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Effect of Blanching and Ultrasound on Drying Time, Physicochemical and Bioactive Compounds of Dried Cashew Apple

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Abstract In the present study, the influence of ultrasound (US) and blanching (BL) compared to untreatment (UN) on the drying rate, color, rehydration, total phenolic content, antioxidant activities and sensory evaluation of cashew apple were investigated. Ultrasound dehydration of cashew apple followed by BL, respectively, showed the faster drying time compared to UN. Ultrasound treatment was effective in retaining on whiteness of dried cashew apple. The color difference of US followed by BL was significantly lower ($p<0.05$) compared to UN samples. Ultrasound caused a higher retention of total phenolic and flavonoids content and presented the highest antioxidant power. It emerged from this study that ultrasound can be employed successfully as pretretment prior to dried cashew apple with better nutritional attributes.

Keywords: *ultrasound, blanching, drying, cashew apple, bioactive compounds*

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1. Introduction

Cashew (*Anacardium Occidentale* L.) fruit belongs to the Anacardiaceae family. It is native to tropical America, and is widely available in several countries of Asia, Africa and Central America as an economically important agricultural crop [1]. Global cashew nut production amounted to 2 971 046 tonnes in 2017 [2]. West Africa contributed nearly one-third (36%) while Latin America and East Africa contributed about 11 and 8%, respectively. Benin is ranked fifth with a cashew nut production estimated at 151 836 tonnes [2]. The edible cashew nut is an extremely important agricultural trade product for Benin. The cashew sector represents a huge agricultural export for Benin after cotton. Cashew production is of high social and economical importance, due to the labour force required in the field and for processing. Almost in all producing countries, nuts are harvested as a major crop, while cashew apples are discarded as waste [3,4]. The loss of cashew apples is estimated at 90% in the world [5]. More than 450,000 tons of cashew apples were left to rot in Benin; this is a great loss [6,7]. Unlike cashew nut, cashew apple is virtually an unknown product in the consumer market [8].

Researchers have reported that cashew apple juice contains significant amount of polyphenols (primarily flavonoids, carotenoids, anacardic acid and tannins), organic acids and vitamins [9,10,11,12]. It is also rich in vitamin C which is three to six times higher than that of orange juice and about ten times more than that in pineapple juice [13,14]. Cashew apple also contains thiamine, niacin and riboflavin in addition to significant amount of minerals, such as copper, zinc, sodium, potassium, calcium, iron, phosphorous and magnesium [15]. Cashew apple juice has been reported to have antitumor, antimicrobial, urease inhibitory and lipoxygenase activity [16]. Unfortunately, cashew apples are very perishable fruits and subject to rapid microbial deterioration. Also, adequate information is not available for proper storage and processing technologies for appropriate utilization of the cashew apple [17]. High losses of the cashew apples could be prevented by processing them into a shelf-stable intermediate moisture product. A number of processes have already been developed for converting cashew apples into value added products such as juice, jam, powder, candy and distilled products [18]. Dried cashew apple powder with good sensory properties could be used in the development of value-added products such as cookies, bread spread, wheat-based confectionaries, chocolates, sponge cakes etc

[19]. However, a major limitation in the production of cashew apple powder is the high capital investment in the drying unit operation. Loss of vitamin C due to drying has been reported in the range of 34-44% [20]. One of the main purposes of modern food technology is to maximize the retention of nutrients during processing and storage. Dried foods can be stored for long periods without deterioration because the microorganisms which cause food spoilage and decay are unable to grow and multiply due to insufficient water contents. Unfortunately, convectional drying methods due to their high temperatures and long drying times lead to high energy consumption even quality destruction of final products. Pre-treatments can improve the drying process leading to high-quality products [21]. Pre-treatment can be used to reduce the initial water content of the fruit or can be used to modify the fruit tissue structure in a way that air-drying becomes faster [22].

Blanching pre-treatment could reduce the drying time and improve product quality, and it is an important step during the processing of fruits and vegetables before commercial drying [23,24]. It is mainly used to inactivate enzymes, but it is also used to remove air from the intercellular spaces in fruits and vegetables [25,26].

