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Physico-Chemical, Sensory And Storage Characteristics Of Crisps Processed From Cassava With Parboiling To Reduce Cyanide Contents

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Abstract:*Cassava (Manihot esculenta Crantz) crisps have become increasingly popular snack foods in urban Kenya. Processing is, however mainly informal on the street sides, although recently a few small-medium processing enterprises have been established especially in Nairobi. Recent studies have indicated that the crisps traded in Kenya have cyanide levels exceeding the statutory limits of 10mg/kg. This study therefore was designed to evaluate the effectiveness of boiling cassava as a preprocessing to reduce the cyanide levels of the crisps to the statutory limits. Samples of cassava roots were collected from three markets in Nairobi namely, Parklands Market, City Market, and Wakulima Market, being the main markets from where most of the processors do the purchase. Each market was sampled three times within intervals of two weeks. The samples were prepared for processing by peeling, washing, and cutting into approximately 10cm long pieces. Each sample was then divided into four batches, which were boiled while submerged in tap water for 0, 10, 20, and 30 minutes respectively. The pieces from each boiling treatment were sliced to 1mm thickness, and fried in vegetable corn oil (Elianto, Bidco Oils Ltd, Nairobi) at 170 ^oC until light golden brown color. The crisps were drained of oil, cooled, and packaged in plastic bags (gauge 350) to await analyses. The crisps were analyzed for moisture, oil, and cyanide contents. They were also subjected to sensory testing and shelf life evaluation by accelerated methods. Results showed that boiling alone up to 30 minutes did not reduce the cyanide levels to the statutory limit. Boiling for 10, 20, and 30 minutes resulted in lowering the cyanide contents of the crisps to below the statutory limits for all samples. At $P < 0.05$, the cyanide contents were however significantly different. The moisture and oil contents were within the statutory limits and were not significantly different. Boiling for 30 minutes yielded significantly the lowest cyanide contents. Boiling for 20 minutes produced the most preferred crisps, especially in terms of color and taste. Finally, the crisps could be stored at room temperature (approximately 25 ^oC) for up to 10 months without detectable changes in eating quality. The study concludes that boiling of cassava can effect production of shelf-stable and acceptable crisps with and the lowering of cyanide contents to the statutory limit of 10mg/kg. The best results are obtained with boiling for 20 minutes.*

Key words: *Cassava crisps, boiling preprocessing, cyanide content, acceptability*

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I. Introduction

Cassava (Manihot esculenta Crantz) locally known as *muhogo* (Swahili) is a woody shrub native to South America[1]. It is the only edible member of the manihot genus. Cassava has been utilized as food in several forms. The root is boiled and consumed alongside a protein or on its own. It is also dried and milled into flour, to prolong shelf life and increase product diversity[2]. Cassava is also commercially processed into many other products including starch and crisps.

In Kenya, processing of cassava crisps has only recently been initiated[3]. Observations show that processing is mainly concentrated in Nairobi and Mombasa metropolitans, mainly by small-scale processors stationed on the street sides. Recently, a few small-medium cassava crisp processing enterprises have been initiated. Observations also indicate that so far, the main consumers seem to be the Asian communities, although the products are becoming a popular snack by all population and currently compete with the already familiar potato crisps. The crisps from the formal sector are sold in supermarkets and along the streets.

Observations have shown that the cassava processing by both the formal and informal sectors are purchased from the markets as roots of mixed varieties that are not even identifiable by the vendors. The roots for processing seem to be of a definite maximum thickness, probably so that the crisps are within the same diameter as potato crisps.

The limited studies so far carried out indicate that cassava crisps sold in Kenya have levels of cyanide beyond the statutory limit of 10 mg/kg[3]. This would indicate that most of the cassava varieties processed are of the bitter types, so that the basic crisp processing of peeling, cutting, and oil frying does not bring down the levels of cyanide sufficiently to the statutory limits. Even normal consumption of crisps containing higher than the tolerance levels can cause toxicity either acute leading to illness or death, or chronic toxicity leading to short term or long-term health impairment[4]. Studies have shown that chronic cyanide toxicity is associated with exacerbation of the manifestations of iodine deficiency, chiefly goiter and myxedematous cretinism[5,6], and Tropical Ataxic Neuropathy (TAN) and spastic parapalesis also known as Konzo[7,8,9]. The last two conditions have been described as neurological disorders, sometimes irreversible, that damage the nerves affecting steadiness and coordination.

