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Research Paper

EFFECT OF STORAGE IN PIT AFTER BLEACHING OF CASSAVA ROOTS (*Manihot esculenta* CRANTZ) ON FUNCTIONAL AND SENSORY CHARACTERISTICS

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Abstract

Cassava (*Manihot esculenta* CRANTZ) is an important food source of carbohydrates in the tropics. Cassava roots have a short shelf life due to a process known as post-harvest physiological deterioration (PPD). The aim of this study was to evaluate the effect of cassava's storage in pit after bleaching roots on functional properties and the sensory properties. For the storage times after bleaching (65 °C; 30s), the Water Absorption Capacity (WAC), Water Solubility Index (WSI), Dispersibility, Wettability capacity, Paste clarity (PC) and the sensory characteristics of boiled cassava roots and Attieke were determined after conservation. Results of the functional properties showed that the Water Absorption Capacity (WAC), the Water Solubility Index (WSI), and the Dispersibility increased significantly ($p<0.05$) and ranged from 128.58±1.22 to 250.39±1 %, 15.97±0.74 to 45.75±0.75 % and 72.23±0.25 to79.77±0.17 % respectively. Otherwise, conservation in pit of cassava roots reduced significantly ($p<0.05$) Paste clarity and Wettability. Sensory evaluation also revealed differences in the scores for some of the assessed attributes. Generally the color and taste of noodles did vary with increasing proportions of tubers flours, in which significant differences were observed. The boiled cassava roots of the TMS4 (2)1425 and Yace varieties were most appreciated during storage in pits after root bleaching (65 °C; 30s).

Key words: cassava, functional properties, sensory evaluation, storage, pit, bleaching.

INTRODUCTION

Cassava (*Manihot esculenta*) is a woody shrub of the Euphorbiaceae family grown mainly for its edible tuberous roots [1]. Worldwide, cassava is the sixth most important crop after wheat, rice, maize, potato and barley and is the fourth most important food source of carbohydrates in the tropics after rice, maize, and sugar cane. It is a staple food for more than 500 million people [1, 2]. In Sub-Saharan Africa, cassava is mainly grown by smallholder farmers, often on marginal land where it is productive even on poor soils and under drought conditions. Thus, cassava is a crop for both food security and income generation in least developed countries [3]. In addition, cassava has low demand for modern inputs and is relatively resistant to diseases, which contribute to its rapid propagation [4]. In Côte d'Ivoire, cassava is grown on about 4/5 of the national territory and is the major food crop after yam [5]. Starch of cassava is also used in the textile, paper, metallurgy, pharmacy, and plastic industries [6]. According to the Food and Agriculture Organization of the United Nations [7], this food has the potential to become the raw material base for a number of processed products. That may increase the demand for cassava and contribute to agricultural transformation and economic growth in developing countries. However, the utilization and efficient commercialization of cassava are affected by its short shelf-life due to a rapid postharvest physiological deterioration (PPD) process, which renders the root unpalatable within 48 hours of harvest. PPD is characterized by a blue-black discoloration of the xylem vessels known as ''vascular streaking", which considerably reduces the palatability and marketability of cassava roots [8]. In addition, initiation of PPD is associated with rapid oxidative burst and accumulation of reactive oxygen species, causally linked to cyanogenesis [1]. Enzymatic browning of roots is generally considered detrimental to food quality from both sensory and nutritional points of view [9]. Due to the importance of this reaction in the food industry, the storage methods of fresh cassava roots has been studied. The present work was carried out to evaluate the impact of a conservation method on the functional properties and the sensory characteristics of products derived from three cassava roots varieties (Bonoua 2, TMS4 (2)1425 and Yace).

MATERIAL AND METHODS

Raw material

Mature roots (six months) of *Manihot esculenta* CRANTZ (varieties Bonoua 2, TMS 4(2)1425 and Yace) were harvested from the Biological Garden of Soumalekro (Bonoua 5°16'20''North ; 3°36'3''West, Côte d'Ivoire) and stored until used.

Conservation methods of the Cassava fresh root

The cassava roots were sorted and the unwounded roots were laid out in a basket, then blanched at 65°C during 30 seconds. They were left to cool down at room temperature (32.81 ± 0.98 °C) then laid out in a box (L: 1m, L: 0.5m and H: 0.5m) whose bottom is covered with wet sawdust (water content: 45%). The roots are then covered with wet sawdust for the conservation in the box (Diagram of conservation). All of these operations were carried out away from sunlight or rain, in a ventilated place.

