discoloration phenomenon on fresh tubers has long been known to be associated with enzymatic activity, e.g., due to the action of polyphenol oxidases and peroxidases. These enzymes are inactivated by blanching [2]. However, blanching reduces nutritional value of foods due to nutrient leaching or degrading by heating [7,8]. Starch properties may also be altered by heating. All of these objectives should be accomplished at the same time, making the selection of blanching conditions essential.

Despite the great importance of yam, it is highly perishable and susceptible to post-harvest losses due to high moisture content. To minimize these losses, harvested yams must be consumed immediately or preserved using technologies such as pretreatment and drying into more stable forms. Oven-drying and blanching are common food preservation technologies, with oven drying being best for high moisture and wet foods. However, studies on the effect of steam blanching and varying storage durations on yam slices' physicochemical properties are limited. This research sought to address the gap by determining the impact of steam blanching and storage durations on the physicochemical properties of yam slices. Findings of this study could be helpful for minimizing post-harvest losses and enhancing shelf life of yam slices.

2. MATERIALS AND METHODS

2.1 Source of Sample and Preparation

A variety of yam, *Dioscorea rotundata* (white yam), locally known as "laribokọ", was selected at random and obtained at full maturity (12 months), of similar sizes, and free of defects from local traders in the Nyankpala market (Tamale, Ghana) and stored on a wooden platform at ambient temperatures (27℃–29℃) and relative humidity (85%–95%). This variety was considered for the study because it is in abundance in the country and moreover the most preferred species for consumption [9]. Using a stainless-steel knife, yam tubers (*Dioscorea* *rotundata*) were peeled and cut into 3 cm-square cubes. The entire cutting process, including the preparation of the slices, was done at room temperature (27°C–29°C). To reduce the physicochemical changes, cut samples were immediately immersed in tap water. Drying of 30g samples for 72 hours at 60°C in an oven yielded the initial moisture content [10]. The flow diagram for the sample preparation is shown in Fig. 1. below.

2.2 Blanching of Yam

The protocol of Midilli et al. [11], blanching temperature, 100℃ and blanching times (1 min, 3 mins, and 5 mins) was used. The cook-and-shock technique was also applied. A beaker filled with water was placed on a magnetic heater and allowed to heat until boiling point, 100℃. Using a stopwatch, slices of the yam for each blanching duration were placed in a sieve and covered with a white transparent poly bag and then placed on top of the boiling water in the beaker and allowed to blanch for each of the durations using 10g of the sample at a time. The slices of yam that had been blanched were drained, labeled with the cooking temperature and duration, and placed in desiccators.

2.3 Color Determination

The color of fresh and dried yam slices was assessed using a Minolta Chromameter, CR-300 (Minolta Co., Osaka, Japan) with regard to the tristimulus color values L*, a*, and b*. Where L* denotes the degree of lightness or darkness of the substance, L* = 0 denotes entire darkness, and L* = 100 denotes complete brightness. The color coordinate in a red-green axis is a*. a* values that are positive for red and negative for green. A yellow-blue axis' color coordinate is b*. In favor of yellowness and against blueness. After establishing the instrument's calibration with a white tile (L* 93.3, a* 0.32, and b* 0.33), the color of the yam slices was measured. Using the color of the control yam as a reference point, the total color difference of the dried yam (ΔE) was computed (Eq.1).

$$\Delta E = \sqrt{(\Delta L *)^2 + (\Delta a *)^2 + (\Delta b *)^2} \quad \text{Equation (1)}$$

2.4 Proximate Analysis

The Association of Official Analytical Chemists [10] recognized protocols were used to conduct the proximate analyses of the raw materials. Particularly, percentages of carbohydrate, ash, crude protein, crude fiber, and fat were calculated.

2.4.1 Moisture content

Freshly chopped yam tuber samples (2g) were weighed and placed into an already dried and weighed aluminum foil plates. The plates containing the yam samples were stationed in a thermostatically controlled oven and heated at 110°C for 5 hours. The plates were taken out, cooled in a desiccator and reweighed. The difference was used to calculate the moisture content (Eq.2) [12], which was then represented as a percentage.

$$\text{Moisture Content (\%)} = \frac{W2 - W3}{W2 - W1} \times 100 \quad \text{Equation (2)}$$

Where, W_1, W_2 and W_3 are tared weight of the aluminum foil plate (g), weight of the aluminum foil plate with yam samples (g) and weight of the aluminum foil plate + yam sample after drying in oven (g) respectively.

