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CASSAVA CHIPS QUALITY AS INFLUENCED BY CULTIVAR, BLANCHING TIME AND SLICE THICKNESS

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ABSTRACT

Cassava forms part of diets in Kenya with both the roots and leaves being consumed as food. The short shelf-life of 72 hours and cyanogenic glucosides limit the extent of utilization. Currently, fried cassava chips and crisps are increasingly being consumed as snacks; and fried cassava chips are produced by street processors. The quality and safety of these products is not known, therefore, the current study was to establish the influence of cassava cultivar, blanching time and slice thickness on quality of fried cassava chips. Moisture, vitamin C and cyanide content in the raw cassava cultivars were determined before processing. The three raw cassava cultivars coded as MH95/0183, MM96/2480 and Fumba chai were washed, peeled and sliced into thickness of 6 mm, 10 mm and 20 mm. Equal groups of the slices were blanched at 95^0C for 0 minutes, 5 minutes and 10 minutes each and then subjected to frying temperature of 170^0C. The physico-chemical and sensory properties of fried cassava chips were determined. Dry matter content, vitamin C content and cyanide levels significantly ($p < 0.05$) differed among the three raw cultivars except in MH95/0183 and MM96/2480. A strong positive relationship ($r = 0.98$) existed between moisture and cyanide contents in the raw cultivars. Mean cyanide levels in the three roots was: 37.04 mg/kg, 16.37 mg/kg and 48.48 mg/kg in MH95/0183, MM96/2480 and Fumba chai, respectively. Dry matter content was 36.79 %, 37.69 % and 30.42 % in MH95/0183, MM96/2480 and Fumba chai. The physico-chemical and sensory properties significantly ($p < 0.05$) differed within and across the cultivars as affected by processing conditions. Mean cyanide range was 1.4 - 11 mg/kg, oil content ranged 3.78 - 18.48 % and vitamin C content ranged 7.59 - 50.48 mg/100 g. Significant ($p < 0.05$) relationship ($r = 0.707$) existed between slice thickness and the redness color parameter. Cultivar, slice thickness and blanching time form important yardsticks in processing fried cassava chips. Proper choice of these parameters is, therefore, important in processing quality and safe cassava fries. Slice thickness of 6 mm combined with long blanching time of 10 minutes result in fried cassava chips with low and acceptable cyanide content as well as satisfactory consumer preference based on color, texture, oiliness and overall acceptability.

Key words: cyanide, quality, cassava, slice thickness, cultivar, blanching, consumer preference

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INTRODUCTION

Cassava (*Manihot esculenta)* is an herbaceous perennial food crop of the low land tropics [1, 2, 3, 4] and is a major component of diets in Kenya. The two major varieties grown are sweet and bitter varieties [5, 6] which are classified on the basis of the cyanogenic glucosides (Linamarin and Lotaustralin) contents of their roots and leaves [7, 8].

In traditional Kenyan society, both the roots and the leaves are used as food, the roots are consumed as fresh boiled or roasted and in some cases dried and used in flour mixes for porridge and *ugali* (stiff porridge), while the leaves are used as vegetable [9]. Currently, cassava crisps and fried chips are popularly consumed as snack in the coastal region of Kenya [10].

Slight variation in the nutritional quality of the root is notable [11]; the root hydrocyanide content ranges from 1-1550 ppm [12] with sweet varieties having hydrocyanide values less than 50 ppm while bitter varieties have values as high as 100 ppm [6]. Cassava roots contain 62.5 % water, 34.7 % starch [13], 1.2 % protein [14], 0.3 % fat, and 36 mg/100 g of vitamin C while the leaves contain 80.5 % water, 9.6 % starch, 6.8 % protein, 1.3 % fat and 265 mg/100 g vitamin C [15]. Significant amounts of iron, phosphorous and calcium are also contained in the root [16]. Blanching reduces the cyanide levels by about 54 % [12]. It also washes off surface bound sugars and serves to even out variations of sugar concentrations at the surface of chips: this is vital in development of lighter and more uniform color on frying [17] thereby enhancing the overall acceptability of the fried chips. Blanched chips are less hardy and need remarkably less force (5.89 N) to break [17]. During frying, the hot cooking oil replaces the free moisture in the chips as they cook, and is dependent on chip thickness, frying temperature and cultivar. Moisture content in fried potato chips ranges from 25.3 % to 55.1 % and the percent fat is in the range of 11.1 % to 22.3 % [18].

Utilization of cassava is compromised by its toxic hydrogen cyanide and short shelf-life of 72 hours post-harvest [19, 20]. Increased promotion of cassava value addition has resulted in street chips producers in Mombasa and Nairobi counties; however, the product quality and safety are unknown. To advise the processing industry accordingly, it is essential to evaluate the suitability of various cassava cultivars for processing. The objective of this study was to determine quality of fried cassava chips obtained from selected Kenyan cultivars MH95/0183, MM96/2480 and Fumba chai as influenced by processing conditions of blanching time and slice thickness.

MATERIALS AND METHODS

Raw materials

Fresh cassava root cultivars coded as MH95/0183, MM96/2480 and Fumba chai were collected from Kenya Agricultural and Livestock Research Organization (KALRO) Kakamega, and transported to University of Nairobi, Department of Food Science, Nutrition and Technology for analysis. Color and texture of the fried chips was determined at Jomo Kenyatta University of Agriculture and Technology (JKUAT), Department of Food Science and Technology.

