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Characteristics and Appropriateness of Made-in-Ghana Equipment for Safe Processing of Cassava

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Authors' contributions

This work was a result of effective collaboration between all four authors. Author GKA collected the field data, analyzed the data, wrote the protocol and the first draft of the manuscript. Author ND worked on the tests and managed the literature searches and proof read the work together with authors IKA and EKK. All authors read and approved the final manuscript.

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ABSTRACT

Introduction: Cassava contains poisonous hydrogen cyanide. However, when well processed it serves as safe cheap source of edible carbohydrate. This study assessed the appropriateness of the available made-in-Ghana cassava processing equipment, the constraints and bottlenecks of the equipment manufacturers, the opinion of users of the equipment, and the effect of the equipment on safety of processed cassava.

Methodology: Snowball sampling technique was used to select forty-eight (48) cassava processing equipment manufacturers and sixty-three (63) users of the equipment across the country and open ended questionnaires were used to solicit information on the characteristics of the manufactured equipment, the manufacturers' constraints and bottlenecks, and the users' opinion of the equipment. Hydrogen cyanide content in cassava dough and pressed cake from the locally manufactured graters were measured and compared statistically.

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Results: Eleven categories of made-in-Ghana cassava processing equipment were identified together with their technical specifications. Majority (92% and 77%) of the manufacturers were found to produce cassava graters and screw press respectively and about half of the users (51%) of the cassava processing equipment were satisfied with how they are functioning. The minimum cyanide content found in the cassava dough and pressed cake were 20.92 mg/Kg and 17.08 mg/Kg respectively.

Conclusion: Most of the cassava processing equipment was not made of stainless steel material. A greater number of the users of these equipment were not satisfied with the durability, efficiency, robustness and post-sale services provided by the manufacturers. The cassava processing equipment manufactured in Ghana was in various ranges and their operation facilitated the removal of poisonous hydrogen cyanide from cassava for safe consumption.

Practical Application: The overall outcome of this study will assist processors to select appropriate equipment for processing safe cassava products. It will also help policy makers and researchers to come up with effective interventions that will build the capacity of manufacturers to ensure the manufacture of appropriate equipment to process safe cassava products.

Keywords: Cassava; food hygiene; Ghana; hydrogen cyanide; processing equipment.

1. INTRODUCTION

Cassava (*Manihot esculenta Crantz*) is a drought-tolerant staple food crop that grows well on poor soil in all the agro ecological zones of Ghana [1,2,3]. It is the third most important source of energy after maize and rice for human and livestock in the world [4] and also a cheap source of edible carbohydrate that can be processed into different forms of human delicacies and animal feeds [5].

The production and processing of cassava has potentials for food security and income generation for millions of people in rural parts of Ghana. It is increasingly becoming a high valued crop with the emergence of its uses in various industries across the world as essential raw material [6]. The importance of cassava to the livelihoods of many millions of poor people especially Africans is epitomised in the Ewe (a language spoken in Ghana, Togo and Benin) name for the plant, “agbeli”, meaning "there is life" [7].

Cassava is a perishable commodity that has a shelf-life of 24 to 48 hours after harvest [8] and is also bulky with about 70% moisture content [9]. All cassava tissues, with the exception of seeds, contain poisonous hydrogen cyanide (HCN) which is produced by the linamarin catalyst and if inadequately processed creates a potential health hazard to consumers [10]. When processed its bulkiness is reduced, the palatability is improved, the shelf life is increased and most importantly, it is detoxified by drastically reducing the cyanide content [11-17]. The technology of pre-soaking cassava roots for about 2 days, washing the roots, cutting into bits, dried and ground into flour also helps reduce the cyanide content and toxicity to humans [18].

Processing of cassava takes various forms and the major activities involved in processing cassava into common Ghanaian food products as gari, agbelima and flour (kokonte and high quality cassava flour) are peeling, washing, grating, dewatering, cake breaking, sifting, roasting, drying and milling.

At the micro and small enterprise level of processing cassava, the activities involved are mostly carried out manually with indigenous equipment that are often characterised with drudgery, low productivity, and occasional injuries to fingers resulting from peeling with knife and grating with metal sheet with sharp extruding face. It was observed that machines were always employed in the grating which is the most labour intensive aspect of the processing. It is a process that involves the disruption of the cassava tissues and cells. This process is noted to remove much of the cyanogenic glycoside [19] resulting in the reduction of the hydrogen cyanide in the cassava to a safe level [20,21] as contact is created between cyanogenic glycosides and hydrolytic enzymes [13,22].