Having been recognized as the effective alternative, ultrasound-assisted drying is applied either as a pretreatment in liquids to cause lasting changes in the product that improve subsequent drying, or as a combination treatment during a drying process to affect the mass transfer directly. Nowadays application of ultrasound as pre-treatment of fruits prior to drying has drawn the attention of researchers to improve drying rate as well as quality of dried fruits [21,22,27]. This application is said to be relatively new and has not yet been fully explored as to how ultrasound affects factors in different fruits and it`s cost.

The objective of this study was to investigate the effects of ultrasound and blanching as a pre-treatment on drying kinetics, physicochemical and bioactive compound of dried cashew apple.

2. Materials and Methods

2.1. Sample Preparation

The raw material was red cashew apples (*Anacardium occidentale* L.) harvested at commercial maturity stage in Ketou city, republic of Benin. After the fruit sanitization and nut removal, the cashew apple (peduncle) were reserved. Samples were cut into 10 mm thick slices. The moisture content of the different samples was determined by the AOAC Official Method. About 5 g of sample was placed in an aluminium disk and dried to a constant weight at 105°C in hot air-drying oven for 24h. The initial moisture content was 87.20 ± 0.72 g/100 g (wet basis, w.b.). Total soluble solid was 10 °Brix and determined using a handheld refractometer (Hanna Instruments, Italy).

2.2. Experimental Design

The fresh slices cashew apples were divided into three groups: a) Untreated (UN) groups is the fresh slices cashew apples without any treatment was used as control. b) Blanched (BL) samples were boiling in water for 1 min at 90°C and immediately cooled in distilled water to avoid over-processing. c) Ultrasound (US) samples treatments were carried out using Bioblock Scientific, Vibra-cell 75115 (with probe diameter of 10 mm) at constant power of 500 W and frequency of 20 kHz for 10 min. The ratio between cashew apples and the liquid medium was maintained at 1:4 (w/w) [22] for ultrasound pretreatments. After ultrasound processing, the samples were air-dried in a forced circulating air-drying oven (Digital display BOV-V45F; Zhangqiu, Jinan, Shandong, China) at 60°C. During the air-drying, the weights of different samples were measured every 30 min using an automatic digital balance.

2.3. Physico-chemical Analysis

2.3.1. Color

Surface color of fresh and dried cashew apple was determined by a chroma-meter (CR-410, Konica Minolta Sensing, Tokyo, Japan) with CIE color parameters L* (light/dark), a* (red/green) and b*(yellow/blue). The mean values of ten pieces for each sample are used for the analysis. For the color homogeneity of the dried cashew apple, the latter had been crushed into powder. Color changes (ΔE) were observed in 3 replicates using a previously described equation.

$$\Delta E = [(L_t^* - L_i^*)^2 + (a_t^* - a_i^*)^2 + (b_t^* - b_i^*)^2]^{1/2}$$

where: ΔE indicates the degree of overall color change in comparison to color values of fresh cashew apple. Li*, ai* and bi* represents those without any treatments and Lt*, at* and bt* refers to the individual readings of drying samples.

2.3.2. Rehydration Ratio

Rehydration experiments were performed by immersing approximately 5 g of dried cashew apple into 100 mL of distilled water at 25°C for 60 min. The samples were then withdrawn, drained, gently blotted with paper towels to eliminate the surface water and then weighed. The rehydration ratio (RR) of the sample was calculated using equation.

$$RR = \frac{\text{Weight after rehydratation}(g)}{\text{Weight before rehydratation}(g)}.$$

2.3.3. Total Phenolic Content

The samples (2 g) were mixed with 20 mL methanol and sonicated for 30 minutes. The homogenate was centrifuged at 10000 rpm for 10 min at 4°C. Its supernatant was filtered through Whatman No.1 filter paper and 1 mL of the filtrate was diluted to 10 mL with methanol and analyzed for total phenolic content using Folin-Ciocalteau method with slight modifications described by Aberoumand et al. [28] Briefly, 200 μL of the extract solution was mixed with 1 mL of Folin-Ciocalteu phenol reagent for 10 min using a Vortex mixer. Next, 800 μL of sodium carbonate (7.5%) was added. The solution was vortexed and allowed to stand for 2 h at room temperature.