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Experimental design

A pre-test – post-test control experimental design consisting of 3 slice thicknesses of 6 mm by 6 mm, 10 mm by 10 mm, and 20 mm by 20 mm commonly used by street processors in Nairobi and Mombasa counties; 2 blanching times at 95°C (5 mins and 10 mins) based on the capacity of the blancher at disposal at the time of the experiment and 3 purposively selected cassava cultivars MH95/0183, MM96/2480 and Fumba chai were used.

Pre-processing operations

The collected cassava cultivars were washed thoroughly with clean water, peeled and then manually sliced to thicknesses of 6 mm by 6 mm, 10 mm by 10 mm and 20 mm by 20 mm in readiness for blanching and then fried.

Determination of moisture content

Moisture content in the raw cassava root cultivars and fried cassava chips was determined as per AOAC [21], Official method 935.29 by drying 5 g of the sample in air oven at 105°C for 5 hrs.

Determination of cyanide content

Cyanide (HCN) content in the fresh and fried samples of cassava chips was determined by alkaline titration method as described by AOAC [21], official method 915.03B.

Determination of vitamin C content

Approximately 2 g of each sample was extracted and stabilised with 25 mls of TCA (trichloro-acetic acid) then titrated using 0.001 N N-Bromosuciinamide and starch as indicator [23]. Titre volume of N-Bromosuciinamide was then used in calculation to determine vitamin C using the formula

V*C*(176/178)*100/weight of the sample = mg/100 g of Vitamin C, where V is titre volume, and C is Bromosuciinamide concentration.

Determination of oil content

Fried cassava chips were grated and duplicate 2.5 g samples were put into thimbles, 8-hr Soxhlet extraction was conducted using analytical grade petroleum ether (boiling point 40-60°C), described by AOAC [22] official method 945.16.

Color measurement

Fries color was measured using a color spectrophotometer (NF 333, Nippon Denshoku, Japan) using the CIE Lab L*, a* and b* color scale [23].

Texture measurement

Texture measurement was performed by a puncture test using a Texture Analyzer (Sun rheometer Compac 100, Sun scientific Co. Ltd, Japan) equipped with a wedge probe imitating front teeth [23].

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Blanching

The pre-processed clean peeled drain dried slices were then grouped equally into 3 batches for steam blanching at 95°C for 0 minutes, 5 min and 10 min (for the 3 batches) using the pilot plant blancher at the Department of Food Science, Nutrition and Technology, University of Nairobi. The blanched slices were then dried to remove free water before frying [17].

Frying

Before frying, the liquid Rina vegetable oil from Pwani Oil Industries (the oil at disposal at the time of frying) was heated for about 10 mins until the required temperature of 170°C, was reached. Each blanched batch of slices was then deep fried until the bubbling ceased as described by Elfnesh *et al.* [17].

Sensory evaluation

The sensory evaluation test was conducted at the Department of Food Science, Nutrition and Technology, University of Nairobi, sensory evaluation laboratory. Ten experienced panelists consisting of students, and faculty staff of the University were selected to rate the quality attributes. A seven - point hedonic scale was used to rate flavor (bitterness), color, texture, oiliness and overall acceptability. Coded samples were presented to each panelist separately in similar glass plates at 4.00 pm. Water was provided to the panelists to rinse their mouth before and between testing samples [17].

Data analysis

Analysis of variance (ANOVA) and least significant difference test for the variables was conducted using GenStat 15th Edition software for statistical analysis ($p < 0.05$). Correlation analysis was performed by IBM SPSS statistics 20 software to determine linear relationship ($p < 0.01$ and $p < 0.05$) between: objective color measurements and color likeness by sensory panelists, oil content measured and the oiliness perceived by sensory panelists, texture as perceived by sensory panelists and the machine texture determination and the association between moisture content and treatment of slice thickness and blanching time.

RESULTS

Cyanide, vitamin C and dry matter content of raw cassava roots

Table 1 shows the mean values and standard deviations of dry matter content, cyanide levels and vitamin C obtained from the three cassava root cultivars. Fumba chai had the lowest dry matter content of 30.32 % and highest cyanide content of 48.48 mg/kg, whereas MM96/2480 had the highest dry matter content of 37.69 % and lowest mean cyanide content of 16.37 mg/kg. MH95/0183 had the lowest vitamin C content of 73.10 mg/100 g and MM96/2480 had the highest vitamin C content of 136.11 mg/100 g. Dry matter content recorded insignificant difference ($p < 0.05$) between MH95/0183 and MM96/2480, but, these values differed significantly ($p < 0.05$) from those of Fumba chai. There was insignificant difference ($p > 0.05$) in vitamin C. Cyanide differed significantly ($p < 0.05$) among the three raw cassava root cultivars.

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Raw roots Moisture content, Cyanide and vitamin C correlation

Table 2 indicates the Pearson correlation values between moisture, cyanide and vitamin C contents in the raw cassava roots. There was a significant ($p < 0.01$) strong positive relationship between moisture content and cyanide content ($r = 0.98$). A weak positive relationship existed between cyanide and vitamin C contents ($r = 0.390$).

Moisture and cyanide contents of fried cassava chips

Table 3 indicates the influence of cultivar, blanching time and slice thickness on both moisture and cyanide content. MH95/0183 blanched for 10 minutes and with a slice thickness of 6 mm had the lowest moisture content of 10.09 % while Fumba chai, unblanched (zero minutes) with slice thickness of 20 mm, had the highest moisture content of 40.74 %. Both slice thickness and blanching time showed significant ($p < 0.05$) effect on moisture content.