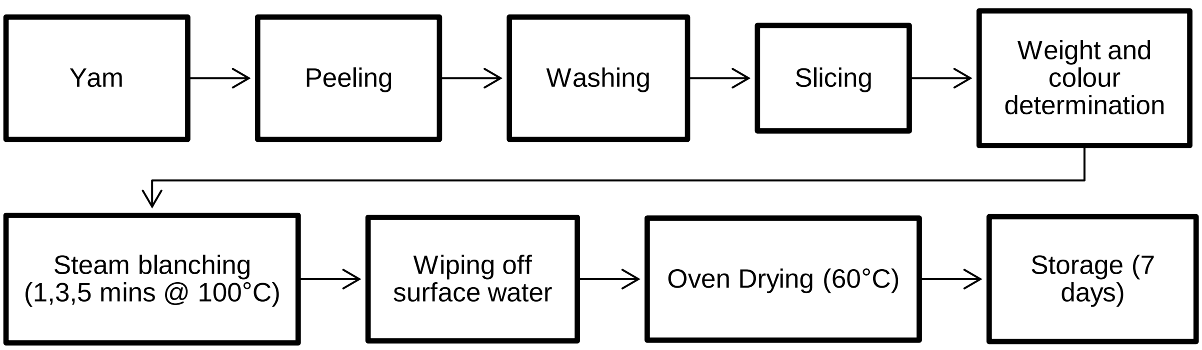

Fig. 1. White yam sample preparation

2.4.2 Ash content (AC)

Ash content was determined using AOAC [13] protocol. A porcelain crucible that had already been lit, cooled, and weighed received 2g of yam flour. After being heated to 600°C in a muffle furnace for 2 hours, the crucible and its contents were taken out, let to cool in a desiccator, and then weighed. It was represented as percentage as calculated in (Eq. 3).

$$\text{AC (\%)} = \frac{W4-W1}{W2} \times 100 \qquad \text{Equation (3)}$$

Where,
W_1 = Tared weight of crucible
W_2 =Original weight of yam sample
W_4 =Weight after ashing

2.4.3 Crude fat content

The AOAC [13] technique was used to calculate the crude fat content of the yam samples. The dried yam flour was weighed in 2g and placed on a filter paper (22×80). The thimble was plugged with glass wool to stop flour loss. The round bottom flask was filled with petroleum ether (50 mL), and the equipment was put together. The quick-fit condenser connected to the soxhlet extractor was refluxed for 16 hours with the help of a heating mantle. After that, the flask was taken out and left to evaporate on a steam bath. The flask and its contents spent 30 minutes in a 150°C oven. It was then weighed after cooling in a desiccator to room temperature. By weight, the fat content was given as a percentage (Eq. 4).

$$\text{Crude fat(\%)} = \frac{Weight\ of\ extracted\ fat}{Initial\ weight\ of\ sample} \times 100 \qquad \text{Equation(4)}$$

2.4.4 Crude fiber content

The AOAC [10] technique was used to calculate the crude fat content. Approximately 0.5g of asbestos was added to the defatted flour used for its' determination before being put into a 750 mL Erlenmeyer flask. After adding 200 mL of boiling 1.25% H_2SO_4, the flask was immediately placed on a hot plate with the condenser attached to the Erlenmeyer flask. For 30 minutes, the flask and its contents were heated. The flask's contents were next filtered using a funnel and a linen cloth before being thoroughly washed with boiling water until it was no longer acidic. The pH meter was used to perform this. The filtrate and asbestos were re-washed into a flask using 200 mL of boiling 1.25% NaOH solution. 30 minutes was spent boiling the flask attached to the condenser, after which the contents were filtered through linen cloth in a funnel and thoroughly rinsed with boiling water until the solution was no longer basic. After being moved into a crucible with water, the residue was then cleaned with 15mL of alcohol. The crucible's contents were dried for one hour at 100°C, cooled, and weighed. The crucible's contents were then burned for 30 minutes in a muffle furnace that had been preheated to 600°C, cooled in a desiccator, and reweighed. It was represented as a percentage as calculated using (Eq. 5).

$$\text{Crude fiber(\%)} = \frac{weight\ of\ fiber}{initial\ sample\ weight} \times 100 \qquad \text{Equation (5)}$$

