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Biowastes Generation by Small Scale Cassava Processing Centres in Wilberforce Island, Bayelsa State, Nigeria

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Research Article

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ABSTRACT

In Nigeria, about 70% of harvested cassava tubers are processed into gari, a toasted granule. Gari production in Nigeria is dominated by smallholders who use simple implements for cassava processing. Nigeria is the largest cassava producing nation in the world. It is suspected that significant amounts of wastes are generated during cassava processing. Hence, the study was designed to assess the amount of cassava processing wastes generated during the traditional processing of cassava to gari. Field study was embarked upon in December 2010. Triplicate samples were measured in eleven cassava processing centres in Wilberforce Island. Results show that for a given unit of raw cassava, gari yield is about 34% while generating 30%, 19.8% and 16.2% of solid, gaseous and liquid wastes respectively. The environmental impacts of cassava processing wastes were discussed. We therefore conclude that the traditional processing of cassava to gari generates several waste streams that could be converted to other useful products to prevent environmental impacts.

Key words: Biowastes, cassava processing, environmental impacts, gari, smallholder, waste streams.

INTRODUCTION

Nigeria is by far the largest cassava producing nation in the world. Nigeria cassava production is at least a third more than that of Brazil and has now doubled the production of Indonesia and Thailand (Philips et al., 2004). Nigeria cassava production has been increasing since 1960 when the country gain independence from Great Britain. The following cassava production figures were recorded for Nigeria; 7.4, 9.1, 11.0, 26.0, 32.0 metric tonnes in 1961, 1971, 1981, 1991 and 2001 respectively. And by 2008 it has reached 45 million tonnes (FAOSTAT, 2009). Several factors are responsible for the increased cassava production in Nigeria including the rising human population and favourable agroclimate for the crop (Nweke et al., 2002), presidential cassava initiatives (Awoyinka 2009a, 2009b; Philips et al., 2004), increased research and development (Okaiyeto and Lamidi, 2006), increased business opportunities (Azaino, 2008), greater access to loans and other farm inputs (Nweke et al., 2002), increased infrastructure especially in rural areas (Nigeria / UNIDO, 2006) and currently the renewed interest in the crop for the production of biofuels and as important industrial feedstock for the production of starch, beverages, flour, glucose syrup etc (Azih, 2007; Philips et al., 2004; Nweke et al., 2002; Nigeria/UNIDO, 2006; Knipscheer et al., 2007).

Cassava is very important in the diet of Africans and Nigerians in particular. In a study conducted by Phillips et al. (2004), over 30% of respondents claimed that they eat cassava more than four times a week. There are instances where people eat cassava more than twice daily in Nigeria. Nweke et al. (2002) reported that cassava is the most important crop in Nigeria after maize. Cassava is the cheapest source of carbohydrate in Nigeria presently. Majority of the cassava tubers produced in Nigeria are processed into food such as gari, fufu and lafun, with little left for the industry. According to Nweke et al. (2002), after accounting for wastes, about 93% of Africa`s cassava production in the mid 1990s was consumed as food, 6% used as animal feed while only 1% was used as industrial raw material. In Nigeria, of the 32 million tonnes of cassava produced in 2001, 84% was consumed as food, while only 16% was utilized as industrial raw material (Phillips et al., 2004). Among the several foods that cassava is processed into, gari is the most dominant. Hence gari is the most commonly traded cassava product. Knipseheer et al. (2007) estimated that 70% of cassava produced in Nigeria is processed into gari. Hence, of the 45 million tonnes of cassava produced in Nigeria in 2008, about 34 million tonnes is converted into gari.

Wastes are typically generated during the processing of agricultural feedstocks to products. Cassava processing to gari generates liquid effluents (whey), solids (mostly peelings and sieviates) and gaseous emissions. Cassava processing to gari is dominated by the smallholders, which are also referred to as micro, small and medium scale enterprises (MSME). Knipscheer et al. (2007) estimated that the smallholders produce and process over 80% of Nigerian cassava. With a cassava industry of over 45 million tonnes per annum, large qualities of biowastes could be generated. Unfortunately, waste management in Nigeria is very poor. The Federal Government is focusing more on large corporations particularly multi-nationals in the oil and gas sector, whereas the smallholders/food processors especially in the cassava sub-sector are generating and releasing large qualities of wastes into the environment, which are largely un-quantified.