Most of the chips' moisture content differed significantly ($p < 0.05$) across the column except Fumba chai blanched for 5 mins and slice thickness of 6 mm, and MM96/2480 blanched for 10 minutes and 6 mm slice thickness. Fumba chai of zero minutes blanching and 6 mm thickness insignificantly ($p > 0.05$) differed from MM96/2480 of 5 minutes blanching and 6 mm thickness.

Fumba chai blanched for 10 minutes with a slice thickness of 6 mm had the lowest cyanide content of 1.41 mg/kg, while MH95/0183 at zero minutes blanching and 20 mm slice thickness had the highest cyanide content of 11.51 mg/kg. Within cultivars, the mean cyanide content differed significantly ($p < 0.05$) as affected by both blanching time and slice thickness. Across the cultivars some insignificant variations were registered ($p < 0.05$) and this can be attributed to the variations in initial moisture and cyanide content in the raw cassava root cultivars.

Vitamin C and oil contents of fried cassava chips

Vitamin C and oil contents of the fried cassava chips as influenced by blanching time and slice thickness from MH95/0183, MM96/2480 and Fumba chai are shown in table 4. Fumba chai with slice thickness of 20 mm and 10 minutes blanching had the lowest mean oil content of 3.78 %, while unblanched 6mm thick Fumba chai had the highest mean oil content of 18.48 %. Fumba chai blanched for 10 minutes and slice thickness of 6 mm had the lowest amount of vitamin C of 7.59 mg/100 g. MM96/2480 at 0 minutes blanching and thickness of 10 mm had the highest amount of 50.48 mg/100 g vitamin C. Significant differences ($p < 0.05$) were observed within the cultivar and across the cultivars for both vitamin C and oil content. The influence of blanching time and slice thickness on the physico-chemical properties in relation to each other is indicated in table 5.

Slice thickness had a significant ($p < 0.01$) strong positive relationship to moisture content, cyanide content and vitamin C. On the other hand, it showed a significant ($p < 0.01$) strong negative association to the oil content ($r = - 0.608$). Moisture and cyanide contents had a significant ($p < 0.01$) positive relationship ($r = 0.606$) and this was also observable in the raw cassava root cultivars. Vitamin C showed a significant ($p < 0.01$) positive relationship to moisture content ($r = 0.764$). Similarly, cyanide showed

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significant ($p < 0.01$) relationship to blanching time ($r = -0.783$) and slice thickness ($r = 0.419$). Oil content had a significant ($p < 0.01$) negative association to moisture content ($r = - 0.361$).

Fried cassava chips texture and color
Mean values and standard deviation of the fried cassava chips textural response and color parameters measured is tabulated in table 6.

MM96/2480 blanched for 10 minutes and thickness of 20 mm showed less resistance to penetrating force with a force of 1.365 N while MH95/0183 at zero minutes blanching and 6 mm thickness showed the highest resistance with a force of 5.67 N. Significant differences ($p < 0.05$) are noted in the hardness of chips with little insignificant variations across cultivars.

Chips with thin slice thickness and long blanching time showed high L* (lightness color) values which tended to white color as opposed to thicker slices. Fumba chai 20 mm and blanching at zero minutes had the lowest L* value of 44.33, while MM96/2480 10 mm thick and 10 minutes blanching had the highest value of 77.2. Similarly, the a* (redness factor) values were affected, Fumba chai 6mm thick and 5 minutes blanching had the lowest a* value of 0.46 while Fumba chai 20 mm thick and 0 minutes blanching had the highest a*value of 10.9. b* (yellowness factor) mean values followed similar trends as the L* and a* mean values. Significant ($p < 0.05$) differences occurred within and across the cultivars for all the lightness, redness and yellowness color parameter indicators.

Organoleptic properties of the fried cassava chips
The organoleptic properties of flavor, color, texture and overall acceptability that have a close association with the physico-chemical properties are also affected as indicated by results in Table 7.

The fried cassava chips differed significantly ($p < 0.05$) in terms of color, texture, oiliness and overall acceptability. MM96/2480 6 mm thick and 10 minutes blanching (*C2, 10, 6*) had the most preferred color, texture, oiliness and overall acceptability. Thick unblanched chips received little preference, MM96/2480 20 mm thick and zero minutes blanching (*C2,0,20*) had the least likeness in terms of oiliness and overall acceptability, and MH95/0183 20 mm and zero minutes blanching (*C1,0,20*) had the least preference to color.

A significant ($p < 0.05$) positive relationship ($r = 0.449$) existed between color perceived by consumer and the L* color parameter**.** Similarly, a significant ($p < 0.05$) negative association ($r = - 0.449$) occurred between a* color parameter and the consumer perceived color. Consumer preference to the fried cassava chips decreased with the increase in oil content ($r = - 0.255$). A very weak positive insignificant association ($r = 0.047$) was observed between the measured texture and consumer perceived texture preference.

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DISCUSSION

Dry mater, cyanide and vitamin C content in the raw cassava root cultivars

Mean dry matter content was in the range of 30 % to 38 %, vitamin C in the range of 73 mg/100 g to 136 mg/100 g and cyanide content in the range of 16 mg/kg to 49 mg/kg in the three raw cassava roots. The observed cyanide contents in the raw cassava roots are similar to findings by Nweke *et al*. [15] and below the 50 mg/kg recommended in sweet varieties [6]. Significant amounts of vitamin C was detected in the three raw cassava roots [16]. Despite being grown in the same place, the inherent genetic composition of the cultivars expressed themselves as noted by significant ($p < 0.05$) variations in dry matter content, cyanide content and vitamin C content except between MH95/0183 and MM96/2480 that showed insignificant variations in their dry matter and cyanide composition as indicated in table 1.

