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Full Length Research Paper

Hazard analysis and critical control points (HACCP) in the production of cassava (*Manihot esculenta*, Crantz) chips

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Studies on the quality and safety of chips produced from cassava were carried out to determine the HACCP for the cyanide content at various stages of production of cassava chips. Five varieties of cassava were sorted, weighed, peeled, washed, chipped and dried (100°C). The pH and cyanide content of fresh roots and dried cassava chips were determined. The results showed that the mean pH of peeled fresh cassava roots and dried cassava chips ranged from 2.66-3.00 and 2.78-3.12 respectively; there was no significant differences (p>0.05) in their mean score, however, a correlation 'r' (p=0.05) was established between pH and cyanide content. There was marked reduction in cyanide content following drying (unpeeled-68 to 155; peeled-32 to 55; dried chips-21 to 39). Fresh local cassava variety root had higher level of cyanide content (155mg HCN/kg) indicating higher risk of toxicity. The result of the study also showed that drying significantly reduced the cyanide content during production of cassava chips and use of HACCP concepts in dried cassava chip production has been shown to be effective in reducing its cyanide content.

Key words: HACCP, cyanide content, cassava, pH, chips.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a member of the euphorbiaceous family and is often classified as bitter and sweet cultivars based on cyanogenic glucoside contained in the tuber (Aregheror and Agunbiade, 1991). The bitter variety of *Manihot* root is used to treat diarrhea and malaria while the leaves are used to treat hypertension, headache and pain (USEPA, 2003). Cassava chips are unfermented white dried products of cassava with an average diameter of 3–5mm often used as a carbohydrate base in the animal feed industry particularly in Europe, or milled into flour for other uses such as in the production of ethanol, cakes, dough-nut and biscuits (Bokanga, 1994). Traditionally, cassava is processed into dried whole roots with undesirable color, irregular shapes and often contaminated with moulds. Freshly harvested cassava can be converted into dried cassava chips having at least 18 months shelf life, containing cyanogenic glucosides within the permitted safe limits suitable for export and other uses (Bokanga, 1994). All dried thin chips had lower residual cyanogenic potential than the thicker storage root segments because glucoside hydrolysis and linamarase activity cease below 20% moisture content. Therefore, sun-drying alone is not appropriate for cultivars with high cyanogenic potential (Charles *et al*., 2005). The HACCP will help in reducing the cyanide intake from improperly processed cassava with high cyanogenic potential (CNP) which is a risk key factor in several diseases. HACCP is a production control system for the food industry, a process used to determine the potential danger points in food production and to define a strict management and monitoring system to ensure safe food products for consumers. Critical Control Point (CCP) is a point, step or procedure at which controls can be applied and a food safety hazard can be prevented, eliminated or reduced to acceptable (critical) levels. The following questions were answered affirmatively for a particular step to be a CCP (NACMCF, 1997):

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Table 1. Weights of five varieties of cassava during processing

	Weight of cassava (kg)[1,2]	
Cassava variety	Before peeling	After peeling
TME/419	1.0[a]	0.886[a]
TMS 98/0505	1.0[a]	0.867[a]
TMS 92/0057	1.0[a]	0.840[a]
TMS 92/0326	1.0[a]	0.896[a]
TMS 4(2)1425	1.0[a]	0.897[a]

[1]Each value is the mean of three replicate determinations

[2]Similar letters within the same column are not significantly different at $p>0.05$

i. Does the step involve a hazard of sufficient likelihood of occurrence and severity to warrant its control?
ii. Does a control measure for the hazard exist at this step?
iii. Is control at this step necessary to prevent, eliminate or reduce the risk of the hazard to consumers?

Since cassava chips are produced mainly for export, it becomes necessary to adopt the hazard analysis critical control points (HACCP) concepts in assessing the risk involved in its production and as well as ascertain the hydrogen cyanide content. This research determined the HACCP for the cyanide content at various stages of production of cassava chips.

MATERIALS AND METHODS

Sample collection

Five varieties of cassava (*Manihot esculenta,*Crantz) namely TMS 4(2)1425 (local variety) and four other hybrids TME/419, TMS 92/0057, TMS 92/0326 and TMS 98/0505 were obtained from International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Production of cassava chips

Fresh cassava tubers (12-24 months) were processed into cassava chips using the method of FDIC/NAFDAC (2004) as illustrated in Figure1 following the HACCP concept.

Weighing of the cassava samples

The five (5) cassava varieties were sorted to select wholesome roots and remove immature roots and foreign materials and weighed before and after peeling.