Processing methods have been employed to reduce the level of cyanogenic glycosides in cassava[10]. Some of the widely used methods are soaking the roots in water, drying (both sun and oven), boiling/cooking in water, and fermentation. The effectiveness of cyanide removal varies from method to method depending on the product and convenience of use[11]

Boiling alone is not very effective in reducing cyanide in cassava because the high temperature (100^0C) of boiling quickly denatures the linamarase enzyme, which is supposed to hydrolyse linamarin to cyanohydrins[12, 13]. For bitter cassava therefore, boiling may leave residual cyanide in the cassava, which is well above the tolerable limits[14] . However, the additional reduction in cyanide from boiling and frying may be presumed to be adequate to reduce the levels of the toxin in crisps to the statutory limits. It was for the reason that this study was designed to include parboiling as a preprocessing step in the manufacture of cassava crisps. Boiling presents one of the easier and effective methods to reduce cyanide in cassava crisps because it is simple and does not require specialised equipment. It can also be carried out at whichever level of production: domestic or industrial.

II. Materials And Methods

Raw Materials: The cassava samples used in this study were purchased from three markets in Nairobi namely: Parklands, City, and Wakulima markets. The markets were purposively chosen because they were identified as the main markets where cassava crisps processors source their raw materials. The reagents used in the laboratory analyses were of analytical grade and were obtained from local manufacturers' agents.

Preprocessing preparation of cassava: The raw cassava roots were transported to the Department of Food Science, Nutrition and Technology, University of Nairobi. The roots were cleaned with water to remove mud and dirt. They were peeled and trimmed. The roots were then cut into approximately 10cm pieces and their diameters measured. The pieces from each market, which weighed a total of approximately 2kg, were randomized and divided into four equal batches. The batches represented four treatments of boiling time of 0, 10, 20, and 30 minutes respectively. For boiling, the cassava pieces in each batch were placed in an aluminum pot and 3 liters of clean tap water added. The water was heated to boil, at which point the timing was started. After boiling, the pieces were cooled under cold running water to a temperature of approximately 20^0 C then placed on aluminium foil to await crisping.,

Frying of the crisps: The cassava pieces were sliced to 1 mm thickness and deep-fried at 170 ^{0}C until light golden in color. The cassava crisps were cooled in air, packaged in 7 cm plastic bags (gauge 350), and stored in a cabinet at ambient temperature to await analysis.

III. Analytical Methods

The diameter of the raw cassava pieces was measured in millimeters; the boiled pieces and the crisps were analyzed for moisture and cyanide contents. Additionally the crisps were analyzed for oil contents and evaluated for sensory characteristics and shelf life. The moisture, cyanide, and oil contents were analyzed in duplicates.

Measurement of diameter: The diameters of the raw cassava pieces was measured in millimeters using a Vernier caliper (Electronic Digital Caliper). Two measurements were taken in perpendicular direction of the diagonal and the average calculated.

Determination of moisture content: Moisture was determined according to AOAC[15] official method 935.29. About 5g of the sample, previously crushed to fine homogenous in a mortar with pestle, were accurately weighed on an aluminium moisture dish and placed in a thermostatically controlled air-oven at 105^0C, and dried to constant weight (approximately 5 hours). The loss in weight of the sample was calculated as percent moisture content against the weight of the sample.