A strong positive relationship ($r = 0.98$) which was significant ($p < 0.01$) between moisture content and cyanide content in raw cassava cultivars is attributed to solubility of hydrocyanide acid in water [15], and also explains why Fumba chai had the highest moisture content corresponding to high cyanide levels. Even though vitamin C is water soluble, its levels is independent of moisture content and apparent to cultivar as explained by MM96/2480 that had the lowest moisture content but recorded the highest levels of vitamin C.

Cyanide and moisture content of fried cassava chips influenced by blanching and slice thickness

The mean moisture content of fried cassava chips from the three cultivars was in the range of 10- 35 % which partially concur to the mean moisture content of potato chips reported by Sherri *et al.* [18]. The moisture content of fried cassava chips with 6 mm thickness and 10 minutes blanching time were below the range of 25.3 % to 55.1 % reported by Sherri *et al*. [18] which was moisture content from potato chips with blanching time and slice thickness treatments unreported.

Even though the chips from the three cultivars differed significantly ($p < 0.05$), slice thickness greatly influenced this as indicated by a strong positive relationship ($r = 0.737$) between moisture content and slice thickness. Cyanide that is bound within the water phase of the tissues responded in a similar way with a significant ($p < 0.01$) strong negative relationship ($r = - 0.783$) to blanching time.

Increased blanching time from zero minutes to 10 minutes increased the amount of heat energy absorbed from the hot blanching water, the absorbed energy aided in disruption of the intact tissue at longer blanching time [12, 24]. More exudation of water from disrupted tissues occurs: the water then diffuses to the blanching media at a rate that is dependent on the diffusion distance explained by the slice thickness. The heat and mass transfer that occurs during deep fat processing that results in water vaporization also contributes positively to the negative correlation observed [25]. Vaporization results in collapse of tissue through loss of other chemical constituents in the vaporized water [17]. Chopping into slices and blanching also detoxified the chips of cyanide [12]. Most of the

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fried cassava chips had cyanide levels less than 10 mg/kg, which is the recommended level for safe consumable products by food standards code.

Effect of blanching and slice thickness on Oil and vitamin C contents of fried cassava chips

Oil content in fried cassava chips was in the range of 4 – 20 % with 70 % of the mean values within the range of 11.1 - 22.35 % fat content of potato chips reported by Sherri *et al.* [18]. Slices that were 20 mm thick had the lowest oil uptake below 11 %. The variation is explained by differences in genetic composition between cassava and potato.

Frying time, food surface area (slice thickness), moisture content of food explained by significant relationship between oil content and moisture content (r = - 0.361) and frying oil influenced the amount of absorbed oil in the chips [26]. Fried foods at optimum frying temperature and time have optimal oil absorption [27] as observed in most of the fried cassava chips.

Disruption and collapse of tissue resulting from increased heat energy from hot blanching water with time, reduced the tissues resistance to oil ingression [17]. Larger slice thicknesses (long penetration distance) offers more resistance to oil ingression into the interior and consequently low oil content in fried chips of 20 mm thick.

Vitamin C is heat sensitive and thus showed a significant ($p < 0.01$) inverse relationship (r = -0.478) to blanching time. Mass transfer resulting from both blanching and frying temperature but dependent on slice thickness, contributes to loss of water soluble vitamin C through vaporization in combination of other chemical constituents as the tissues collapse [17, 25].

Texture and Color of fried cassava chips

Resistance to oil ingression into the interior offered by the larger slice thickness of 20 mm resulted in overheating at the chips surface only and consequently less hardy texture within the interior indicated by the significant ($p < 0.05$) negative correlation to the texture by slice thickness (r = - 0.482). Similarly, blanching collapses the tissues prior to frying shown by a significant ($p < 0.01$) inverse relationship (r = - 0.579) to fried chips texture [17]. Most of the mean texture values are less than the ones reported by Elfnesh *et al*. [17], since their chips only had a single slice thickness at a single blanching time.

Unblanched chips with large slice thickness of 20 mm had L* values that tended towards the dark tan color observed in potato chips [17]. As the slice thickness increased, the resistance to oil ingression into the interior of the chips during frying increased, frying oil temperature in combination to the resistance by large slice thickness resulted in overheating on the chips surface and consequently darkening of the chips at the surface. There was a significant ($p < 0.05$) positive correlation of slice thickness to the redness value a* (r = 0.707). Blanching washed off surface sugars and served to even out variations of sugar concentrations at the surface of cassava chips. Consequently, an observed development of lighter and more uniform color on frying indicated by a significant ($p < 0.01$) positive correlation between blanching time (r = 0.671) and the

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mean L* values indicator for lightness color parameter. Blanching also reduces the formation probability of carcinogenic acrylamide in potato chips during frying [28].

Sensory properties of fried cassava chips

Sensory properties of color, texture, oiliness and overall acceptability significantly ($p < 0.05$) differed across the cultivars. Consumer fried cassava chips preference significantly ($r = 0.463$) increased as the lightness color parameter tended towards white color. Dark tan color originating from large slice thickness and non-blanching pre-treatments [28] with high a* values, significantly ($p < 0.05$) impacted negatively ($r = - 0.449$) on consumer color preference.

Oil content and consumer perception of the fried cassava chips oiliness are negatively correlated ($r = - 0.225$). Tissue collapse dependent on blanching time and slice thickness subsequently impacted on moisture content and the surface area that are key factors influencing hot oil ingress during frying [26]. Oil content insignificantly ($p < 0.05$) influenced consumer oiliness perception of the chips. Nevertheless, slight difference was detectable with reduced likeness as oil content of the chips increased.