Cassava waste waters have high COD in excess of 32,000 mg/L, high BOD (16,000 mg/L), suspended solids (15,000 mg/L), low pH (3.8 – 4.2) (Plevin and Donnelly, 2004) and high cyanide content in the range of 10.4-274mg/L (Adeyemo, 2005). In other countries, especially in Brazil, China and Thailand with large-scale cassava bio-ethanol refineries, these by-products are processed for the production of animal feed, fertilizer and biogas for electricity generation. In Nigeria, where cassava is mostly processed by MSME, the associated waste streams are not treated by disposed freely into the environment. Ehiagbonarie et al. (2009) reported that cassava processing wastewater is released freely into Nigerian environment without any proper treatment. At the point of cassava effluent discharge, Okafor (2008) recorded 4.0, 6.16ppm, 400ppm and 700ppm for pH, BOD, COD and total solids respectively. Cassava processing effluents also decrease river water dissolved oxygen because of their high oxygen demand. Okafor (2008) also reported a high concentration of cyanide in soil receiving cassava wastes. Effluent emanating from the traditional processing of cassava to gari, flour and starch are often not processed in Nigeria but released into the environment, contaminating nearby drinking water sources. Several reports from Nigeria shows that cassava processing effluents have serious environmental impacts causing acidification due to the hydrolysis of cassava cyanogenic glucoside, linamarin and lotaustralin (methyl linamarin) producing hydrogen cyanide, which is also toxic to household animals, fisheries and other organisms (Adeyemo, 2005, Abiona et al., 2005; Arimoro et al., 2008). Onyedineke et al. (2010) who evaluated the toxicity of cassava processing effluent to a crustacean ostracod, *Strandesia prava* show that the effluents had a LD_{50} values of 0.4786, 0.311 and 0.2818% of effluent concentrations for 24, 48 and 96 hours respectively, with LT_{50} of 169.82, 346.74, 446.68, 562.34 and 2754.23 minutes for 25, 12.5, 6.25, 3.125 and 1.5625% of effluent concentrations respectively. Processing is essential for the removal of cyanides from cassava roots (Cardoso et al., 2005). Other waste stream produced during cassava processing includes peels and bagasse/pulp. During the processing of cassava tubers >10% of the tubers result in peelings whereas 3.25% pulp is produced.

Cassava peels have about 140·90 ppm free cyanide (Balogun and Bawa, 1997). Such waste could contaminate nearby drinking water sources and pollute the air with fermentation odours. Though, the use of cassava peelings for the production of biogas has been demonstrated in the laboratory in Nigeria (Ofoefule and Uzodinma, 2009; Itodo et al., 2007), it has not been widely adopted. Fermentation odours are common in major cassava processing communities in Nigeria like Okada, Ibillo, Omotosho, Ologbo, Ijebu and Mosogar. Hence, the aim of this study is to evaluate the traditional processing of cassava, quantifying the waste production at every stage of the process with the view of suggesting measures to tackle the wastes to minimize environmental impacts.

MATERIALS AND METHODS

This section of the paper contained the procedure for the traditional processing of cassava tubers to gari, field data collection methods and statistical analysis.

Traditional Cassava Processing to Gari

A flow chart for the traditional processing of raw cassava tubers to a toasted granule, gari is presented in Figure 1. Cassava is highly perishable and begins to degenerate shortly (2-3 days) after harvest, hence, the need to process and convert the tubers to a more stable product with long shelf life. There are at least 7 – 8 unit operations in the conversion of cassava to gari including peeling, washing, grating, dewatering, sieving, frying/toasting (garifying), re-sieving and packaging. The smallholder processors typically obtain raw/fresh cassava tubers from their farms or buy from local market. The tubers are peeled manually using knives, after which they are washed and the wash water containing soil particles disposed. The resultant peelings are disposed into the environment without any form of treatment. Next is grating, where mechanical graters are used to grind the peeled cassava tubers. The next unit operation is dewatering, which expels wastewater (cassava whey) from the grinded cassava.