Chemical analysis

pH determination

The pH of fresh cassava roots before and after peeling and the cooled, dried cassava chips were determined in triplicates after standardization with pH 4 and 7 buffers (BDH, England)using Jenco Model 6071 pH-meter according to the procedure described by Fleming *et al*. (1983).

Determination of cyanide content

The pyridine-barbituric acid colorimetric method as described by USEPA (2003) was used to determine the cyanide content of fresh and dried cassava tubers and chips. This procedure is used to determine cyanide concentrations below 1mg/l and is sensitive to about 0.02mg/l; the cyanide is then converted to cyanogen chloride (CNCl) by reaction of the cyanide with chloramine-T at a pH less than 8. After the reaction is completed, color is formed on the addition of pyridine-barbituric acid reagent. The absorbance is read at 578mm for the complex colors of comparable intensity formed with pyridine-barbituric acid reagent and CNCL (USEPA, 2003).

Statistical analysis

Analysis of variance (ANOVA) was carried out for the pH, cyanide content and cassava tubers both peeled and unpeeled and the dried chips. The mean scores were computed and significant differences among the mean was determined (Duncan, $p=0.05$) using 2006 Statistical Packages for Social Sciences (SPSS) for windows version 15.0 (SPSS, 2006). Correlation coefficient (r) between pH and cyanide content of the cassava chip was computed using Minitab statistical packages for windows

Table 2. pH and correlation coefficient of pH versus cyanide in cassava.

Cassava variety	pH of cassava (kg)[1,2]			Correlation coefficient('r')[3]
	Before peeling	After peeling	After drying	pH vs cyanide content
TME/419	3.80[a]	3.00[a]	2.89[a]	0.96022
TMS 98/0505	3.99[a]	2.82[a]	3.12[a]	0.7573
TMS 92/0057	3.60[ab]	2.66[a]	2.78[a]	0.9260
TMS 92/0326	3.42[b]	2.95[a]	3.10[a]	0.8559
TMS 4(2)1425	3.53[ab]	2.97[a]	2.91[a]	0.9992

[1]Each value is the mean of duplicate determinations

[2] Different letters within the same column are significantly different at p<0.05

[3]Correlation coefficient ' r' (p=0.05)

Table 3. Cyanide contents of five varieties of cassava during production of cassava chips.

Cyanide content (mgHCN/kg)[1,2]	
Before peeling	After peeling
82[b]	44[ab]
74[bc]	48[ab]
72[bc]	43[ab]
68[c]	32[b]
155[a]	55[a]

[1]Each value is the mean of triplicate determinations

[2]Different letters within the same column are significantly different at p<0.05

version 15.1 (Minitab, 2005).

RESULTS AND DISCUSSION

The weight of the five fresh cassava tuber varieties (TMS 4(2)1425, local variety) and the hybrids (TME/419, TMS 92/0057, TMS 92/0326 and TMS 98/0505) as shown in Table 1 ranged from 0.840-0.897kg. There was no significant difference (p>0.05) in weight of the five varieties after peeling, the implication of this is that peeling does not have any effect on the weight of the cassava. The pH of the five cassava varieties (Table 2) ranged from 2.66-3.0 (after peeling) and 2.78-3.12 (after drying). A sharp decrease in pH was observed for all varieties after peeling; 3.42-3.99 (unpeeled) and 2.66-3.00 (peeled) but these were not significantly different (p>0.05)(Table 2) . A great reduction of the cyanogenic content (unpeeled: 68-155mg HCN/kg and peeled: 32-55mg HCN/kg, Table 3) of the raw material was observed. The first step in processing cassava roots is often to remove the peel resulting in a decrease because the peel represents about 15 percent of the weight of the root, and its cyanogenic content is usually 5 to 10 times greater than that of the root parenchyma (Lancaster et al., 1982; Montaldo, 1973). However TMS 4(2) 1425 (local variety) and TME/419 showed consistent decrease in pH, even after drying while varieties TMS 92/0057, TMS 92/0326 and TMS 98/0505 only reduced after peeling and on drying, the pH increased though not tremendously. There was a strong correlation between the pH and the cyanide concentration in the five cassava variety (r =0.96022, 0.7573, 0.8559, and 0.9992 respectively (Table 2) indicating that acidity is directly proportional to the cyanide concentration of cassava.