Fried cassava chips texture difference was not significantly detectable by the consumers, shown by a weak relationship ($r = 0.047$) between the objective texture measurement and the sensory texture perception. Color, texture and oiliness preference increased as the L* values for lightness color tended to white. It was the thin slices at longer blanching time that had higher L* values implying optimal oil absorption and desirable quality of fried cassava chips [17, 29]. The redness color parameter, a* values negatively influenced consumer preference for color, texture and oiliness. Large chips slices which were unblanched had low lightness color values that tended to dark tan and a corresponding high a***** values [28]. This was detectable by consumer panelists that showed a negative response in preference of the unblanched large sliced fried cassava chips.

CONCLUSION

Dry matter, cyanide and vitamin C content in raw cassava roots significantly vary with cultivar. Blanching time and slice thickness collapse the tissue and influence the surface area for mass transfer during frying contributing significantly to enhanced fried cassava chips quality. Destruction of cyanogenic glucosides and leaching of surface sugars that are implicated in off flavor and color is also achieved. Consumers also responded positively to sensory properties of the thin blanched fried cassava chips. Large slice thickness of 20 mm, which is used mainly by current processors gave undesirable fried cassava chips quality, on the other hand blanching time of 10 minutes on 6 mm chips thickness produced preferred fried cassava chips with satisfactory safety based on low cyanide levels. Therefore, it is essential to incorporate blanching and slice thickness on various cassava cultivars as a yardstick for quality development and maintenance.

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Table 1: Dry matter content, cyanide levels and vitamin C in raw cassava root from MH95/0183, MM96/2480 and Fumba chai

Cultivar	Dry matter content (%)	Vitamin C (mg/100g) DMB	Cyanide content (mg/kg) DMB
MH95/0183	36.79±0.85b	73.10±6.45 a	37.04± 0.424b
MM96/2480	37.69±0.45b	136.11±2.86 a	16.37± 3.26 a
Fumba chai	30.32±0.49 a	105.80±2.84 a	48.48±0.431c

1. Values are means of three determinations ± standard deviation
2. Values with the same letters on the same column are not significantly different at 5% level of significance

DMB-dry matter basis

Table 2: Pearson correlation between moisture, cyanide and vitamin C contents in the raw cassava root cultivars

Parameters	Moisture content (%)	Cyanide content (mg/kg)	Vitamin C content (mg/100g)
Moisture content	1	0.98**	-0.353
Cyanide content	0.98**	1	0.390
Vitamin C content	-0.353	0.390	1

N=9; ** correlation is significant at 0.01 level (2-tailed)

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Table 3: Moisture and cyanide contents of fried cassava chips as influenced by cultivar, slice thickness and blanching time

Cultivar	Blanching time	Slice thickness	Moisture content (%)	Cyanide content (mg/Kg)
MH95/0183	0mins	6mm	16.71±0.82 b	6.12±0.001 gh
		10mm	32.88±2.55 ghijk	6.90±0.86 h
		20mm	40.45±1.29 lm	11.51±0.66j
	5mins	6mm	10.38±0.78 a	5.67± 0.19efgh
		10mm	29.38±2.65 fgh	5.49±0.24efgh
		20mm	34.67±0.74 ghijkl	5.39±0.07efgh
	10mins	6mm	10.09±0.22 a	2.13±0.01ab
		10mm	23.29±2.45 cde	4.21±0.04cdef
		20mm	28.85±3.95 efg	4.42±0.16 cdef
MM96/2480	0mins	6mm	26.20±2.02 def	6.79±0.07 h
		10mm	35.73±1.69 ijklm	9.95±0.78ij
		20mm	37.67±0.08 klm	11.25±0.23j
	5mins	6mm	22.70± 0.54 cd	3.97±0.02cde
		10mm	31.41±0.24 fghij	5.22±0.11efgh
		20mm	34.82±0.87 hijkl	6.25±0.0.049h
	10mins	6mm	21.66±0.58 bcd	3.12±0.023 abc
		10mm	30.37±0.19 fghij	4.23±0.02 cdef
		20mm	32.91±0.65 ghijk	5.10±0.01 defgh
Fumba chai	0mins	6mm	22.96±0.85 cde	5.87± 0.66 fgh
		10mm	34.92±0.60hijklm	6.81±0.78 h
		20mm	40.74±0.43 m	8.91±0.26 i
	5mins	6mm	20.95±0.38 bcd	3.20±0.01abc
		10mm	32.88±1.33 ghijk	4.21±0.08 cdef
		20mm	35.83±2.10 jklm	6.81±0.80 h
	10mins	6mm	17.91±0.44 bc	1.41±0.47a
		10mm	29.86±0.33 fghi	3.38±0.22 bcd
		20mm	32.08±0.48 fghijk	2.65±0.73 abc

1. Values are means of two determinations ± standard deviation
2. Values with the same letter in the same column are not significantly different at 5% level of significance

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Table 4: Effect of blanching time, slice thickness and cultivar on Oil content and vitamin C content of fried cassava chips