Determination of cyanide contents: Cyanide content was determined in the fresh, boiled cassava and crisps by alkaline titration according to AOAC[15] official method 915:03B. About 10g of the sample, previously crushed to fine homogenous in a mortar and pestle, were accurately weighed and placed in a Kjedahltech distillation flask and mixed with 100ml distilled water. The mixture was allowed to stand for atleast 2 hours. The distillation flask was then connected to a distillation system and the distillate collected to the mark in a 200ml volumetric flask containing 25ml of 2.5% sodium hydroxide solution. Then 100ml of the distillate was placed in a 300ml Erlenmeyer flask, 8ml potassium iodide solution added and mixed. The mixture was then titrated against 0.02N silver nitrate solution. The end point is indicated by the appearance of a faint permanent turbidity. .By this method, 1ml titer represents 1.08mg HCN. This relationship was used to calculate the cyanide content of the sample as mg/kg.

Determination of Oil Content of the crisps: The oil content of the crisps was determined by AOAC[16] official method 945.16 by Soxhlet continuous distillation. The crisps were ground in a grinder to a coarse homogenous powder for the analysis. The oil contents were calculated as percent of crisps.

Sensory Evaluation: Sensory evaluation was carried out in the sensory evaluation room of the Department of Food Science, Nutrition, and Technology, University of Nairobi. The panel consisted of 14 members drawn from the students and staff of the Faculty of Agriculture who were familiar with the products. A 7-point hedonic rating scale (1 = dislike very much and 7 = like very much)[17] was used to evaluate the products against the attributes, color, appearance, flavor (odour and taste), crunchiness and overall acceptability. Coded samples were presented to each panelist separately in similar plates at 12:30 Pm. Water was provided in plastic tumblers to rinse mouth before and between testing samples.

Shelf Life Evaluation of Crisps: Accelerated shelf life was done. The crisps from each treatment of 0, 10, 20 and 30 minutes of boiling were packed in 50g quantities in plastic bags (150 microns gauge). The samples were the stored in an air oven at 55^0C. One-day storage at this temperature represents one-month normal storage at 25^0C. A sample from each treatment was drawn from the oven every two days and presented to a panel of six individuals to sniff to detect any off odours and then taste to detect any changes in crunchiness of the product.

Statistical Analysis of Data: Data was subjected to analysis of variance (ANOVA) using GenStat 15th Edition software for statistical analysis at P< 0.05. Least Significant Difference (LSD) test was used to separate different means.

IV. Results And Discussion

Diameter of cassava pieces: The diameter of raw cassava pieces ranged between 5cm and 9cm.Cassava roots of larger size than this were rarely found in the market. Usually cassava roots have been reported to grow to diameters of up to 15cm[18], but such size of cassava was really found in the market. It is possible that the limit of size found in the market was the preferred by the processors as they tried to mimic the size of the potato crisps, or the size of the cassava was delimited by the size of the cutter. The larger size cassava would probably be purchased for roasting as cut strips or chunks, the other products that are commonly but more rarely found selling on the street sides. Sometimes it is not uncommon to find street vendors who deal in crisps and fried or roasted strips or chunks.

Moisture Contents

The distribution of moisture contents by market and boiling time are shown in Table 1, while the same distribution for the crisps is shown in Table 2.

Table 1: Distribution of mean moisture content of boiled cassava chunks by market and boiling time

Market	Boiling time in minutes and corresponding moisture contents (%)			
	0	10	20	30
Parklands	61.96±0.57^a	64.49±6.55^a	67.95±0.44^b	74.31±6.98^c
City market	60.62±1.48^a	64.54±0.10^a	68.03±0.38^b	75.64±10.14^c
Wakulima	61.36±0.21^a	62.15±2.29^a	67.97±2.28^b	70.70±2.33^c
Average	61.32±0.93^a	63.73±3.33^a	67.98±10.05^b	73.55±6.05^c

*Mean±SD (N = 3). Means with different subscripts across a row and down a column are statistically different at p<0.05

As Table 1 shows, the market did not have any significant effect (p<0.05) on the moisture contents of the fresh and boiled cassava chunks. The moisture content of the cassava from the three markets varied between about 61 – 62%. There was no significant difference (p<0.05) between the moisture contents the fresh cassava and those boiled for 10 minutes. Both these moisture contents were significantly lower than the moisture contents of the boiled for 20 and 30 minutes, which were also significantly different from each other. The average moisture contents increased significantly from 61.32% to 73.55% from the raw cassava to that cooked for 30 minutes. The reason for the increase in the moisture content was probably due to the leaching out some dry matter components so that the dry matter content decreased and the cassava was able to accommodate more water. The swelling of starch during boiling could also have led to absorption of more water by the cassava.