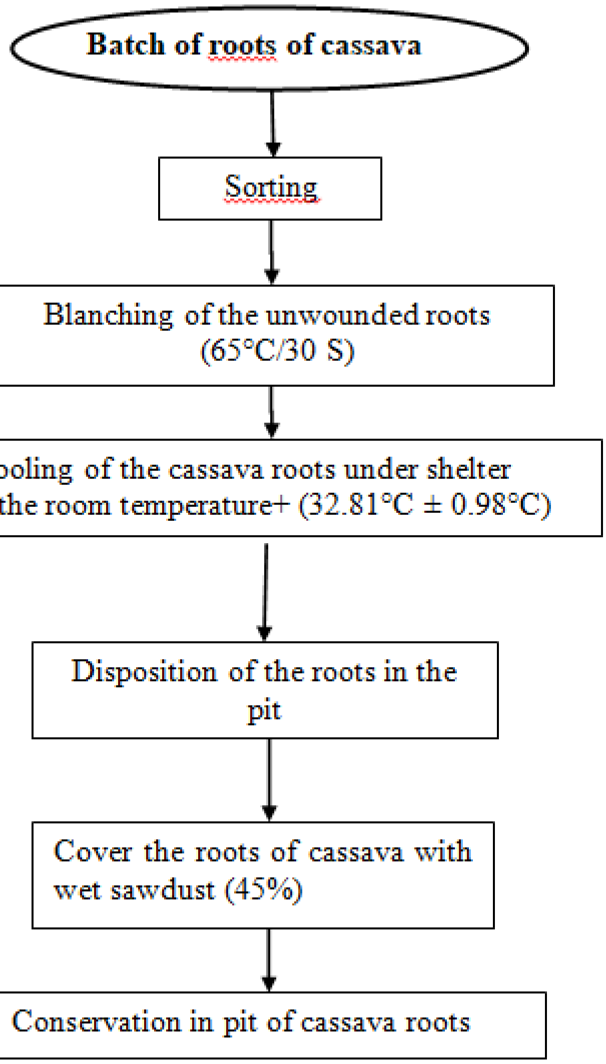

Figure 1: Diagram of conservation in pit of fresh cassava roots after blanching

Preparation of cassava flour

The fresh roots of cassava (2 kg of roots per variety) were peeled off with a stainless steel knife, and washed with distilled water. The pulps of cassava were cut out in fine pieces (1mm). The pieces obtained were put into an oven and dried at 55 °C for three days. The dried pieces were transformed into powder by crushing, passed through a sieve of 250 µm and then stored in airtight containers for analysis [10].

Water absorption capacity (WAC) and water solubility index (WSI)

The water absorption capacity and solubility index of cassava (*Manihot esculenta* CRANTZ) pulp flours were evaluated according to [11, 12] methods respectively. One (1) g of flour (M0) was mixed with 10 ml of water into a centrifuge tube. The mixture was shaken for 30 min, then kept in a water bath (PRECISTERM) (37ºC) for 30 min, and finally centrifuged (TGL-16M) at 5000 rpm for 15 min. The resulting sediment (M2) was weighed and then dried at 105ºC to constant weight (M1). The WAC and WSI were then calculated as follows:

$$\text{WAC}(\%) = \frac{M_2 - M_1}{M_1} \times 100 \quad (1)$$

$$\text{WSI}(\%) = \frac{M_0 - M_1}{M_0} \times 100 \quad (2)$$

Flour dispersibility

The flour dispersibility was determined according to the method described by [13]. Ten (10) g of flour were weighed into 100 ml measuring cylinder and distilled water was added to a final volume of 100 ml. The mixture was stirred vigorously for 1 min. The volume of the settled particles was recorded after one h hours. The volume of the settled particles was subtracted from 100. The difference was reported as percentage of dispersibility.

Wettability capacity

The wettability capacity of flours was determined according to the method of [14]. 1 g of cassava flour was introduced into a 25 ml graduated cylinder with a diameter of 1 cm, added. A finger was placed over the open end of the cylinder which was inverted and clamped at a height of 10 cm from the surface of a 600 ml beaker containing 500 ml of distilled water. The finger was removed and the rest material allowed to be dumped. Wettability was determined as the time required for the sample to become completely wet.