In the rural areas, the cassava is packed into jute bags. The bags are sealed and a heavy weight such as boulders placed upon it to express the liquid wastes from the grinded cassava. Hydraulic and screw presses are now commonly used for dewatering cassava. The dewatering process takes about 2-7 days, during which fermentation takes place. The length of the fermentation period depends on the desired sourness of the final gari product. During the dewatering process, the toxic cyanogenic glucosides present in cassava are expelled along with the effluents. Cassava cake is the end product of the dewatering operation.

Next the cassava cake is sieved manually or mechanically (though not widely adopted yet) using BS 10 sieve. While the sieved cassava is further processed, the sieviates (solid wastes) are discharged into the environment. The sieved cassava is roasted/toasted/fried at 80°C in a process called garification. Optionally, trace quantities of oil palm is added during frying, depending on the desired colour (white or red) of the gari. Additionally, the oil prevents burning during frying; it also helps to detoxify residual cyanide in the gari. The final gari is packed but sometimes an additional re-sieving step is added to produce fine textured gari using BS 14-18 sieve. The resultant gari sieviates (a solid waste) is either disposed of or eaten as snacks or used as animal feeds.

Field Data Collection

Eleven traditional cassava processing centres in Wilberforce Island, Bayelsa State, were sampled. Among the smallholders, cassava is typically processed in small batches <50kg. Samples were collected in triplicates at each unit of operation from the eleven cassava processing centres and weighed using Spring Dial Hoist scale. The raw cassava, process intermediaries and by-products/wastes were weighed in triplicates. Air emission was however estimated by difference between the weight of the sieved cassava and the final product gari.

Statistical Analysis

Eleven cassava processing centres were randomly selected for the study. At each centre, the weight of the raw cassava tubers was measured in triplicates after cleaning the tubers to remove sand particles. Replicate weight measurements were made for all the intermediaries and the final product, gari. Because the initial weight of the starting cassava feedstock is different at all the cassava processing centres, the ratio of the intermediaries relative to the initial cassava weight was computed in order to permit the comparison of the intermediaries among the different processing centres.