The cassava boiled for 30 minutes recorded the highest moisture content and was the softest. This softness presented challenges during slicing due to excessive breakage. The slices were not of uniform size due to the breakage and therefore boiling for 20 minutes was taken as maximum boiling time for ease of slicing to produce good quality crisps.

Table 2: Distribution of mean moisture contents of cassava crisps by market and boiling time

Market	Boiling time (mins) and corresponding moisture contents (%)			
	0	10	20	30
Parklands	3.21±0.01[a]	3.24±0.04[a]	3.41±0.45[a]	3.47±0.08[a]
City market	3.63±0.54[a]	3.61±0.44[a]	3.62±0.23[a]	3.31±0.47[a]
Wakulima	3.21±0.23[a]	3.42±0.52[a]	3.58±0.46[a]	3.63±0.03[a]
Average	3.35±0.34[a]	3.42±0.35[a]	3.53±0.32[a]	3.47±0.25[a]

*Mean±SD (N = 3)
Values with different superscripts across rows and down the column are statistically different at p<0.05

As Table 2 shows market and boiling had no significant (p<0.05) effect on the moisture contents of the crisps. The mean moisture content of the cassava crisps across markets ranged between 3.21% and 3.63%, with average of 3.35%.The mean moisture contents of the crisps across boiling temperatures ranged between 3.24% and 3.62%, with the average across boiling ranging between 3.42% and 3.53%. There was no significant difference (p<0.05) between the average across markets and the averages across the boiling temperatures.

Oil Content

Table 3 shows the oil content of the crisps across markets and across the boiling times. At P< 0.05, there were no significant market and boiling time effects on the oil contents of the crisps. The oil content varied between 18.58% and 25.94%.

Table 3: Distribution of mean oil contents of the crisps by market and boiling time

Market	Boiling time (min) and corresponding oil contents (%)			
	0	10	20	30
Parklands	24.52±0.15[a]	18.58±0.93[a]	26.80±0.64[a]	25.08±5.16[a]
City market	23.27±1.00[a]	22.61±2.93[a]	21.68±0.51	25.94±0.38[a]
Wakulima	22.31±1.95[a]	20.48±1.74[a]	21.59±4.12[a]	22.20±0.51[a]
Average	23.37±1.40[a]	20.56±2.40[a]	23.35±3.26[a]	24.41±2.91[a]

*Mean ± SD (N = 3)
Values with the same superscripts across a row and down a column are not statistically different at p<0.05

Notable is that the oil contents were within the East Africa Standard requirements of not more than 30%[19]. Oil content in crisps is one of the crucial quality indicators as it influences the eating and keeping quality. Process optimization should therefore be done to ensure the oil content is within acceptable limits[20]. When the oil content is too high, the resultant product is soggy and non- appealing. The shelf life is also markedly reduced due to increased propensity to develop off flavors due to oxidative rancidity[21]. Increased awareness on lifestyle-associated diseases has also led to consumers demanding for products that are not too oily, which increases energy intake. Therefore, for a product to compete effectively in the market, the processor has to ensure that the oil content is within acceptable limits. On the other hand, very low oil content also results in hard crisps, which are non- appealing to the consumer. Therefore, any pre-processing method should not negatively affect the oil content of the resultant crisps.

Cyanide Content

The mean cyanide contents of boiled cassava pieces are shown in Table 4. Market had no significant effects on the cyanide contents, but boiling had significant effects on the cyanide contents (p<0.05). All the fresh cassava roots contained cyanide levels slightly above 50mg/ kg, the boundary value between sweet and bitter cassava. The highest mean cyanide content was 59.4mg/kg in cassava from City Market and the lowest 54.54mg/kg in cassava from Wakulima Market.