Paste clarity (PC)

The paste clarity of flours was determined according to the method of [15]. One (1) % aqueous suspension was made by suspending 0.2 g of flour in 20 ml of distilled water in a stoppered centrifuge tube. The suspension was heated in a boiling water (100ºC) bath for 30 min. After cooling, clarity of the flour was determined by measuring the transmittance at 650 nm against water blank on a spectrophotometer (MS-V5100 visible spectrophotometer).

Processing for sensory analyses

The sensory analyses were described by [16]. The panel of 12 people (comprising of 6 girls and 6 boys) was trained and selected in order to evaluate the sensory quality of the food. Regarding the boiled cassava and Attieke, the sensory attributes considered were as follow: aspect (farinaceous or translucent), color (white or yellow), texture (crumbly or hardness), taste (bitter or sweet), and presence of fibers (little or much). These criteria are evaluated on a linear scale of interval ranging from lowest to high intensities (0-10).

Statistical analysis

Data obtained from the functional and sensory analyses were recorded in triplicate and subjected to analysis of variance (ANOVA), with the mean values separated by Duncan's multiple range test at 5% level of significance.

RESULTS AND DISCUSSION

Functional properties of food are defined as physicochemical properties reflecting complex interactions between the composition, structure, conformation and physicochemical properties components [17]. The functional properties of flours from cassava roots preserved in pit after bleaching could be influenced by storage time.

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Water absorption capacity (WAC) indicates the capability of flour to absorb water [18]. It is also the ability of the flour to retain water. This ability is a very important property of all flours in food preparations. Bleaching and storage period had significant ($p<0.05$) effect on the WAC of flours. WAC of flours of cassava roots stored in pit after bleaching increased during the six weeks of storage (Table 1). The values range from 204.39 ± 0.75 to 250.39 ± 1.00 % for the variety Bonoua 2, from 128.58 ± 1.22 to 157.45 % for TMS4 (2) 1425, and from 169.28 ± 1.22 to 201.66 ± 0.75 % for the variety Yace. These results suggest that the conservation after bleaching of cassava roots in pit would increase the affinity of flours to water. Water absorption capacity is a useful indication of whether flours can be incorporated into aqueous food formulations, especially those involving dough handling [19]. Water absorption capacity is important in bulking and consistency of products as well as baking applications [20]. Results could also be attributed to the difference in their carbohydrate contents [21]. Indeed, according to [22], some absorbent carbohydrates would be responsible of the increase of the Water absorption capacity of flours. The same observations have been reported by [23] on the conservation of cassava flours, by [24] on *Sesamum indicum* grain flour, by [25] on tapioca and soybean flour (125-170 %). Furthermore, [26] found a WAC value between 140 and 220 % for Macuna flour and suggested that it could be used for the formulation of bakery products and soups. Bonoua 2, TMS4 (2) 1425 and Yace roots flours after storage could be used for the same formulations.

The water solubility index (WSI) reflects the extent of particle degradation in water [27]. WSI increases significantly ($p<0.05$) during roots storage (Bonoua 2, TMS4 (2) 1425 and Yace) in the pit (Table 2). The increase of water solubility index would be due to the variation in the content of sugars, proteins and fats during storage. Indeed, proteins, total sugars and crude fat could play an important role in the change in functional properties [28]. The increasing values of WSI would also be due to the degradation of macromolecules in small molecules. High swelling capacity had been reported as part of criteria for a good quality product [29]. Our results (WSI ranged from 15.97±0.74 to 45.75± 0.75 %) were higher than those recorded by [30] for the storage of cassava starches in Nigeria (4.25 to 5.96 %), by [31] for yam starches (8.90 - 9.3 %). Similar results were reported by (2012) [32] for Beni grain flour (*Sesamum indicum*) (10.92 to 25.89 %). This physico-functional characteristic plays an important role in the choice of flours to be used as thickeners of sauces and soups [28].