2.4.5 Protein content determination

Protein content of the yam samples was estimated using the Kjehdahl method [13]. Stages of digestion, distillation, and titration are all components of this process. In a digesting flask, 2g of yam flour were introduced, along with half of a selenium-based catalyst and crushed porcelain crucibles (an anti-bumping agent). A concentrated H_2SO_4 solution volume of 25 mL was added. After that, the flask was shaken to get evenly moist flour. On a digestive burner, the flask was gradually heated until boiling stopped and a clear solution was obtained. The solution was placed into a 100 mL volumetric flask and allowed to cool at room temperature before being filled to the mark with distilled water. Before usage, a distillation device was flushed with hot distilled water and attached in a way that would ensure at least 10 minutes of circulation inside the condenser. Two drops of mixed indicator were added to 25 mL of 2% boric acid that had been pipetted into a 250 mL conical flask. The condenser was submerged in the solution with the tip of the condenser completely submerged. The digested solution was measured at 10mL. The decomposition flask received an additional forty percent (40%) addition of NaOH, and the funnel stopcock was shut. To drive the released ammonia into the collection flask, the steam trap outlet's stopcock was closed. This forced steam through the decomposition chamber. The 0.1 N HCl solution was used to titrate the distillate. Once the solution was colorless, acid was added. The mixture turned reddish from the addition of more acid. Repetition of the process was done for the blank and protein content computed (Eq. 6).

Protein (%)=$Nitrogen\ Content\ x\ 6.25$ Equation (6)

2.4.6 Carbohydrate

It is usually calculated by difference: subtracting the percentages of moisture content, ash, lipid, and protein from 100%.

Thus, Carbohydrates (%) = 100 - (Moisture + Ash + Crude Protein + Crude Fat + Crude Fiber).

2.5 Weight Determination

Weight of the yam slice is determined using a digital weighing scale. The weighing scale was placed on a flat surface and turned on for it to stabilize at "0.00g" on the display. The yam slice was placed on the scale gently. The weight Figures displayed on the scale and reweighed again.

$$W = \frac{Wo - Wf}{Wo} \times 100 \qquad \text{Equation (7)}$$

Where: W= weight of yam, Wo= Initial weight of yam, Wf= Final weight of yam [14].

2.6 pH Determination

The pH of yam was determined using a pH meter (Starter 2100 Bench pH meter), which measures the acidity or alkalinity of a solution on a scale from 0 to 14, with a neutral pH of 7. One gram of the sample was weighed, 10 ml of distilled water was added to make a slurry, and the resultant mixture was then let to stand for 10 minutes. A pH meter was used to measure the yam slurry's pH. The pH of the yam flours was measured using Kafilat [15] protocol.

2.7 Total Soluble Solids Determination

The total soluble solids (TSS) were determined using Abbe refractometer (Kernco Instruments Co. Texas). Adjustments was made for the calculation and done in duplicates. The TSS content is expressed in percentage (%).

2.8 Titrable Acidity Determination

Titrable Acids was determined by titrating prepared yam tissue slurries and drained water against 0.1N sodium hydroxide (NaOH) with phenolphthalein as an indicator [16].

$$\text{Titrable Acidity} = \frac{VxNxM}{W} \qquad \text{Equation (8)}$$

Where: V = Volume of NaOH solution (mL); N = Normality of the NaOH solution; M = molar mass of the titrable acid; W = weight of the yam sample (g)

2.9 Statistical Analysis

XLSTAT Version 2019 was used for the statistical analysis after the data were imported into Microsoft Excel. All data were subjected to Analysis of Variance (ANOVA), and Tukey Multiple comparison option was used to distinguish the mean values at the 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Effect of Steam Blanching on the Physicochemical Properties of Yam (*Dioscorea rotundata*)

The physicochemical properties determined from the yam samples are presented in Table 1. It was found that the steam blanching durations significantly ($p < 0.05$) affected all the physicochemical properties measured. The proximate results showed that the non-blanched (control) samples to have significantly higher moisture, crude protein, crude fat, fiber and ash contents than the blanched samples with exception of the carbohydrate content where the control samples had lower values. Generally, the proximate components of the samples decreased considerably as the blanching duration increased, except for carbohydrate content where the values increased with an increase in blanching duration. The moisture and crude protein values of this study were consistent with earlier findings reported by Onwuka and Ihuma [17]. *D. rotundata* exhibited a fiber content of 1.42% that was highly significant ($p < 0.0001$). Steam blanching significantly reduced the moisture content of white yam. This could be due to the heat and steam causing moisture loss through evaporation. Steam blanching initially reduces fat content, possibly due to some fat being lost during the blanching process, but it later increases slightly. This change could be due to the redistribution of fats within the yam tissue during processing. There is a significant decreased in fiber content. This could be attributed to the breakdown of some fiber components during blanching, making the yam potentially softer or less fibrous in texture. The ash content shows a minor decrease, indicating that there is a minimal loss of mineral content during steam blanching. The carbohydrate content significantly increased during steam blanching. This could be due to the concentration of carbohydrates as moisture content decreased. The Total Titrable Acidity (TTA) decreased significantly during steam blanching. This could be due to changes in the acidity of the yam as a result of the blanching process. 'L*' decreased, indicating darkening, while a* and b* values change, suggesting changes in color attributes. These color changes could impact consumer acceptability and appearance of the yam. The 'h' value changed significantly with steam blanching, indicating alterations in the hue of the yam. This is in line with the changes observed in color properties. Steam blanching led to an increase in pH. This change in acidity can affect the overall taste and quality of the yam product. Total Soluble Solids (TSS) content significantly decreased during steam blanching. This may suggest a reduction in the sweetness or sugar content of the yam. Hence, the results indicate that steam blanching has a significant impact on the physicochemical properties of white yam. These changes may have implications for the taste, texture, color, and overall quality of the yam product.