The absorbance was measured at 765 nm with a spectrophotometer (UV-1600PC. Shanghai. China). The calibration curve of gallic acid was made and the total phenolic content was calculated and expressed as mg gallic acid equivalent (GAE)/100 mg for the samples.

2.3.4. Flavonoids

Flavonoids content were determined according to the methods used by Amoussa et al. (2015) [29]. Namely, 0.5 mL of extract (1mgmL^{-1}) was added to 1.5 mL of methanol, 0.1 mL of potassium acetate (1M) and 0.1 mL of trichloride aluminium (AlCl3) in methanol (10%), to all is added 2.8 mL of distilled water. The absorbance was read at 415 nm after 30 minutes of incubation against a blank. Thus, obtaining a stable yellow color allows to evaluate by spectrophotometer (UV-1600PC, Shanghai, China). The results were expressed in mg / ml equivalents quercetin (mg / ml).

2.3.5. DPPH Assay Scavenging Activity

The DPPH (1.1-diphenyl-2-picrylhydrazy) radical scavenging activity of the flesh and dried samples was determined according to Turkmen et al. [30] The samples (0.5 g) were mixed in 50 mL methanol, then filtered with a filter paper No. 4. Then, 1 mL of the extract solution was mixed and vigorously shaken with 2 mL of 0.1 mM DPPH solution in methanol. The mixture was left to stand for 60 min in the dark. The absorbance was measured at 517 nm. The percentage of DPPH scavenging activity was calculated as [1-(absorbance of sample/absorbance of control)] × 100.

2.3.6. Vitamin C content

Vitamin C content in the fresh and MVD sample was determined using High-Performance Liquid Chromatography (HPLC) according to Spinola et al. [31] The samples (2.5 g) were added to 25 mL of extraction solution (3% MPA), vortexed in the darkness, and then centrifuged for 10 min with a velocity of 6000 rpm. The supernatant was filtered through 0.22 µm PTFE filters (Milipore. USA). All operations were performed under reduced light. An isocratic mobile phase consisting of aqueous 0.2% (v/v) MPA with a flow rate of 0.8 mL/min was used. The volume of injection was 20 µL and the detection wavelength for the PDA was equalled at 240 nm. The L-ascorbic acid was determined by a comparison with the standardized retention time matching with the UV absorption spectrum. The analysis was carried out in duplicate for each type of sample.

2.4. Sensory Evaluation of Tea from Cashew Apple Dried

For the sensory evaluation, the dried cashew apple had been crushed into powder to make tea. The tea option was chosen because of its high bioactive content. Sensory evaluation of the cashew apple tea was performed with a 25 panel at Laboratory of Biochemistry and Bioactive Natural Substances. The quality attributes tested were color, aroma, taste and overall quality. Samples were randomly coded with three-digit numbers and their order of presentation was completely randomized for each panelist. The aspects were evaluated on a scale of 9-1 points, where 9 = liked extremely, 8 = liked very much, 7 = liked moderately, 6 = liked slightly, 5 = liked (limit of acceptable), 4 = disliked slightly, 3 = disliked moderately, 2 = disliked much and 1 = disliked extremely.

2.5. Statistical Analysis

All experiments were performed in triplicate. Data were expressed as mean ± standard deviation (SD). The Tukey's test and one-way analysis of variance (ANOVA) used for multiple comparisons by the SPSS 17.0 (SPSS, Chicago, USA). Difference was considered to be statistically significant if $P < 0.05$.