Njoku [23] also observed that dehydrating causes loss of the poisonous hydrogen cyanide in the form of prussic acid and the drying process eliminates the remaining prussic acid to a considerable extent, thus reducing the problem of toxicity in instant cassava food. The efficiency of removal of cyanogenic glycosides in this process depends somehow on the rate of moisture loss. McMahon and Sayre [10] indicate that rapid drying results in lower cyanogen removal, while slower rates of drying result in a higher reduction.

The demand for processed cassava products in the urban areas and the increased recognition of its industrial potential as identified by Jumah et al. [24], calls for cassava processing at commercial levels. This requires that the processing activities be mechanised to speed up production and also ensure food safety and hygiene. Producing safe food from cassava goes with enormous challenges amongst which the use of appropriate equipment, the adherence to measures that identifies and prevents hazards, reducing products loss as a result of spillage and spoilage, and ensuring safety of the processed cassava is critical. There is the need for the design of equipment that avoids corners not easy to reach for cleaning when it retains food materials after usage and also equipment that functions properly and facilitates the removal of the poisonous hydrogen cyanide in cassava. Good manufacturing practices are very important for the promotion of safe products. For instance, pathogenic thermophiles could be controlled or prevented at the grating and de-watering stages when clean grating machine, de-watering machine and polypropylene sacks are used and also washed thoroughly after the end of daily operation [25].

There have been lots of innovative cassava processing equipment developed by the local artisans and some research institutions towards the promotion of safe and hygienic cassava products. However, in most instances, the appropriateness of the equipment (especially products of local artisans) are of great concern. The appropriateness of design, material selected for the manufacture of the equipment, the ease of cleaning food substances in the equipment after usage, dismantling and repairing without conveying the whole equipment to a workshop is also a great challenge.

The difficulty faced by cassava processors is getting to know the various types of cassava processing equipment available and manufactured locally as well as accessing the right technical information about the equipment to help evaluate and select appropriate equipment to produce safe food.

This paper therefore attempts to provide important information (related to the types of equipment capacity, type and source of operating power, and the type of material used to manufacture) on all the appropriate cassava processing equipment manufactured in Ghana and also determine the effect of the available grating machines on the content of hydrogen cyanide in processed cassava (dough and pressed cake). It further unearthed some constraints and bottlenecks associated with the manufacture of the equipment and the opinion of the equipment users about the locally manufactured cassava processing equipment.

It is expected that this work will make it easy for cassava processors to assess and adopt the appropriate cassava processing equipment to promote safe processing of cassava, eliminate drudgery and increase productivity. It will also bring to the fore some of the issues that should be addressed for the manufacturers of cassava processing equipment in order to produce safe processing equipment.

2. METHODOLOGY

The research was in two main parts. The first part was a study conducted on forty-eight (48) major cassava processing equipment manufacturers across the country and sixty-three (63) users (service providers including the equipment operators) of the manufacturers' equipment using a snowball sampling technique. Two types of open ended questionnaires were used to collect the data. One type of the questionnaire was used to collect data on the characteristics of the made-in-Ghana cassava processing equipment. The data collected covered the capacity of prime mover used to power the equipment, the capacity of equipment manufactured, the materials used to construct the equipment, and the overall dimension of the equipment. The dimensions (in cm) were taken using a measuring tape and the capacities (in kg/hr) were assessed by considering what the manufacturer assigned to the product as against what the users (processors) using the equipment of the manufacturer realised over the years. The weights of the equipment were obtained by summing up weights of components of the equipment using weighing scale. However judgments of the manufacturers together with what the users observed were averaged to estimate weights of the installed equipment. Finally, a range was used for the outcomes of the capacities and weights. The other type of questionnaire meant for the equipment makers and users was used to gather data on the number of manufacturers of the various equipment, the manufacturers' constraints and bottlenecks with respect to equipment manufacturing, and the equipment users' opinion of the manufactured equipment with respect to the equipment uniqueness, equipment durability, equipment robustness, post sales services, how well the equipment is functioning and its efficiency. The opinion of the users was used to identify the forty-eight (48) major manufacturers of appropriate cassava processing equipment.