3.2 Effect of room temperature storage on the physical properties of yam (*Dioscorea rotundata*)

The storage duration on its own did not affect the measure attributes significantly. However, blanching duration and storage duration had a combined significant effect on the physicochemical attributes. From Table 2a, the control value (59.9 %) of moisture content represents the initial moisture content of the yams before any exposure to room temperature storage. This serves as a reference point for comparison. The blanched duration column represents the moisture content of yams measured at different time intervals after being stored at room temperature. As time (7 days) passes during room temperature storage, there is a significant decrease in the moisture content of the yams. This trend is evident as you move from the control value to the values at 1 minute, 3 minutes, and 5 minutes. The most notable change occurs between the control and the 5-minute measurement, with the moisture content dropping from 59.9% to 29%. This indicates that yams are losing a substantial amount of moisture during room temperature storage. This reduction in moisture content can have several practical implications for yam storage and quality. Therefore, the data suggests that room temperature storage has a substantial effect on the moisture content of yams, causing a notable decrease over time. A similar trend was observed by Boakye and Essuman [18] when the effects of storage conditions on physicochemical properties of *D. rotundata* were studied.

From Table 2a, pH measurement taken at the beginning (Control) represents the baseline pH of the yam samples before any exposure to room temperature storage. The pH of blanched sample durations taken at these time points after the start of room temperature storage provide insights into how the acidity or alkalinity of the yam samples changes over time. The pH of each sample was seen to decrease over time; it could indicate that the yams are becoming more acidic. This could be due to metabolic processes or chemical reactions occurring within the yams as they age or respond to the room temperature conditions.

Table 1. Physicochemical properties of slices of white yam (*Dioscorea rotundata*) subjected to steam blanching for different times

Properties	Control	1 Min	3 Mins	5 Mins	P-value
Moisture content (%)	65.04±0.35	57.87±1.25	34.96±0.41	19.06±0.71	<0.0001
Crude Protein (%)	4.55±0.04	4.30±0.03	4.08±0.11	3.94±0.06	0.003
Fat (%)	0.53±0.01	0.47±0.01	0.30±0.05	0.35±0.02	0.004
Fiber (%)	1.42±0.02	1.37±0.03	1.10±0.02	0.71±0.01	<0.0001
Ash (%)	2.25±0.02	2.24±0.02	2.22±0.07	2.07±0.00	0.025
Carbohydrate (%)	26.22±0.29	33.76±1.27	57.38±0.53	73.87±0.64	<0.0001
TTA (%)	0.169±0.03	0.017±0.01	0.036±0.02	0.017±0.00	<0.0001
L*	83.19±0.50	74.66±2.72	73.06±0.97	71.67±3.58	0.001
a*	-1.95±0.25	-5.34±1.19	-5.56±0.86	-5.58±0.43	0.001
b*	19.22±1.14	24.83±0.68	20.97±1.96	25.00±1.58	0.002
c*	19.31±1.16	25.42±0.79	21.69±2.11	25.63±1.53	0.002
H	95.84±0.43	102.11±2.52	104.80±0.92	102.63±1.36	0.001
pH	5.81±0.03	6.18±0.01	6.46±0.06	5.75±0.04	0.0001
TSS (%)	0.31±0.00	0.20±0.01	0.10±0.01	3.20±0.01	<0.0001