Cultivar	Blanching time	Slice thickness	Oil content (%)	Vitamin C (mg/100g)
MH95/0183	0 mins	6mm	18.29±0.12 q	13.26±0.34abcd
		10mm	16.19±0.56 p	27.02±2.77 klmn
		20mm	15.84±0.91 p	28.44±0.65 lmno
	5mins	6mm	15.67±0.07op	10.91±0.58 abc
		10mm	15.07±0.5mn	15.39±1.07 cdef
		20mm	7.60±0.14 e	23.13±2.72 hijkl
	10mins	6mm	11.25±0.19 hi	8.88±0.45 ab
		10mm	10.81±0.35gh	13.31±0.46abcd
		20mm	4.82±0.09 b	18.36±2.04defghi
MM96/2480	0mins	6mm	15.21±0.04no	22.12±0.42 ghijk
		10mm	13.70±0.20 k	50.48±2.00 p
		20mm	12.37±0.63 j	33.28±0.23 o
	5mins	6mm	13.75±0.14 k	16.84±0.01 cdefg
		10mm	10.53±0.56 g	30.92±0.86 mno
		20mm	5.86±0.28 c	31.73± 0.94 no
	10mins	6mm	11.48±0.35 i	14.85±0.99 bcdef
		10mm	7.31±0.63 de	19.49±1.77efghij
		20mm	4.47±0.08 b	23.91± 0.72 ijkl
Fumba chai	0mins	6mm	18.48±0.13 q	13.64±0.93 bcde
		10mm	12.59±0.03 j	24.48±2.64 jkl
		20mm	10.91±0.17gh	28.84±0.46 lmno
	5mins	6mm	14.57±0.27lm	9.36±0.71 ab
		10mm	7.38±0.11 de	20.17±0.45 fghij
		20mm	8.54±0.08 f	25.33±1.19 jklm
	10mins	6mm	14.11±0.18 kl	7.59±0.47 a
		10mm	7.52±0.55 d	17.26±1.58 defgh
		20mm	3.78±0.30 a	20.64±0.73 fghij

1. Values are means of two determinations ± standard deviation.
2. Values with same letter in a column are significantly indifferent at 5% level

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Table 5: Correlation between slice thickness, blanching time and physico-chemical properties of cassava chips

	Moisture content (%)	Cyanide content (g/kg)	Oil content (%)	Vitamin C content (mg/100g)
Thickness (mm)	0.737**	0.419**	-0.608**	0.496**
Blanching (mins)	-0.337*	-0.783**	-0.634**	-0.478**
Moisture (%)	1	0.606**	-0.361**	0.764**
Cyanide (g/kg)	0.606**	1	0.299*	0.728**
Oil content (%)	-0.361**	0.299*	1	-0.155
Vitamin C (mg/100g)	0.764**	0.728**	-0.155	1

N=54; ** Correlation is significant at 0.01 level (2-tailed)
*Correlation significant at 0.05 level (2-tailed)

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Table 6: Mean texture and color measurements of fried cassava chips from the three cultivars

Cultivar/ blanching time	Slice thickness	Texture (N)	L*	a*	b*
MM95/013 0mins	6mm	5.670±0.048 o	66.1±0.5fghij	1.3±0.7abce	15.9±1.7 abc
	10mm	3.236±0.145 jk	64.5±0.8 efghi	5.4±0.4 gh	37.6±3.0 l
	20mm	3.208±0.148 jk	49.0±0.7 ab	9.7±0.4 jk	27.3±1.7 ijk
5mins	6mm	3.952±0.366 l	67.7 ±0.2ghijkl	1.2±0.8 abcd	14.8±1.1 ab
	10mm	2.542±0.087efgh	71.7±1.9 ijklm	1.5±0.2abcde	24.9±2.1eghij
	20mm	2.720±0.044 ghi	58.9±1.6 cdef	7.033±0.4 hi	30.4±0.6 k
10mins	6mm	3.222±0.164 jk	69.3±1.0hijklm	1.4±0.3abcde	18.2±0.6abcdef
	10mm	2.118±0.091 cde	62.5±2.0 defgh	1.4±0.6 abcde	20.4±1.3 cdefg
	20mm	1.628± 0.097 ab	67.5±3.4ghijkl	2.0±0.4 abcde	29.7±1.5 jk
MM96/280					
0mins	6mm	5.598±0.303 o	55.4±3.1 bcd	1.5±0.1 abcde	17.5±1.8abcdef
	10mm	3.540±0.224 kl	51.3±5.0 abc	1.4±1.3 abcde	13.1±3.6 a
	20mm	3.062±0.053 ij	56.8±2.5 bcde	8.1± 1.4ij	28.2±1.2 jk
Fumba chai					
0mins	6mm	3.688±0.077 l	57.0±3.5 bcde	0.4±0.3 a	14.5±1.3ab
	10mm	2.900±0.072 hij	57.3±2.3 bcde	8.6±0.3 ij	26.5±0.7hijk
	20mm	2.218±0.072cdef	44.3±1.5 a	10.9±0.8 k	21.5±0.2defgh
5mins	6mm	2.596±0.075 fgh	64.6±3.8efghi	0.4± 0.4a	18.0±2.9abcdef
	10mm	2.540±0.154efgh	67.63±2.8ghijkl	1.6±0.2abcde	18.6±1.4bcdef
	20mm	2.014±0.086 bc	50.7±2.9 abc	9.6±0.9 jk	26.0±1.1hijk
10mins	6mm	2.046±0.084 bc	71.9±1.6 ijklm	0.8±0.1 ab	21.6±0.5defgh
	10mm	2.086±0.079 cd	73.2 ±0.8 jklm	1.3±0.1abcde	26.1±0.3hijk
	20mm	1.546±0.121 a	68.8±1.1ghijklm	2.4±0.6bcdef	26.37±1.5 hijk
MM96/2480					
5mins	6mm	5.052±0.047 n	66.9±5.0ghij	0.9±0.5 ab	17.2±1.5 abcd
	10mm	2.846± 0.820hijk	72.0±1.4ijklm	0.9±0.1 ab	26.8±0.6 hijk
	20mm	2.474±0.817defh	60.2±0.7defg	5.6±0.5 gh	25.1±0.3ghij
10mins	6mm	4.586±0.177 m	67.5±1.1defghijk	1.1±0.5 abc	17.4±0.7abcde
	10mm	2.396±0.131 cdeg	77.2±0.1 km	3.2±0.0 cef	22.2±0.2 efghi
	20mm	1.365±0.194 a	64.1±1.6 efghi	4.1±0.4 fg	29.1±0.8 jk