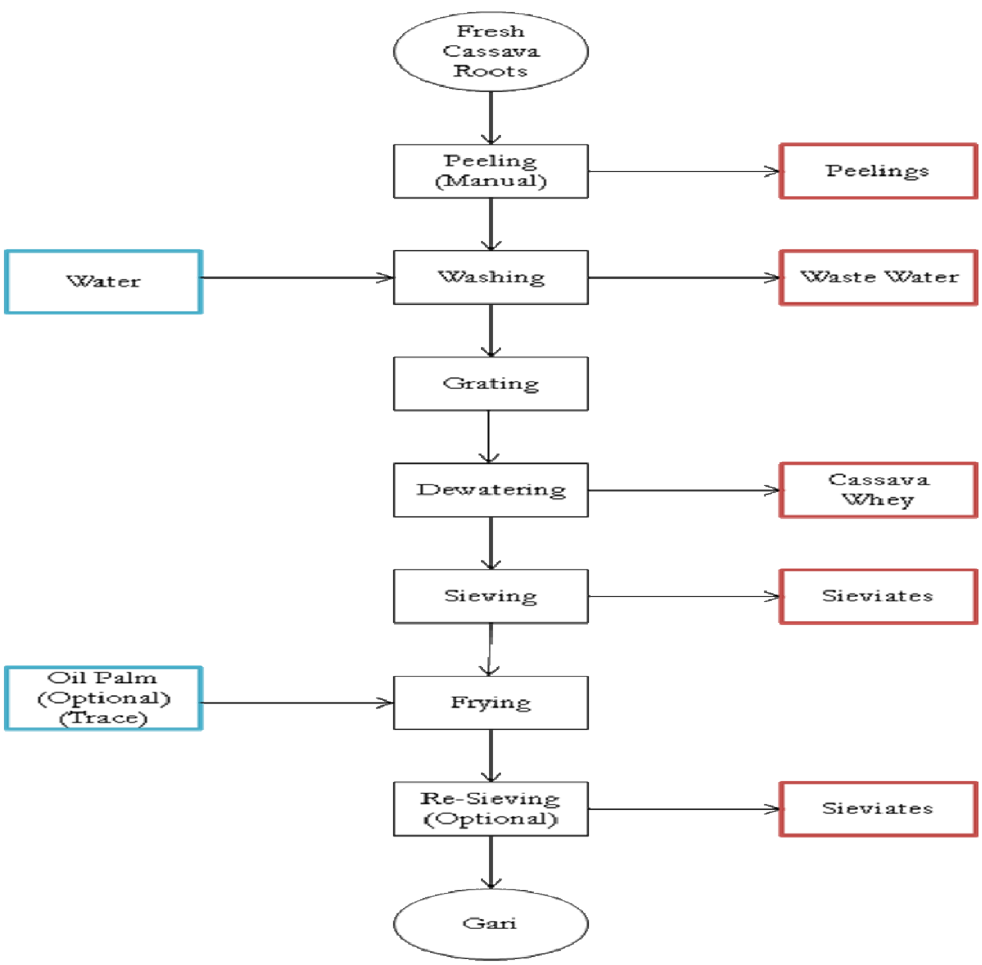

Fig 1: Flow Chart for the traditional processing of Cassava tubes to Gari.

Analysis of variance (ANOVA) was carried out at α=0.05 using SPSS version 17 (SPSS Inc, Chicago). Based on the result of the statistical analysis, the traditional cassava processing flow chart (Fig. 1) was modified using only the significant process operation and indicating the mass balance/fraction during each unit process operations (Fig. 2).