3. Results and Discussions

3.1. Effect of Pretreatments on Drying Process of Cashew Apple Slices

The effects of different pretreatments on the drying rate of cashew apple slices dried by hot air-drying were shown in Figure 1. The moisture content decreased continuously with the extension of drying time. The moisture content of the samples decreased with the increasing HAD time. At the initial stages of drying (t < 2 h), the drying curves for UN and BL samples did not deviate much from each other. However, after this time, the BL sample began to show a steady decrease in drying rate, whereas the US samples maintained greater drying rates. The results indicated that the different pretreatments played an important role in drying time. Ultrasound dehydration of cashew apple followed by BL, respectively, showed the faster drying time compared to UN. Thus, for example, after 4 h of drying at 60°C, the moisture content of different samples reached 12.55, 16.34 and 20.48 for US, BL, and UN, respectively. Ultrasound treatments were relatively more effective regarding drying time than other treatments. This could be due to the ultrasonic energy that penetrates into the samples during the compressions and expansions and causes the "perturbation" effect which could not only expand capillary channels for moisture diffusion and produce microcapillary channels, but also help water molecules inside the samples to overcome the binding force from organizational structure which might have eased moisture removal and increased the diffusivity of the water [22,32]. This result confirms the observations of De la Fuente-Blanco et al. [33] who showed that ultrasonic pretreatment affects the fruit tissue making it easier for the water to diffuse during air-drying and showed that the microscopic channels may contribute with the higher water [22]. It was also shown that the drying rate was increased by the blanching treatment compared to untreated samples. The causes of the increase in drying rate of the blanched samples are probably due to the increasing penetration of water into the sample surface by decreasing the hardening of the sample surface [34], or by the destroying of cell membrane stability [35], and changing the resistance to internal moisture diffusion by altering the microstructure due to physical damage to the sample [36]. These factors interact to enhance the drying rate.

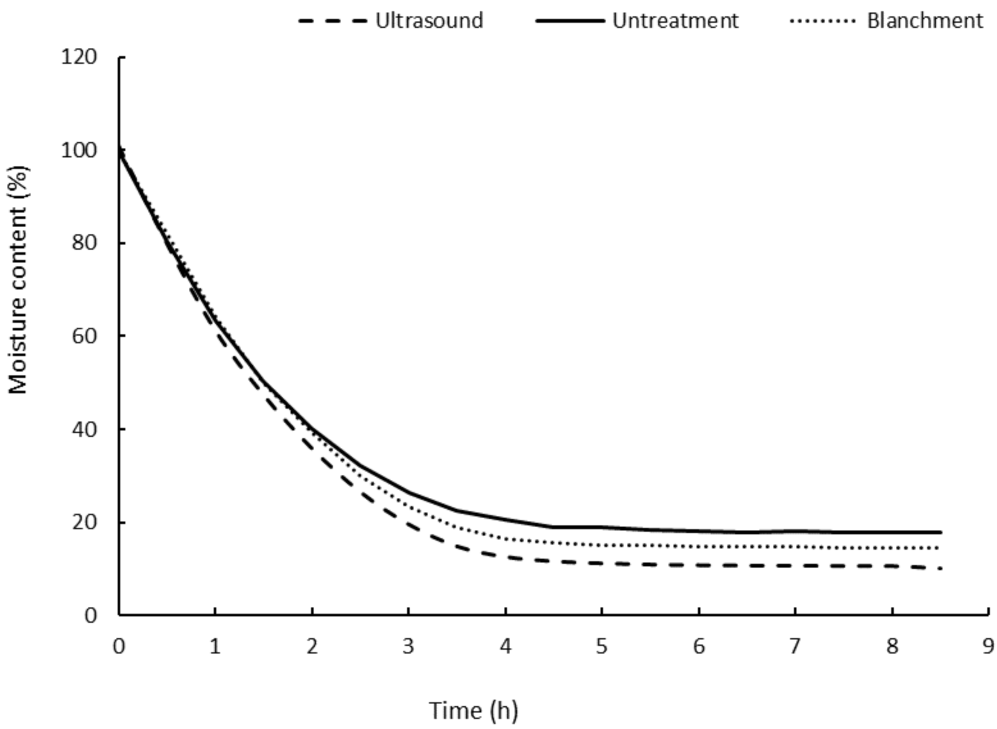

Figure 1. Evolution of the moisture content during drying time at 60°C of different treatments of cashew apple samples

Table 1. Color parameters of dried cashew apple after different pretreatment conditions

	Color				Rehydration ratio
	L*	a*	b*	ΔE	
FR	70.79±0.93[c]	6.45±1.31[a]	40.24±0.87[c]	-	
UN	51.23±0.33[a]	10.51±1.04[b]	9.08±1.11[a]	37.01±0.21[c]	1.94
BL	59.28±0.66[b]	11.33±1.37[b]	16.13±0.59[b]	27.15±0.77[b]	2.14
US	68.25±0.16[c]	11.92±0.87[b]	18.63±0.33[b]	22.43±0.96[a]	2.24

Values are Mean±standard deviation (n = 3). Data in same column with different letters are significantly different (p<0.05).