Table 1: Water absorption capacity (WAC) of flours of stored cassava roots

Varieties	Water absorption capacity			
	0 Day	**2 Weeks**	**4 Weeks**	**6 Weeks**
Bonoua2	204.39 ± 0.75^{h}	229.58 ± 0.68^{i}	244.2 ± 0.87^{j}	250.39 ± 1^{k}
TMS 4(2)1425	128.58 ± 1.22^{a}	130.81 ± 0.79^{b}	141.48 ± 0.71^{c}	157.45 ± 0.44^{d}
Yacé	169.28 ± 1.22^{de}	180.15 ± 0.93^{f}	190.52 ± 0.80^{g}	201.66 ± 0.75^{h}

The means with different superscript letters within the same row indicate significant different at $p< 0.05$.

Table 2: Water solubility index (WSI) of flours of stored cassava roots

	Water solubility index of cassava flours			
Varieties	**0 Day**	**2 Weeks**	**4 Weeks**	**6 Weeks**
Bonoua 2	22.23±0.65[g]	30.27±0.64[h]	37.81±0.63[j]	45.75±0.75[l]
TMS 4(2)1425	15.97±0.74[a]	17.15±0.48[b]	19.12±1.08[c]	21.3±0.61[d]
Yace	22.64±0.71[e]	26.14±0.15[f]	34.68±1.02[i]	38.34±1.23[jk]

The means with different superscript letters within the same row indicate significant different at $p< 0.05$

Flour dispersibility gives an indication of particles suspensibility in water [33]. The dispersibility of flours from stored cassava roots (in pit) increases with storage time and range from 72.23 ± 0.28 % to 79.07 ± 0.13 % (Table 3). These results are superior to those of [34], rice (56 to 66 %). These results are similar to those of [25] on yams (63-87%) and also those of [32] on cassava (87%). The high dispersibility of our flours would be due to the absence of fat in cassava roots. According to [13], a high percentage of dispersibility is an indicator of good flour water absorption capacity and an indicator of good frost quality [35]. The high dispersibility values shown by cassava flours are an indicator of their ability to produce smooth and consistent dough [36]. Therefore, flours of the Bonoua 2, TMS4 (2) 1425 and Yace varieties stored in pit after bleaching at 65 °C could serve as an ingredient for the improvement of products resulting from emulsions and foams.

Wettability is a function of the ease of dispersion/displacement in water by any sample. The sample with the lowest time of wettability would dissolve in water faster than samples with higher wettability [37]. The wettability time of cassava flours increased from 10.26 ± 0.25 seconds to 39 ± 1 seconds during the six weeks of storage of the roots (Table 4). The sample with the lowest time of wettability would dissolve in water faster than samples with higher wettability. The results are similar to those of [38] on soybean meal (31 s) and cassava (37 s). Besides, our results were lower than that of wheat flours (52 s). This difference in time would be due to the density of the starch in the flours. According to [39], a powder is considered wettable if its wettability time is less than 60 s and very wettable if it is less than 30 s. Compared to wheat, it could be said that the starch contained in these flours is denser.

Table 3: Dispersibility of flours of stored cassava roots

	Dispersibility of cassava flour			
Varieties	**0 Day**	**2 Weeks**	**4 Weeks**	**6 Weeks**
Bonoua 2	72.23±0.25[a]	73.29±0.53[b]	73.78±0.47[b]	75.09±0.17[c]
TMS 4(2)1425	75.16±0.18[c]	75.33±0.13[c]	77.65±0.10[d]	78.92±0.15[e]
Yace	75.23±0.26[c]	77.87±0.87[d]	79.07±0.31[ef]	79.77±0.17[g]

The means with different superscript letters within the same row indicate significant different at $p< 0.05$

Table 4: Wettability of flours of stored cassava roots

Varieties	Wettability of cassava flour (S)			
	0 Day	**2 Weeks**	**4 Weeks**	**6 Weeks**
Bonoua 2	11.22±1.2^{ab}	24.56±0.80^{e}	29.48±0.61^{g}	37.56±1.17^{ij}
TMS 4(2)1425	10.26±0.25^{a}	11.37±0.74^{ab}	17.24±1.02^{c}	22.56±1.22^{d}
Yace	28.66±0.57^{f}	30±1^{gh}	36.33±1.15^{i}	39±1^{k}

The means with different superscript letters within the same row indicate significant different at p< 0.05