1. Values are means of five determinations ± standard deviation,
2. Values with the same letters in the same column are not significantly different at 5% level of significance

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Table 7: Sensory properties of fried cassava chips from MM96/2480, MH95/0183 and Fumba chai

Treatment	Color	Texture	Oiliness	Acceptability
C1,0,6	3.0±0.8 abc	4.2±0.7abcdef	3.0±0.8abcde	3.8±0.7abcdef
C1,0,10	3.0±0.7abc	2.6±1.1 abc	3.4±1.5 abcdef	3.0±0.7 ab
C1,0,20	2.6±0.9 ab	2.6±0.8 abc	2.6±0.5 ab	3.0±0.7 ab
C1,5,6	5.0±0.7 dfghij	4.8±0.8 acdef	3.8±0.8abcdefh	4.2±0.9 abcdefg
C1,5,10	3.6±0.5 abcdef	3.8±0.8 abcde	3.8±0.8abcdefh	3.8±0.7 abcdef
C1,5,20	4.0±0.abcdefgh	2.0±0.8 a	2.7±0.5 abc	3.0±0.3 abc
C1,10,6	5.2±0.8 fghij	5.0±1.2 acdef	5.4±1.1 fgh	5.0±1.0bcdefgh
C1,10,10	4.2±0.8abcdefg	4.4±0.9 abcdef	4.0±0.8abcdefh	4.0±1.0 abcdefg
C1,10,20	4.0±1.0abcdefg	4.6±1.1 abcdef	5.2±0.8cefgh	4.4±1. abcdefgh
C2,0,6	3.6±0.5 abcdef	3.6±0.5 abcd	3.6±1.1 abcdef	4.4±0.5abcdefh
C2,0,10	2.6±0.9 ab	3.0±0.7 abcd	2.8±0.8 abcd	4.0±0.8 abcdefg
C2,0,20	2.4±0.5 a	2.2±0.8 ab	2.0±1.0 a	2.4±0.5 a
C2,5,6	5.6±0.5 ghij	5.4±1.1 adef	6.0±0.7 h	6.4±0.9 ch
C2,5,10	4.4±0.5bcdefghi	4.8±0.7 acdef	5.0±0.8 cdefgh	4.8±1.3 bcdefgh
C2,5,20	3.6±0.5 abcdef	3.0±0.8 abcd	3.2±0.7 abcdef	3.6±1.1 abcd
C2,10,6	6.6±0.5 hj	6.4±0.9 f	6.0±1.0 h	6.0±0.7 ce
C2,10,10	4.2±0.8 abcdefg	4.4±1.1 abcdef	4.2± 1.0abcdefgh	4.4±0.5abcdefgh
C2,10,20	4.0±0.7abcdefi	4.2±0.8 abcdef	4.2±1.3abcdefgh	4.2±0.8 abcdefg
C3,0,6	3.6±0.9 abcdef	3.2±0.8 abcd	3.2±0.7 abcdef	3.6±0.5abcd
C3,0,10	2.8±0.8abc	4.6±1.5 abcdef	4.6±1.1 bcdefgh	3.4±0.5 abcd
C3,0,20	3.0±0.7 abcde	3.2±0.8 abcd	3.2±0.8 abcdef	3.4±0.5 abcd
C3,5,10	5.2±0.8fghij	5.4±1.1 adef	4.6±0.5 bcdefgh	5.4±1.1 cdefgh
C3,5,20	4.6±1.1 cdefghi	4.8±0.8 acdef	4.8±0.4 bcdefgh	5.2±0.8 cdefgh
C3,10,6	4.6±1.1 cdefghi	5.4±1.6 adef	5.8±1.3 gh	5.4±0.5 cdefgh
C3,10,10	4.6±0.5 cdefghi	6.2±0.8 ef	5.8±0.8 gh	5.4±1.1 cdefgh
C3,10,20	4.2±0.8abcdefg	4.4±0.5 abcdef	5.0±0.7 cdefgh	4.8±0.8 bcdefgh

1. C1, C2 and C3 are MH95/0183, MM96/2480 and Fumba chai, respectively.
2. The ordering of C1, 0, 6 shows the cultivar, blanching time and slice thickness, respectively
3. Values are means ± standard deviations. Significant different at 5% level (different letters)

REFERENCES

1. **Nwosu JN, Owuamanam CI, Omeire GC and C Eke** Quality parameters of bread produced from substitution of wheat flour with cassava flour using soybean as an improver. *American Journal of Research Communication*; (2014); **2(3):** 99-118.

2. **Olanbiwoninu AA and SA Odunfa** Enhancing the Production of Reducing Sugars from Cassava Peels by Pretreatment Methods. *International Journal of Science and Technology*; (2012); **2(9)**: 35-42.

3. **Nassar NM and R Ortiz** Cassava improvement, challenges and impacts. *Journal of Agricultural Science*; (2007); **145**: 163-171.

4. **Barratt N, Chitundu D, Dover O, Elsingal J, Eriksson S, Guma L, Haggblade M, Haggblade S, Henn TO, Locke FR, O'Donnell C, Smith C and T Stevens** Cassava as drought insurance, Food security implications of cassava trials in central Zambia. *Agrekon*; (2006); **45(1)**: 106 -123.