Figure 2. Color of dried cashew apple after different pretreatment conditions

3.2. Color

Color is an important quality attribute that affects the appearance, presentation, and acceptability of many foods. Color parameters L*, a*, b* and ΔE changes of cashew apple dried were shown in Table 1. Significant differences ($p < 0.05$) were observed in color of the dried samples in comparison to fresh samples. The L*, a*, b* mean values for fresh cashew apple were 70.79, 6.45 and 40.24, respectively. In comparison of FR sample, the dried cashew apple showed a decrease in chromatic parameters *L** (lightness) for UN and BL sample while no significant difference with US treatment. On the other hand, there is a decrease in the value of b* (yellowness) and an increase of a* (redness). As reported in the literature in the case of dehydrated apples and carrots, the pre-treatment with ultrasound leads to an increase in lightness (L*) compared to the untreated fruit [37] which could be connected to US treatment in liquid medium. Ultrasound treatment was effective in retaining on whiteness of dried cashew apple (Figure 2). When the plant tissue is immersed in the medium during the US treatment, the color is better preserved due to the limited access of air [38]. The higher ΔE value is related to the bigger color difference between the initial samples and the pretreated samples. The color difference of US followed by BL was significantly lower ($p<0.05$) compared to UN samples. Thus, the higher ΔE of UN and BL pretreatment was probably due to the longer drying time.

3.3. Rehydration Ratio

Rehydration is a complex process aims at the restoration of raw material properties and is widely used as a quality indicator. Rehydration indicates the chemical and physical changes caused by drying and pretreatments [39]. Table 1 displays the effect of different pretreatments on rehydration of the dried cashew apple. US followed by BL samples exhibited the higher rehydration ratio as compared to UN samples. This can be explained by the formation of micro-channels by ultrasound pretreatment, which turned into pores on the surface of dried cashew apple that enhances the mass transfer through the pores of the sample. The water penetrated into the pores of the samples more easily during the rehydration process. Similar results were also found for carrot [40,41] and in apple samples [42].

3.4. Total Phenolic Content (TPC) and Total Flavonoids (TF)

Polyphenolic compounds are very important fruit constituents because of their antioxidant activity in chelating redox-active metal ions, inactivating lipid free radical chains and preventing hydroperoxide conversion into reactive oxyradicals. Total phenol contents of cashew apple from different treatments are presented in Table 2. TPC value was high in US (2.41±0.69) followed by UN (1.80±0.88) and BL (1.05±0.37) pretreatments, respectively. Data obtained from this study for total phenolics in UN samples were comparable with that of Adou et al., (2012) [43]. In this study, the higher TPC in US samples may be related to an increased extractability for some of the antioxidant components following ultrasound processing, which can give rise to pores in vegetal tissue and consequently improve the extraction of polyphenols [27]. However, blanching caused a significant reduction in the total phenolic content. Most of the researchers attributed the decrease of TPC to loss of water soluble by leaching or the thermal degradation of phenolic compounds during blanching [44,45,46].

Similar to total phenolic, flavonoids presented also the same profiles (Table 2). In this study, like with total phenolics, ultrasound caused a higher retention of flavonoids. Similar results have been reported for the studies of carrot-grape juice [47].

3.5. DPPH Assay Scavenging Activity

DPPH results of different samples used in this study are also included in Table 2. Ultrasound had a higher level of reduction in DPPH in contrast with BL and UN one. There was no significant difference ($P > 0.05$) between BL and UN samples. However, a high antioxidant activity of US sample might be due to that technique increased bound antioxidants such as phenolics and ascorbic acid contents, leading to increased antioxidant activity. Further, ultrasonic treatment may inactivate enzymes, for instance, polyphenol oxidases which are responsible for enzymatic browning leading to improved DPPH values [47].