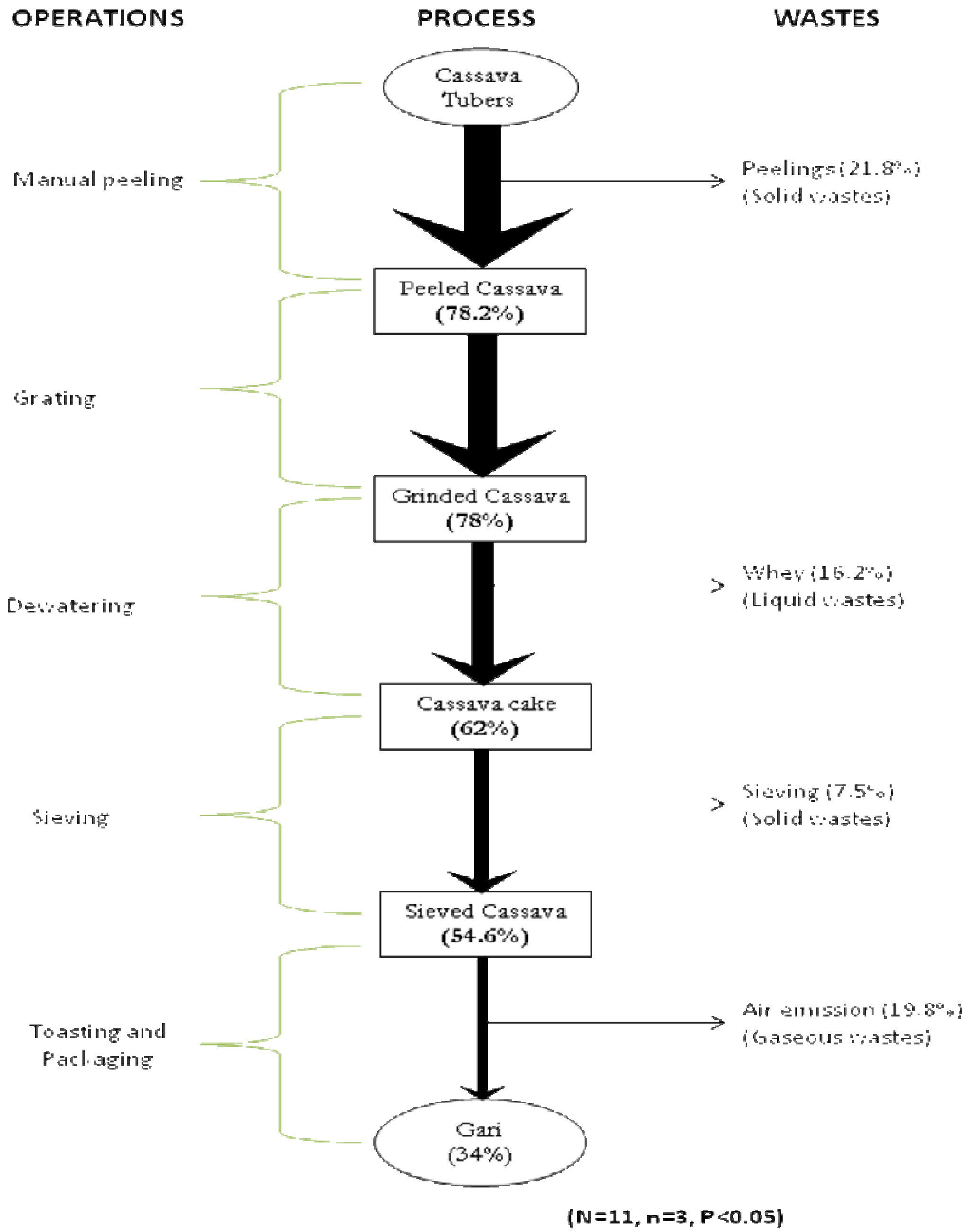

Fig. 2: Analysis of waste stream during the traditional processing of cassava to gari.

Finally, based on the mean measurements at the eleven cassava processing centres (N=11, n=3 P<0.05), the total waste stream generated was estimated.

RESULTS AND DISCUSSION

Table 1: Statistical analysis for the processing of cassava to gari in Wilberforce Island

		Mass Ratio of process intermediaries and products relative to whole cassava tuber biomass										
	Whole cassava, kg	Peeled cassava	Peelings	Grinded cassava	Cassava cake	Cassava whey	Sieved cake	Cake sieviate	Gari	Gari sieviates	Air emissions	Total solid wastes
1	35.533 ±0.067f	0.847 ±0.001f	0.153 ±0.001a	0.858 ±0.012e	0.723 ±0.003e	0.134 ±0.013d	0.587±0.000e	0.136±0.002f	0.451 ±0.002g	0.008 ±0.000a	0.127±0.002a	0.298±0.003c
2	39.933 ±0.067h	0.855 ±0.015f	0.145 ±0.015a	0.867 ±0.002ef	0.782 ±0.011f	0.085 ±0.007b	0.666±0.001g	0.116±0.007e	0.486 ±0.001h	0.023 ±0.000a	0.158±0.000b	0.283±0.008bc
3	28.000 ±0.000b	0.854 ±0.000f	0.146 ±0.000a	0.854 ±0.000e	0.704 ±0.000e	0.150 ±0.000d	0.529±0.000d	0.175±0.000g	0.282 ±0.000c	0.007 ±0.000a	0.239±0.000e	0.329±0.000de
4	35.267 ±0.291e	0.712 ±0.010c	0.288 ±0.010d	0.711 ±0.008b	0.502 ±0.023b	0.209 ±0.009f	0.492±0.008bc	0.013±0.007a	0.268 ±0.002b	0.003 ±0.000a	0.221±0.006d	0.303±0.010c
5	33.900 ±0.058	0.774 ±0.006e	0.226 ±0.006b	0.738 ±0.002c	0.549 ±0.006c	0.190 ±0.006e	0.505±0.001c	0.043±0.004c	0.325 ±0.001e	0.003 ±0.000a	0.177±0.002c	0.272±0.006b
6	29.667 ±0.167d	0.662 ±0.001b	0.338 ±0.001e	0.675 ±0.003a	0.472 ±0.003a	0.203 ±0.002ef	0.454±0.009a	0.018±0.009ab	0.303 ±0.002d	0.007 ±0.000a	0.144±0.008ab	0.363±0.008e
7	34.100 ±0.361e	0.834 ±0.008f	0.166 ±0.008a	0.780 ±0.011d	0.508 ±0.025b	0.273 ±0.003g	0.479±0.009b	0.029±0.008abc	0.264 ±0.003b	0.006 ±0.000a	0.210±0.007d	0.200±0.006a
8	36.167 ±0.318fg	0.739 ±0.006d	0.261 ±0.006c	0.769 ±0.005d	0.658 ±0.007d	0.111 ±0.008c	0.623±0.010f	0.035±0.009bc	0.402 ±0.007f	0.003 ±0.000a	0.219±0.015d	0.298±0.013c
9	38.033 ±0.384g	0.628 ±0.007a	0.372 ±0.007f	0.685 ±0.007a	0.658 ±0.013d	0.026 ±0.001a	0.593±0.007e	0.066±0.001d	0.452 ±0.004g	0.005 ±0.000a	0.135±0.002a	0.444±0.006f
10	27.233 ±0.176a	0.850 ±0.005f	0.150 ±0.005a	0.877 ±0.006f	0.567 ±0.010c	0.311 ±0.002h	0.534±0.003d	0.033±0.004bc	0.241 ±0.002a	0.004 ±0.000a	0.289±0.001h	0.187±0.004a
11	28.867 ±0.033c	0.849 ±0.001f	0.151 ±0.001a	0.853 ±0.002e	0.708 ±0.003e	0.145 ±0.000d	0.543±0.002d	0.165±0.003g	0.271 ±0.001b	0.007 ±0.000a	0.264±0.001g	0.323±0.003cd