Table 2a. Moisture content and pH of yam samples during storage

Storage Duration (days)	Treatment	Moisture Content (%)	pH
	Control	59.90	5.43
	1 min	47.22	5.74
1	3 min	40.98	5.78
	5 min	29.00	6.70
	Control	59.81	5.37
2	1 min	46.73	5.69
	3 min	40.57	5.73
	5 min	28.85	6.66
	Control	59.53	5.29
3	1 min	46.61	5.64
	3 min	40.54	5.68
	5 min	28.78	6.63
	Control	59.84	5.19
4	1 min	46.59	5.58
	3 min	40.42	5.62
	5 min	28.25	6.58
	Control	59.75	5.15
	1 min	46.56	5.56
5	3 min	40.40	5.61
	5 min	28.65	6.55
	Control	59.72	5.36
	1 min	46.47	5.43
6	3 min	40.36	5.57
	5 min	28.58	6.53
	Control	59.68	5.28
	1 min	46.41	5.33
7	3 min	40.27	5.49
	5 min	28.48	6.49
P-value		< 0.0001	< 0.0001

Table 2b. Colour changes of the yam samples during storage

Storage Duration (days)	Sample ID	L*	a*	b*	c*	h
1	Control	83.19	-1.95	19.22	19.31	95.84
	1 min	74.66	-5.34	24.83	25.42	102.11
	3 mins	73.06	-5.56	20.97	21.69	104.80
	5 mins	71.67	-5.58	25.00	25.63	102.63
2	Control	83.12	-1.91	19.18	19.27	95.67
	1 min	74.63	-5.31	24.78	25.36	102.06
	3 mins	73.00	-5.51	20.92	21.63	104.71
	5 mins	71.62	-5.52	24.95	25.56	102.51
3	Control	83.06	-1.85	19.12	19.20	95.51
	1 min	74.57	-5.25	24.72	25.29	101.95
	3 mins	72.30	-5.46	20.88	21.58	104.60
	5 mins	70.92	-5.46	24.24	24.85	102.73
4	Control	80.06	-1.78	18.07	18.16	95.64
	1 min	73.24	-5.21	24.01	24.59	102.19
	3 mins	71.91	-5.39	20.48	21.18	104.69
	5 Mins	70.83	-5.37	24.15	24.75	102.58
5	Control	78.48	-1.73	18.02	18.11	95.50
	1 min	73.17	-5.14	23.94	24.50	102.07
	3 mins	71.83	-5.31	20.41	21.08	104.54
	5 mins	70.74	-5.29	24.07	24.65	102.43
6	Control	78.18	-1.64	17.76	17.84	95.29
	1 min	72.81	-5.07	23.88	24.43	101.93
	3 mins	71.78	-5.27	20.35	21.02	104.46
	5 mins	70.68	-5.24	24.02	24.59	102.33
7	Control	78.13	-1.60	17.71	17.78	95.17
	1 min	72.73	-4.99	23.82	24.36	101.77
	3 mins	71.73	-5.20	20.29	20.95	104.33
	5 mins	70.63	-5.18	23.97	24.52	102.23
	P-value	< 0.0001	<0.0001	< 0.0001	< 0.0001	< 0.0001

From Table 2b, 'L*' values indicate how light or dark the yams are. Increased 'L*' values over time might suggest that the yams are getting lighter in color. This could be due to factors such as moisture loss or changes in the yam's surface characteristics during storage. 'a*' values represent the red-green color component. The 'a*' values of control samples become more negative (moving towards green) over time, it suggests that the yams are developing a greenish tinge. This could be a sign of spoilage or changes in the yam's internal composition while the blanched samples of 'a*' values become less negative (moving towards red) over time; it suggests that the yams are developing a reddish tinge. This could be a good sign of safe consumption. 'b*' values represent the yellow-blue color component. Changes in b* values could indicate shifts in the yam's color towards either yellow or blue hues. c* values represent colorfulness or Chroma. An increase in c* values suggests that the yams are becoming more colorful or saturated in their appearance. This could be related to changes in the yam's surface texture or pigmentation during storage. h* values represent the hue angle, which indicates the type of color (e.g., red, green, blue) in the CIELAB color space. Changes in h* values could indicate shifts in the dominant color of the yams.

4. CONCLUSION

It was found that the steam blanching durations significantly affected all the physicochemical properties measured. The proximate results showed that the non-blanched (control) samples to have significantly higher moisture, crude protein, crude fat, fiber and ash contents than the blanched samples with exception of the carbohydrate content where the control samples had lower values. Generally, the proximate components of the samples decreased considerably as the blanching duration increased, except for carbohydrate content. The storage duration on its own did not affect the measured attributes significantly. However, blanching duration and storage duration had a combined significant effect on the physicochemical attributes. This study recommends that steam blanching can be a useful pre-treatment method for commercial processing of white yam slices. Producers should incorporate this process to improve product shelf life and quality to help reduce food wastage.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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