The second part of the research was a test conducted to determine the effect of the appropriate locally made cassava equipment (specifically the three common graters manufactured locally) on the content of hydrogen cyanide in the processed cassava (precisely cassava dough and pressed cake). The cassava variety used for the study was Bankye hemaa, and the graters employed were the conventional manual feed type, the disc self-feed type, and the conventional self-feed type. Each grater was used to grate one kilogram (1 kg) of peeled cassava and finally pressed into cake. Samples of the peeled raw cassava, grated cassava dough and the pressed cake from each grater were taken and the cyanide content determined using the alkaline titration method. Twenty grams (20 g) of sample was weighed into 1 L distillation flask and 200 mL distilled water added for steam distillation. The distillate (150 mL) was collected in 20 mL of 1 N NaOH. The apparatus was adjusted in order for the tip of the condenser to dip below the surface of the NaOH solution in the receiver. The distillate in NaOH solution was transferred into 250 mL volumetric flask made to the mark and 100 mL of this solution titrated against 0.02 N $AgNO_3$ solution to permanently turbid end point. The results were calculated using the relation 1 ml 0.02 N $AgNO_3$ = 1.08 mg HCN.

The HCN content value of the cassava dough and pressed cake from each grater were compared for significant differences in the graters' effect using a nonparametric statistical test tool, Kruskal Wallis H.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Appropriate cassava processing equipment manufactured

In total, eleven main categories of cassava processing equipment were identified as locally made and used in Ghana. The percentage of cassava processing equipment manufacturers producing the equipment are shown in Fig. 1.

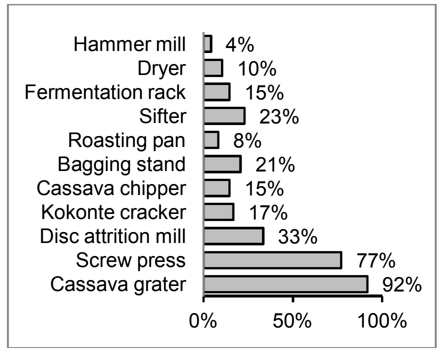

Fig. 1. Percentage of manufacturers fabricating cassava processing equipment

The various types of cassava processing equipment of the eleven main categories that users have accepted as appropriate and being manufactured and used in Ghana are shown in Fig. 2.

3.1.2 The equipment manufacturers' challenges and the users' opinion of the equipment

The local manufacturers' opinion about the constraints and bottlenecks associated with the manufacturing of the equipment and the user's opinion about the locally manufactured equipment are shown in Figs. 3 and 4 respectively.

3.1.3 Technical specification of the manufactured equipment

The technical specifications compiled on the appropriate cassava processing equipment manufactured locally are shown in Table 1.

3.1.4 Effect of the equipment on hydrogen cyanide in cassava

Table 2 shows the content of hydrogen cyanide in raw cassava, grated cassava dough, and pressed cassava cake.

3.2 Discussion

The most common cassava processing equipment produced by the cassava equipment manufacturers are the Grater and Screw Press and they are manufactured by 92% and 77% respectively of the cassava processing equipment makers interviewed across the country (Fig. 1). The common graters found among the manufacturers and users were the self-feed types, the conventional type, and the disc type shown in Fig. 2(a to c) and the screw press were the single screw and the double screw types shown in Fig. 2(e and f).

(a)
Disc type Grater

(b)
Self-feed type Grater

(c)
Conventional type Grater

(d)
IITA type Grater

(e)
Single screw press

(f)
Double screw press

(g)
Disc attrition mill

(h)
Hammer mill

(i)
Kokonte cracker

(j)
IITA type Manual chipper

(k)
IITA type Power chipper

(l)
IITA type Bagging stand

(m)
Gari roasting pan

(n)
Cassava dough sifter

(o)
Cassava flour sifter

(p)
Gari sifter

(q)
IITA type Cassava dough/gari sifter

(r)
IITA type Fermentation rack

(s)
Cassava chip dryer

Fig. 2. Cassava equipment manufactured in Ghana

The disc type of grater has a vertical shaft that rotates the peeled cassava on a horizontal punched sheet with sharp extruding face to produce the cassava pulp whiles the other two types (self-feed and conventional types) have a horizontal shaft with a grating drum that is wrapped with punched sheet with extruding face which serves as grating teeth when the shaft rotates.