Data based on N=11, n=3; mean ± standard error
Mean values with the same alphabet are not significantly different (P>0.05)

The results presented in Table 1 shows that the weight of cassava feed stock used by the different processing centres is different (P<0.05) but are generally <50kg. This is typical of micro and small scale enterprises; whereas medium scale cassava processing centres can scale process up to 2000kg in a single batch. Because of the difference in the initial weight of the cassava feedstock used by the different processors, it became necessary to convert the weight of subsequent intermediaries to ratios relative to the weight of the starting biomass. The mass ratio of the peeled cassava and peelings differs significantly (P<0.05) among the various processing centres. About 62.8 - 85.4% (mean=78.2%) of the mass of the raw cassava was recovered after peeling operations (Fig. 2). Hence, the remaining 14.5 - 37.2% (mean=21.8 ± 8.5%) end up as solid wastes, which are typically dumped into the environment. The peeling wastes generated among the various processing centres was highly varied. This is because peeling is typically done manually, hence the wastes produced is varied and dependent on several factors such as the size and shape of the tubers, the experience of the peelers (operator), sharpness of the knife used for peeling, the number of days that have elapsed since the tuber was harvested, the variety of cassava etc. Cassava processing is highly labour intensive. However, it has been well documented that cassava peeling is the major challenge of cassava processing in Nigeria (Nwokedi 1983; Olukunle, 2005, 2007; Olukunle et al., 2006). Of all the cassava processing steps, peeling appears to be the most time consuming. Jekayinfa and Olajide (2007) reported that a total of 44.88 hours is used to process 1 tonne of raw cassava tubers to gari, the peeling process alone account for 25 hours, i.e. over 55% of the time is spent on peeling alone. In order to overcome peeling constraints, several cassava peeling machines have been designed and some tested to be efficient (Nwokedi, 1983; Adetan et al., 2006; Olukunle, 2005, 2007; Olukunle et al., 2006). But unfortunately, the use of cassava peeling machine is not widespread. In a survey conducted by Adebayo and Sangosina (2005), 89.3% of the 112 respondents had no idea of what a peeling machine is, while the remaining 10.7% who have heard of it, but none has tried to use it or acquire it. Several factors may be responsible for the slow adoption of this new technology of cassava peeling machine. Though, there are prototypes, pilot and field-scale peelers, they have not been extensively tested in the field. Many new agro processing equipments that have been locally fabricated are faced with the problem of high cost, high feedstock losses due to inefficiencies in the conversion processes and frequent breakdowns.