Boiling rapidly lowered the cyanide contents. At P < 0.05, there was significant difference in the cyanide contents from different boiling times. Boiling for 30 minutes resulted in the highest cyanide reduction. There was no significant difference in the cyanide contents of the roots from different markets

Table 4: Distribution of mean cyanide contents of cassava chunks by market and boiling time

Market	Boiling time (min) and corresponding cyanide contents(mg/kg)			
	0	10	30	20
Parklands	56.70 ± 3.82^{a}	21.6 ± 3.06^{b}	13.50 ± 3.82^{c}	15.12 ± 4.58^{b}
City Market	59.40 ± 1.53^{a}	15.66 ± 0.76^{b}	14.04 ± 1.53^{c}	15.12 ± 1.53^{b}
Wakulima	54.54 ± 2.29^{a}	16.20 ± 1.53^{b}	11.88 ± 1.53^{c}	12.96 ± 0.00^{c}
Average	56.88 ± 3.03^{a}	17.82 ± 3.33^{b}	13.14 ± 2.21^{c}	14.40 ± 2.43^{bc}

*Mean ±SD (N = 3)
Values with different letters across a row and along a column are statistically different at $p<0.05$

The results indicate that boiling significantly reduces cyanide in cassava. This agrees with study by Nambisan[13]. However to increase the efficiency of boiling as a method of cyanide reduction, the cassava size should be reduced. Water volume is also a crucial factor. In the study, it was reported that water should be fivefold to reduce the retention to at least 24%.

The mean cyanide contents of the crisps from the three markets and boiling for 0, 10, 20 and 30 minutes are shown in Table 5. The mean cyanide contents of the crisps from the unboiled cassava fell by 41.1% from 56.88 mg/kg to 33.48mg/kg. The mean cyanide level of the crisps remained above the tolerable level of 10mg/kg.

Table 5: Distribution of mean cyanide contents of the crisps by market and boiling time

Market	Boiling time (mins) and corresponding cyanide content(mg/kg)			
	0	10	20	30
Parklands	31.86 ± 0.76^{a}	9.72 ± 1.53^{b}	9.18 ± 0.76^{b}	5.94 ± 2.29^{c}
City Market	34.02 ± 0.76^{a}	9.72 ± 0.00^{b}	9.72 ± 1.53^{b}	5.40 ± 0.00^{c}
Wakulima	34.56 ± 1.53^{a}	11.34 ± 0.76^{b}	9.18 ± 0.76^{b}	5.40 ± 1.53^{c}
Average	33.48 ± 1.53^{a}	10.26 ± 1.13^{b}	9.36 ± 0.88^{b}	5.58 ± 1.26^{c}

*Mean ± SD (N = 3)
Values with different superscripts across a row and down a column for an attribute are statistically different at $p<0.05$

The overall mean cyanide contents over markets dropped drastically due to boiling for 10, 20, and 30 minutes to 10.26, 9.36, and 5.58 mg/kg respectively. At $P< 0.05$, there was significant difference between the boiling times. However, there was no significant difference between boiling for 10 and 20 minutes, which were significantly different from 30 minutes. All the samples boiled for 20 and 30 minutes had cyanide levels below 10mg/kg while 10 minutes boil had some samples slightly above 10mg/kg. It can therefore be concluded that boiling the cassava for 20– 30 minutes results in levels of cyanide, which are within the tolerable limits by law.

Sensory attributes

The sensory attributes scores of the crisps are shown in Table 6. For sensory evaluation, the crisp from each market with the same boiling time were combined. This was possible because market was found to have no significant ($p< 0.05$) effect on all characteristics studied.

As Table 6 shows, all the crisps from all boiling times were acceptable in all attributes (scores more than 4). However, the crisps from the raw cassava were not acceptable in the attributes of color and appearance, and only borderline scores in flavor and overall acceptance. The score of the crisps on crunchiness was however, not significantly different from the scores of the same attribute of the boiled crisps, showing that boiling does not influence the attribute. Boiling produced acceptable crisps in all the attributes tested, and there was no significant difference ($p < 0.05$) in all attributes within the same boiling time.