Almost all the grating parts of the graters found with the users and manufacturers were made from mild steel except for equipment that the client purposely requested that, parts be made of stainless steel. Manufacturers of the equipment often compromise on the use of appropriate material for manufacturing the cassava processing equipment for reasons of challenges faced with financing (lack of working capital), the high cost of steel especially stainless steel (which represented 75% of their constraints and bottlenecks) and the unavailability of other appropriate materials (which also represented 35% of their constraints and bottlenecks) as shown in Fig. 3.

It was also found that there were variations in the dimensions of the same capacity of equipment manufactured (Table 1) and the capacities of the locally made equipment as stated by the manufacturers were quite higher than what the users observed and experienced. This probably suggests that not much research work with regards to designs, detail drawings and performance evaluations were carried out by the local manufacturers. The opinion of the users about the equipment (Fig. 4.) strongly confirms this assertion because only half (51%) were satisfied with how the equipment were working, only 7% received post sales services from the manufacturers, 22% were satisfied with the equipment durability, and only 9% were satisfied with the efficiency and robustness of the equipment though the opinion of 98% of the manufacturers (in Fig. 3.) did not acknowledge that inadequate research work was a serious manufacturing constraint and bottleneck.

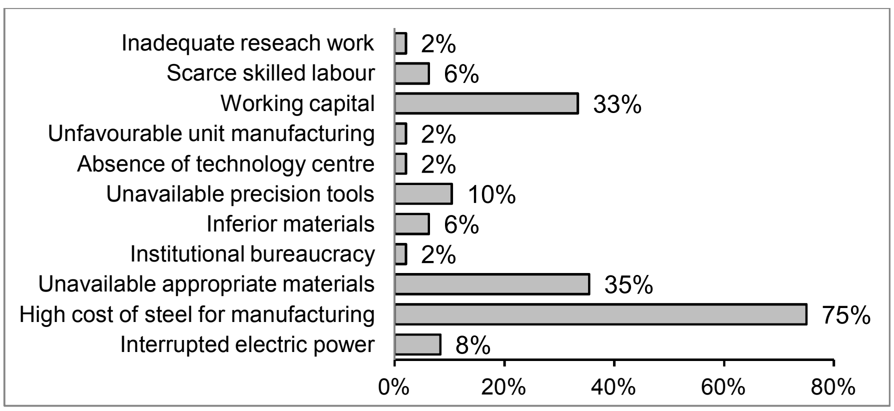

Fig. 3. Constraints and bottlenecks in the equipment manufacturing

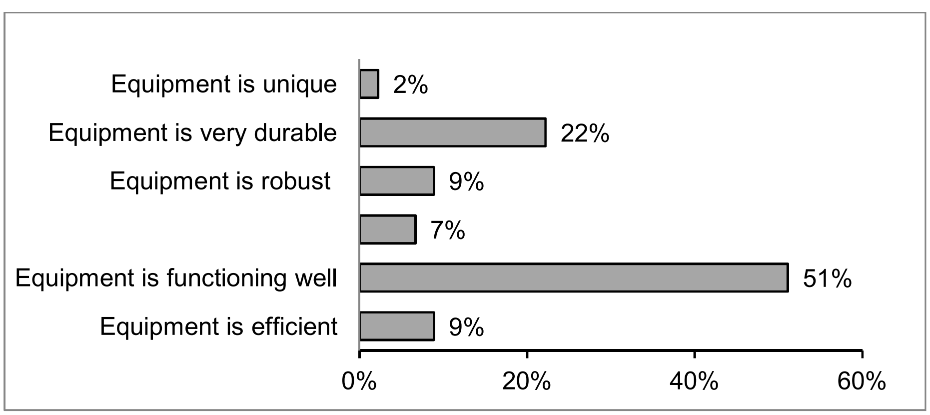

Fig. 4. Users' opinion about the locally manufactured equipment

Table 1. Technical specification of different types of locally manufactured cassava equipment