5. **Erhabor PO and CO Emokaro** Relative Technical efficiency of cassava farmers in the three Agro-Ecological zones of Edo state, Nigeria. *Journal of Applied Science*; (2007); **7(19)**: 2818-2823.

6. **Wilson WM and DL Dufour** Why "bitter" cassava? The productivity of bitter and sweet cassava in Tukanoan Indian settlement in Northwest Amazon. *Journal of Economic Botany*; (2002); **56(1)**: 49-57.

7. **Uyoh EA, Udensi O, Natui V and I Urua** Effect of different processing methods on cyanide content of garri from four cultivars of cassava. *Journal of Food, Agriculture and Environment*; (2007); **5(3-4)**: 105-107.

8. **Etonihu AC, Olajubu O, Ekanem EO and SS Bako** Titrimetric evaluation of cyanogens in parts of some Nigerian cassava species. *Pakistan Journal of Nutrition*; (2011); **10(3)**: 260-263.

9. **Umuhozariho MG, Shayo NB, Msuya1 JM and PYK Sallah** Cyanide and selected nutrients content of different preparations of leaves from three cassava species. *African Journal of Food science*; (2014); **8(3)**: 122-129.

10. International Institute of Tropical Agriculture (IITA). Cassava Recipes for Household Food Security. http://www.iita.org/c/documentlibrary/593f240d-7fc9 (2006): 10-25: Accessed on 15th June, 2015.

11. **Chaves AL, Sanchez T, Jaramillo G, Bedoya JM, Echeverry J, Bolanos EA, Ceballos H and CA Iglesias** Variation of quality traits in cassava roots evaluated in landraces and improved clones. *Euphytica*; (2005); **143**: 125-133.

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12. **Cardoso AP, Mirione E, Ernesto M, Massaza F, Cliff J and MR Haque** Processing of cassava roots to remove cyanogens. *Journal of Food Composition Analysis*; (2005); **18**: 451-460.

13. **Tonukari NJ** Cassava and the future of starch. *Electronic Journal of Biotechnology*; (2004); **7(1)**: 05-08.

14. **Salcedo D, Valle AD, Sanchez B, Ocasio V, Ortiz A, Marquez P and D Siritunga** Comparative evaluation of physiological post-harvest root deterioration of 25 cassava accessions: visual verses hydroxycoumarins fluorescent accumulation analysis. *African Journal of Agricultural Research;* (2010); **5**: 3138-3144.

15. **Nweke FI, Dunstan SC, Spencer DSC and TK Lyman** Cassava Transformation. University Press, Michigan State, USA; (2002): 272.

16. **Enidiok SE, Attah LE and CA Otuechere** Evaluation of moisture, Total cyanide and fiber contents of Garri produced from cassava varieties obtained from Awassa in Southern Ethiopia. *Pakistan Journal of Nutrition*; (2008); **7(5)**: 625-629.

17. **Elfnesh F, Tekalign T and W Solomon** Processing quality of improved potato cultivars as influenced by growing environment and blanching. *African Journal of Food Science*; (2011); **5(6)**: 324-332.

18. **Sherri NS, Jill FK and HI Cliff** Lipid and Moisture Content of Commercial Reduced-Fat Deep-Fried Potatoes Compared to Advertised Claim. *Journal of Food Research*; (2014); **3(5)**: 45.

19. **Adepoju OT, Adekola YG, Mustapha SO and SI Ogunola** Effect of processing methods on nutrient retention and contribution of cassava to nutrient intake of Nigerian consumers. *African Journal of Food, Agricultural and Nutritional development*; (2010); **4(7)**: 422-426.

20. **Oluwole OB, Olatunji OO and SA Odunfa** Process technology for conversion of dried cassava chips into gari. *Nigerian Food Journal*; (2004); **22**: 65-77.

21. **AOAC.** Association of Official Analytical Chemists. AOAC International 16th edition, *Washington DC*; (2007).

22. **A0AC**. Association of Official Analytical Chemists international (AOAC). 18th edition, *Washington DC;* (2005).

23. **Abong' GO, Okoth MW, Imungi JK and JN Kabira** Effect of slice thickness and frying temperature on color, texture and sensory properties of crisps made from four Kenyan potato cultivars. *American Journal of Food Technology*; (2011); **6(9)**: 753-762.

24. **Siritunga D and R Sayre** Engineering cyanogen synthesis and turnover in cassava (*Manihot esculenta*). *Journal of Plant Molecular Biology*; (2004); **56**: 661–669.

25. **Maneerote J, Noomhorm A and PS Takhar** Optimization of processing condition to reduce the oil intake to enhance physico-chemical properties of deep fried rice crackers. *Journal of Food Science and Technology*; (2009); **42**: 805-812.

26. **Moreira DL, Guimaraes EF and MC Kaplan** Butyl-3, 4-methylenedioxybenzene as a major constituent of the essential oil from *Ottonia anisum*. *Journal of Essential Oil Research*; (1997); **9**: 565-568.

27. **Choe E and DB Min** Chemistry of deep-fat frying oils. *Journal of Food Science*; (2007); **72(5)**: 77-86.

28. **Pedreschi F, Moyano P, Kaack K and K Granby** Color changes and acrylamide formation in fried potato slices. *Food Research International*; (2005); **38(1)**: 01-09.

29. **Boskou G, Salta FN, Chiou A, Troullidou E and NK Andrikopoulos** Content of trans-2, 4-decadienal in deep-fried and pan-fried potatoes. *European Journal of Lipid Science and Technology*; (2006); **108**: 109–115.