The clarity of the cassava roots flours resulting from the storage in pit after bleaching (Table 5), it decreases significantly (p <0.05) with the shelf life. This difference could be explained by the difference in starch concentration in flours. In addition, retrogradation of the starch may cause aggregation, phase separation and rapid opacification of the gel which reduces the clarity of the dough [40]. According to these authors, the uninflated starch granules would reflect the maximum light. These results are consistent with those reported by [41] during the storage of cassava roots at room temperature. On the other hand, these values of clarity are lower than those found by [42], which recorded values of 28.56 - 49.30 % for cocoyams (*Colocasia esculenta*). There are many factors that influence paste clarity, such as amylose (lower amylose starches are easily dispersed, increasing transmittance and clarity), lipid and protein contents [15], the botanical source and the capacity of granules to form aggregates [43]. The flours of stored cassava roots in pit after bleaching would be ideal for salad dressing.

Table 5: Paste clarity of stored cassava roots

Varieties	Paste clarity			
	0 Day	**2 Weeks**	**4 Weeks**	**6 Weeks**
Bonoua 2	10.03±0.51^{f}	9.57±0.12^{e}	8.45±0.33^{bc}	7.91±0.21^{b}
TMS 4(2)1425	8.95±0.22^{d}	8.27±0.35^{bc}	7.49±0.14^{ab}	7.05±0.37^{a}
Yace	9.66±0.18^{e}	8.57±0.32^{c}	8.09±0.44^{c}	7.66±0.43^{ab}

The means with different superscript letters within the same row indicate significant different at p< 0.05

The sensory scores of the boiled cassava roots, after bleaching and storage (6 weeks), are shown in Table 6. The results revealed that in general, there were relation between the storage time and the sensory characteristics such as aspect, color, fibers, texture, and taste at 5% significance level. Organoleptic characteristics of boiled cassava roots have slightly increased during the storage period (6 weeks conservation in pit after bleaching). The increasing of organoleptic characteristics could be attributed to the high dry matter content of the roots [44]. Similar observations were reported by [45] for cooked sweet potato cultivars. The color (2.40 – 5.58) and the taste (5.83 – 7.08) of boiled cassava roots were appreciated after storage. According to [46], t sensory criteria that influence the acceptability of foods are taste, aroma and color. After storage, the boiled cassava roots of the TMS 4(2)1425 and Yace varieties had the highest scores for the taste and color.

Table 6. Sensory properties of different boiled cassava roots varieties after bleaching and after 6 weeks of storage

Varieties	Cons times	Parameters				
		Aspect	Color	Fibers	Texture	Taste
Bonoua 2	0 week	1.92 ± 0.57 [a]	2.40 ± 0.86 [a]	1.63 ± 0.55 [a]	1.65 ± 0.36 [a]	5.83 ± 1.74 [b]
	6 weeks	2.29 ± 0.83 [a]	3.33 ± 0.64 [b]	1.92 ± 0.23 [a]	1.50 ± 0.38 [a]	6.88 ± 1.79 [c]
TMS4 (2)1425	0 week	3.33 ± 0.60 [b]	3.62 ± 0.72 [b]	3.37 ±0.62 [c]	3.38 ±0.64 [c]	6.13 ± 1.66 [bc]
	6 weeks	3.68 ±0.34 [b]	4.33 ± 0.42 [c]	2.50 ± 0.87 [abc]	2.92 ± 0.27 [b]	6.17 ± 0.21 [bc]
Yacé	0 week	3.33 ± 0.59 [b]	4.33 ± 0.98 [c]	1.85 ± 0.55 [a]	2.56 ± 0.56 [b]	6.07 ± 0.73 [bc]
	6 weeks	4.38 ±0.53 [c]	5.58 ± 0.47 [d]	2.08 ± 0.02 [ab]	3.42 ± 0.48 [c]	7.08 ± 1.24 [d]

The means with different superscript letters within the same row indicate significant different at $p < 0.05$

CONCLUSION

Storage in pit of cassava root after bleaching has resulted in a longer shelf life of cassava (6 weeks).The study also revealed that this method of conservation of fresh cassava roots (pit and body preservation after root bleaching) have significantly influenced the functional and sensory properties studied. Thus, the functional properties such as solubility index, water absorption capacity and dispersibility of cassava flours increased with shelf-life. On the other hand, the wettability of the flours and the clarity of the paste decreased during the six weeks of storage of the cassava roots. In addition, the boiled cassava from the conserved TMS 4 (2) 1425 and Yace varieties were most appreciated.

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