	Cassava Equipment	Capacity	Power (HP)	Dimension (cm)	Weight (kg)	Material used
Cassava grater	Disc type Grater	550 – 750 kg/hr	▪ 10 (for electric motor) ▪ 8 (for diesel engine)	L = 66-69 W = 48-66 H = 104-112	108 – 115	▪ Mainly mild steel, or ▪ Mild steel and stainless steel (only on request)
	Self-feed type Grater	2,000 – 2,500 kg/hr	▪ 10 (for electric motor) ▪ 8 (for diesel engine)	L = 160 W = 160 H = 122	200 – 250	▪ Mainly mild steel, or ▪ Mild steel and stainless steel (only on request)
	Conventional type Grater	550 – 750 kg/hr	▪ 10 (for electric motor) ▪ 8 (for diesel engine)	L = 91-122 W = 61-91 H = 97-135	89 – 200	▪ Mainly mild steel, or ▪ Mild steel and stainless steel (only on request)
	IITA type Grater	550 – 750 kg/hr	▪ 3-4 (for petrol engine)	L = 66-69 W = 48-66 H = 104-112	83 – 85	▪ Mainly mild steel, or ▪ Mild steel and stainless steel (only on request)
Cassava press	Single screw Press	60 – 320 kg/batch	Manual	L = 96-100 W = 55-76 H = 107-142	58 - 110	▪ Mild steel coated with paint
	Double screw Press	350 kg/batch	Manual	L = 112-127 W = 51-70 H = 104-122	79 – 97	▪ Mild steel coated with paint
Cassava mill	Disc attrition mill	200 – 250 kg/hr	▪ 10 (for electric motor) ▪ 8 (for diesel engine)	L = 109-135 W = 52-74 H = 117-142	110 – 200	▪ Mild steel coated with paint
	Hammer mill	1,000 - 2,000 kg/hr	▪ 10 (for electric motor) ▪ 8 (for diesel engine)	L = 122-206 W = 91-142 H = 152-246	200 - 400	▪ Mild steel coated with paint, or ▪ Stainless steel and mild steel coated with paint.
	Kokonte Cracker	500 kg/hr	▪ 10 (for electric motor) ▪ 8 (for diesel engine)	L = 91-94 W = 46-53 H = 137-142	95 – 105	▪ Mild steel coated with paint
Cassava chipper	IITA type Manual Chipper	150 - 250 kg/hr	Manual	L = 53 W = 51 H = 58	16.5	▪ Mild steel frame ▪ Stainless steel chipping disc
	IITA type Power Chipper	500 kg/hr	▪ 3-4 (for petrol engine) ▪ 2-3 (for electric motor)	L = 81-84 W = 66-68 H = 72-77	82 – 85	▪ Mild steel frame ▪ Stainless steel chipping disc

	Cassava Equipment	Capacity	Power (HP)	Dimension (cm)	Weight (kg)	Material used
Bagging stand	IITA type Bagging Stand	154,000 – 167,000 (cm^3)	Manual	L = 61-64 W = 61-64 H = 79-81	8 – 8.5	▪ Mild steel coated with paint
Roasting pan	Gari Roasting Pan (Open pan type)	20 kg/batch	Manual	L = 100-142 W = 74-100 H = 13	33 – 35	▪ Aluminium
Sifter	Cassava Dough Sifter	500 kg/hr	Manual	L = 153 W = 90 H = 135	150	▪ Stainless, ▪ Plastic mesh, and ▪ Mild steel
	Cassava Flour Sifter	1,000 kg/hr	2 (for electric motor)	L = 130 W = 60 H = 165	87	▪ Stainless, ▪ Plastic mesh, and ▪ Mild steel
	Gari Sifter	1,000 kg/hr	5.5 (for electric motor)	L = 165 W = 92 H = 125	102	▪ Wood, ▪ Nylon mesh, and ▪ Mild steel
	IITA type Cassava Dough/Gari Sifter	250 kg/hr	Manual	L = 120-122 W = 60-63 H = 81-90	20 - 30	▪ Wood
Fermentation rack	IITA type Fermentation Rack	500 kg/batch	Manual	L = 183-193 W = 84-91 H = 81-86	33 – 50	▪ Wood
Dryer	Cassava Chip Dryer (Gas fuelled batch type)	1,500 kg/batch	10 (for electric motor of blower)	L = 312 W = 221 H = 127	270	▪ Mild steel ▪ Aluminium

Source: Field survey, 2008
L = Length, W = Width, H = Height

Table 2. Hydrogen cyanide content of raw cassava, cassava dough and pressed cassava cake

Type of sample	Mean value (mg HCN/Kg)
Raw cassava (Bankye hemaa)	28.42±1.61
Dough from Self feed type grater	22.37±5.49
Dough from Conventional type grater	20.92±0.76
Dough from Disc type grater	22.03±2.60
Cake from Self feed type grater	19.14±3.19
Cake from Conventional type grater	17.08±0.71
Cake from Disc type grater	17.72±0.53