The cyanide content of the samples after drying ranged from 20-39 mg HCN/kg (Table 3). There was significant difference (p<0.05) among the samples with the lowest cyanide contents observed for TME/419 roots (20mg HCN/kg), and the highest cyanide contents were observed in variety TMS 4(2)1425 (39mg HCN/Kg). These results are in accordance with the classification used by Beninese farmers (Nago and Hounhouigan, 1998). Drying or peeling significantly (p<0.05) reduced the total cyanide content in fresh root. Sun and oven drying reduced the cyanide content in the dried chips to approximately 15-30% of the initial cyanide content of fresh chips. Cyanide content in fresh roots after peeling ranged from 32-55mg HCN-equivalent per kg, only variety TMS 4(2)1425 is considered moderately poisonous (55mg HCN-equivalent per kg. However, the

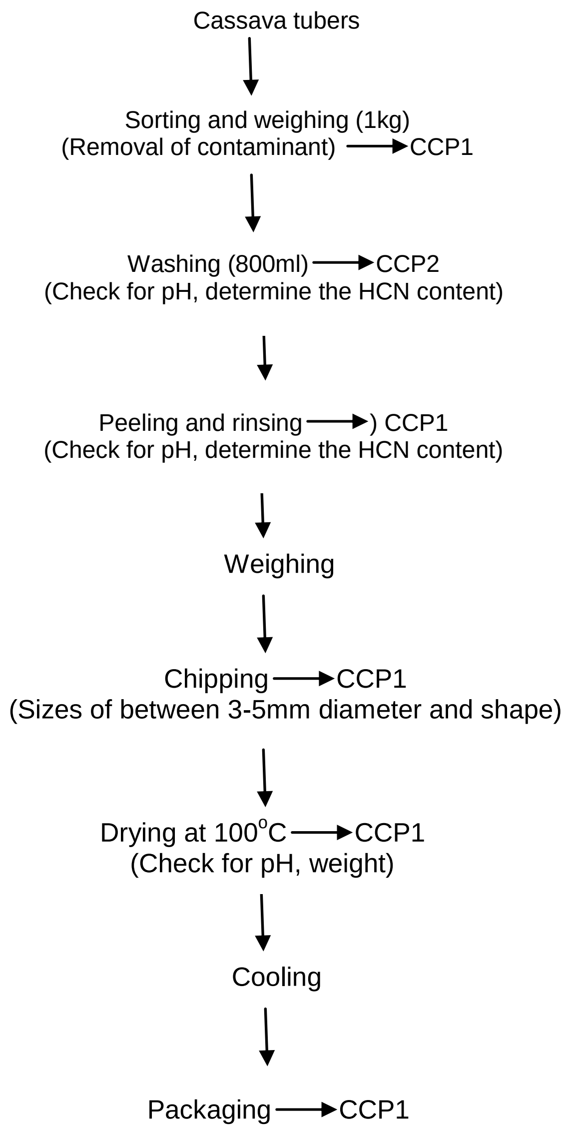

Figure 1. Flow chat for cassava chip processing showing the CCP's
CCP1: critical control points that can affect the total production process adversely
CCP2: critical control points which can be removed along production process

cyanide content of the unpeeled local variety as shown in Table 3 is 155 mg HCN/kg and this is considered to be dangerously poisonous since it is above 100mg HCN/kg equivalent (Bolhuis, 1954; Hann and Keyser, 1985). In humans, the clinical signs of acute cyanide intoxication are constriction of the throat, nausea, vomiting, stomach pains, giddiness, headache, palpitations, hyperpnoea and unconsciousness (ATSDR, 2006).

The critical points identified in the production of cassava chips are, sorting, washing, peeling chipping, drying and cooling (Figure 1). Sorting followed by washing with water is a control measure that would reduce or eliminate the potential risk. Sorting is classified as CCP1 as this could affect the total production process adversely if left unattended to. Peeling and rinsing is a CCP1 because when not done adequately as specified, the cyanide content is retained, instead of reducing along the line of processing, thereby affecting the quality of the product. Also, chipping process is a CCP1 because it affects cassava drying time (shape and size), the control measure is to ensure that the size of the cassava chip is between 3-5mm diameter in shape for the moisture content to be reduced during drying and this prevents, eliminate or reduce the risk of microbiological and chemical hazard. Drying is CCP1 because drying kinetics is generally affected by factors which include drying temperature, pre-treatment method, relative humidity, and chip sizes (Charles *et al*., 2005).The changes in concentration of free cyanide (non-glycosidic) and bound cyanide (cyanogenic glycosides) in fresh cassava chips during drying rapidly remove free and bound cyanide from the chips. This step prevents, eliminate or reduce the risk of microbiological and chemical hazard. Dried cassava chips are vacuum packaged in high density polythene bags to minimize the loss of nutrients by oxidation and to eliminate dust and dirt. Adequate packaging which is a control measure, will contribute significantly to the quality and shelf-life of the cassava chips.

The result of the present study has shown that drying and the use of critical control points is a veritable tool in reducing the cyanide content of cassava chips to appreciable safe levels; the desired attributes preferred by farmers includes low cyanide content in their products.

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