3.6. Vitamin C

The effects of ultrasound and blanching on vitamin C of cashew apple compared to untreatment sample are shown on Table 2. The vitamin C content of cashew apple treated whit US was significantly higher than that of BL and UN. Such result might be related to a disruption of cell wall as a result of alternate compression and expansion force on the solid sample which loosened the bound vitamin C [48]. It was also discovered that the vitamin C content of blanching sample was similar to fresh (untreated) sample.

3.7. Sensory Evaluation of Tea from Dried Cashew Apple

Figure 3 shows the sensory evaluation including color, aroma, taste and overall preference of different treatments. It was shown that US treatment presented the higher score for color, taste and overall quality. Blanching treatment was affected the sensory attribution in terms of taste but had higher scores in the aroma than the other treatments. Based on the overall quality, US following by BL samples reached the higher score than UN treatment. In conclusion, ultrasound improved the sensory quality of cashew apple tea.

Table 2. Total phenolics, total flavonoids, DPPH free-radical scavenging activity and vitamin C of different samples of dried cashew apple

Samples	Total phenolic (mg/ml)	Total flavonoids (mg/ml)	DPPH (%)	Vitamin C (mg/100g)
UN	1.80±0.88^{a}	0.12±0.88^{a}	74.46^{a}	3.01±0.13^{b}
BL	1.05±0.37^{a}	0.10±0.88^{a}	75.04^{a}	2.9±0.74^{a}
US	2.41±0.69^{b}	0.24±0.88^{b}	82.89^{b}	5.7±0.28^{c}

Values are Mean±standard deviation (n = 3). Data in same column with different letters are significantly different ($p<0.05$).

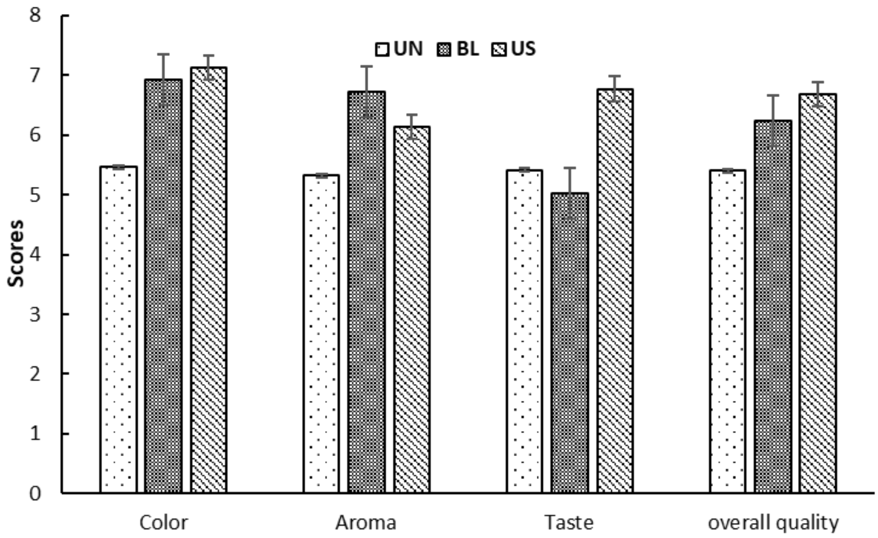

Figure 3. Sensory panel evaluation of dried cashew apple after different pre-treatments

4. Conclusion

This study has demonstrated the advantages of utrasound treatement in terms of its positive effect on the drying rate, rehydration and functional properties. Also, that treatment showed a significant effect on quality attributes with bright color and high sensory qualities.

Blanching presented the medium quality results as regards the rehydration rate and overall sensory quality but it occurred high degradation on vitamin C.

From the research results, it is clear that ultrasonic technology is a green and nonthermal process that enhances the functional properties of dried cashew apple which can be used as tea as demonstrated by the increase in phenolic, flavonoid and antioxidant capacity.

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