Result represents mean value of two samples of each cassava product taken in mg/Kg wet weight equivalent of HCN

The effect of these commonly manufactured and used cassava graters (the conventional type, the disc type, and the self-feed type) on hydrogen cyanide content in processed cassava (cassava dough and pressed cake) showed some reduction from a mean value of 28.42 mg/Kg in raw cassava to minimum of 20.92 mg/Kg in cassava dough and 17.08 mg/Kg in pressed cassava cake. These findings support the statements of Hahn [20] and Yohanna et al. [21] though the HCN content was outside the acceptable limits of 10 mg HCN equivalent/Kg dry weight recommended by FAO in 1988 for safe cassava products [26].

A comparison of the effects of each of the three graters on HCN in the cassava dough and pressed cake using a nonparametric statistical test tool (Kruskal-Wallis H) has shown no significant difference as presented in Table 3 for the cassava dough and Table 4 for the pressed cake.

The Kruskal-Wallis H test results in Table 3 and 4 show that $\chi^2(2) = 0.000$ and the p value (= 1.000) is greater than 0.05, with a mean rank HCN in cassava dough of 3.50 for the Self-feed Grater, 3.50 for the Conventional Grater and 3.50 for the Disc Grater. Again with respect to the pressed cassava cake, $\chi^2(2) = 0.857$ and p = 0.651 (which is also greater than 0.05) with a mean rank HCN in pressed cake of 4.00 for the Self-feed Grater, 2.50 for the Conventional Grater and 4.00 for the Disc Grater.

Table 3. Kruskal-Wallis H Test for HCN in cassava dough

Ranks

	Grater	N	Mean rank
HCN in cassava dough	Self	2	3.50
	Conv	2	3.50
	Disc	2	3.50
	Total	6	

Test statistics[a,b]

	HCN in cassava dough
Chi-Square	.000
df	2
Asymp. Sig.	1.000

a. Kruskal Wallis Test
b. Grouping Variable: Grater

Table 4. Kruskal-Wallis H Test for HCN in pressed cake

Ranks

	Grater	N	Mean rank
HCN in Pressed Cake	Self	2	4.00
	Conv	2	2.50
	Disc	2	4.00
	Total	6	

Test statistics[a,b]

	HCN in pressed Cake
Chi-Square	.857
df	2
Asymp. Sig.	.651

a. Kruskal Wallis Test
b. Grouping Variable: Grater

Inference from this analysis suggest that there is no single grater out of the three common types in use that is superior over the other with respect to the reduction of HCN in the processed cassava into dough and pressed cake.

The disadvantage of some of these manufactured graters is the inability to remove all particles of cassava material in the grating chamber especially on the grating drum as a result of corners that are difficult to reach and clean. These left over residues of previous processing promotes pathogenic microbial organism contaminations as mentioned by Yohanna et al. [21]. On the other hand, the graters have helped eliminate the possible hazards of introducing pathogenic thermophiles in the process of using hand grating technology as the frequency of handling of the cassava with bare hands is reduced drastically.

4. CONCLUSION

There are wide ranges of appropriate cassava processing equipment for processors to choose from depending on the scale of operation. Capacity of the equipment manufactured spanned 20 kg per batch for a gari roasting pan to 2,500 kg per hour for a cassava grater. The prime movers for the motorised equipment ranged from 3 to 4 HP petrol engines, or 8HP diesel engines, or 2 to 10 HP electric motors. The weight of the equipment ranged from 8 kg for a bagging stand to about 400 kg for a hammer mill. The minimum floor space covered by equipment was 53 cm x 51 cm (0.27 m^2) for the IITA type manual chipper and the maximum was 312 cm x 221 cm (6.90 m^2) for the dryer.

The challenges faced by the equipment manufacturers made most of them adopt the use of inappropriate food safety materials to manufacture the cassava processing equipment. Most of the users of such equipment were not satisfied with the equipment durability, the efficiency, the robustness and the post sales services provided by the manufacturers. Although, the commonly used cassava graters manufactured locally helped reduced the hydrogen cyanide content in raw cassava when processed into the dough and pressed cake, none was found to be superior to the other in terms of reducing the hydrogen cyanide.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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