Table 6: Distribution of means of sensory attribute scores by boiling time

Boiling time (minutes)	Sensory Attributes				
	Appearance	Colour	Crunchiness	Flavor	Overall acceptability
0	3.64 ± 2.17^{a}	3.86 ± 1.61^{a}	5.29 ± 1.14^{ab}	4.07 ± 1.77^{ab}	4.29 ± 0.99^{a}
10	5.79 ± 1.58^{b}	5.50 ± 1.45^{bc}	5.36 ± 1.69^{ab}	5.07 ± 1.27^{bc}	5.57 ± 1.22^{bc}
20	5.93 ± 0.62^{b}	6.21 ± 0.80^{c}	6.43 ± 0.65^{c}	6.29 ± 0.73^{d}	6.14 ± 0.95^{c}
30	5.36 ± 1.50^{b}	5.71 ± 1.38^{c}	6.14 ± 0.95^{bc}	6.14 ± 1.10^{d}	6.07 ± 0.73^{c}

*Mean ±SD (N = 14)
Values with different superscripts along a column or row are statistically different at $p<0.05$.

The crisps from the parboiled cassava were more preferred in all the attributes. The 20-minute boil scored highest for overall acceptability with a mean of 6.14. The panelists indicated that the crisps from the boiled cassava had a nice golden colour that was even throughout the surface. This is attributable to the fact that boiling hydrolyses some starch to produce some reducing sugars that participate in the browning during frying[22]. The 30-minute boil cassava presented a challenge during crisping whereby the cassava had become difficult to slice so that most of the slices got broken and thus were not fully round. In fact, the panelists described these crisps as too broken.

The crisps from the raw unboiled cassava scored poorly in appearance and colour due to the formation of a dark brown ring on the edges and panelists found this unappealing. The surface immediately below the peel is known to contain much higher cyanogenetic glycoside contents, which decreases into the flesh[23]. The high temperature of the frying oil and the water in the fresh cassava may have caused hydrolysis of the cyanogen releasing the sugar, which caramelized to deepen the color of the rind more than the general surface of the crisp. The crisps also had some bitter taste, and this is due to the significantly higher levels of cyanide as shown in Table 4. This was also regarded as a negative attribute and lead to a poor score for flavor.

Shelf life evaluation

About shelf life evaluation by accelerated method, none of the panelists detected any off flavors until the 12th day of storage, when three panelists could detect some off odours from two to three of the four samples for each panelist. The off odour was characteristically indicative of rancidity due to fat autoxidation. One day under this kind of rancidity represents 1 month of storage at 25 ^{o}C. It can therefore be concluded with a high degree of assurance that the crisps will have a shelf life of 10 moths at this temperature. .

During frying, crisps absorb considerable amounts of fat as shown in Table 3. The oil content can be as high as 35%[24]. During storage, there is fat oxidation mainly due to the presence of oxygen entrapped if the package is not evacuated, or from permeability into the package[21]. The oxidation produces volatile compounds that are detected as off flavours. This is an indicator of product quality deterioration.

After storage for 10 months equivalent, the crunchiness of the crisps had slightly decreased but not to levels that made them unacceptable. The frying process also results into rapid moisture loss[25]. This is also shown in Tables 1 and 2. Moisture content is a paramount determinant of shelf life. High moisture levels lead to faster rate of quality loss including loss of sensory attributes of crunchiness. Crisps are usually hygroscopic because of the low moisture content. They can therefore absorb moisture from the atmosphere if the package is permeable to water, thereby reducing crunchiness. It is therefore, important to select packages with low moisture permeability in order to ensure long shelf life of the crisps.

V. Conclusion

It is possible to produce crisps with cyanide contents below the statutory maximum level of 10mg/kg by parboiling cut cassava chunks. Boiling for 20 minutes produces the best results also in terms of the moisture and oil contents and the acceptability of the crisps. The crisps can be stored for up to 10 months without detectable change in organoleptic quality.

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