During this study, nearly 22% of the raw tubers consist of peelings. This finding is in line with what has been previously reported by other authors who estimated that peelings account for 10 – 20% of the raw cassava tuber (Jekayinfa and Olajide, 2007; Nweke et al., 2002; Kniper et al., 2007). Ubalua (2007) reported that cassava peels contains a higher level of cyanogenic glucosides than the pulp, which makes the peels unsuitable for animal feeds. Hence the peels are typically dumped into the environment and allowed to decompose naturally. Okafor (2008) reported a large concentration of cyanide in the soil receiving gari processing effluents. During this study, 78.2% of the original cassava tuber was left after the peeling exercise. The peeled cassava was grated and dewatered using screw press. While 47.2 – 78% (mean 62.1 ± 10.5%) of the raw cassava tubers resulted in the production of cassava cake, liquid effluents (whey) accounted for the remaining 2.6 – 27.3% (mean 16.7 ± 8.2%) of the raw cassava tuber. The weight of the whey expelled was significantly different among the different cassava processing centres. It has been variously reported that raw cassava tubers is made up of 70% water (Nweke et al., 2002; Kniper et al., 2007; Plevin and Donnelly, 2004; Knipscheer et al., 2007). Jekayinfa and Olajide (2007) recorded 60% water removal during dewatering using hydraulic press. Depending on the species of cassava, Ehiagbonare et al. (2009) reported that 40 – 70% of the total cyanide in cassava is expelled along with the wastewater. Apart from cyanide concentration, other water quality parameters are also a cause of concern. Okafor (2008) reported cassava effluent discharged to the environment in Bida, Niger State had pH, BOD, COD and total solids of 4.0, 616ppm, 400ppm and 700ppm respectively. Ehiagbonare et al. (2009) compared the level of pH and cyanide in the soil at the discharge point and a control point. pH was 5.37 at the discharge point while it is 6.04 in the control. A cyanide concentration of 25.6 and 0.00 ppm was recorded respectively at the cassava effluent discharge point and control point. In Thailand, cassava processing effluent was characterized with high COD (32,000mg/l), BOD (18,000mg/l), total suspended solids (14,500mg/l) and pH in the range of 3.8 – 4.2 (Plevin and Donnelly 2004). The impact of cassava processing effluents on the environment is heavy. The effluent is highly toxic on account of the high concentration of cyanide compounded by the high acidity. Cassava processing effluent has been shown to cause death to plants and domestic animals including goat and sheep (Ehiagbonare et al., 2009). Arimoro et al. (2008) reported the impacts of cassava effluent on the productivity and abundance of fish and benthic invertebrates. Foul odours are perceived even at a distance of 90.3m from the point of cassava effluent discharges (Ehiagbonare et al., 2009).

During sieving operation 45.4 - 66.6% (mean=54.6 ± 6.5%) of the initial raw cassava is converted to sieved cake, while the remaining 1.3 - 16.5% (mean=7.5 ± 6.1%) emerged as cassava cake sieviates. This solid waste, which consist mostly of fibres are typically dumped into the environment. They were also significantly different among the different cassava processing centres. Gari is the major product of the cassava processing activities. Gari yield range from 24.1 - 45.2% (mean=34.0 ± 9.0%), with the yield significantly different among the various cassava processing centres. Jekayinfa and Olajide (2007) recorded a gari yield of 25%. Gari sieviates produced during cassava frying in Wilberforce Island was in the range of 0.3 – 2.3 (mean=0.7 ± .06%) but was not statistically significant ($p>0.05$) among the different cassava processing centres. During the frying of gari, air emission was in the range of 12.7 – 28.9% (mean 19.8 ± 5.4%). The air emission is suspected to contain moisture and cyanide. This range is quite different from the 1.5% recorded by Jekayinfa and Olajide (2007).

On the final analysis, the total solid wastes produced during cassava processing consisting of peelings and sieviates accounting for 18.7 – 44.4% (mean 30.0 ± 7.1%), which differ significantly among the different cassava processing centres. Total liquid waste is 16.2%, while the gaseous emission consisting of moisture and cyanide accounted for the remaining 19.8% (Fig 3).

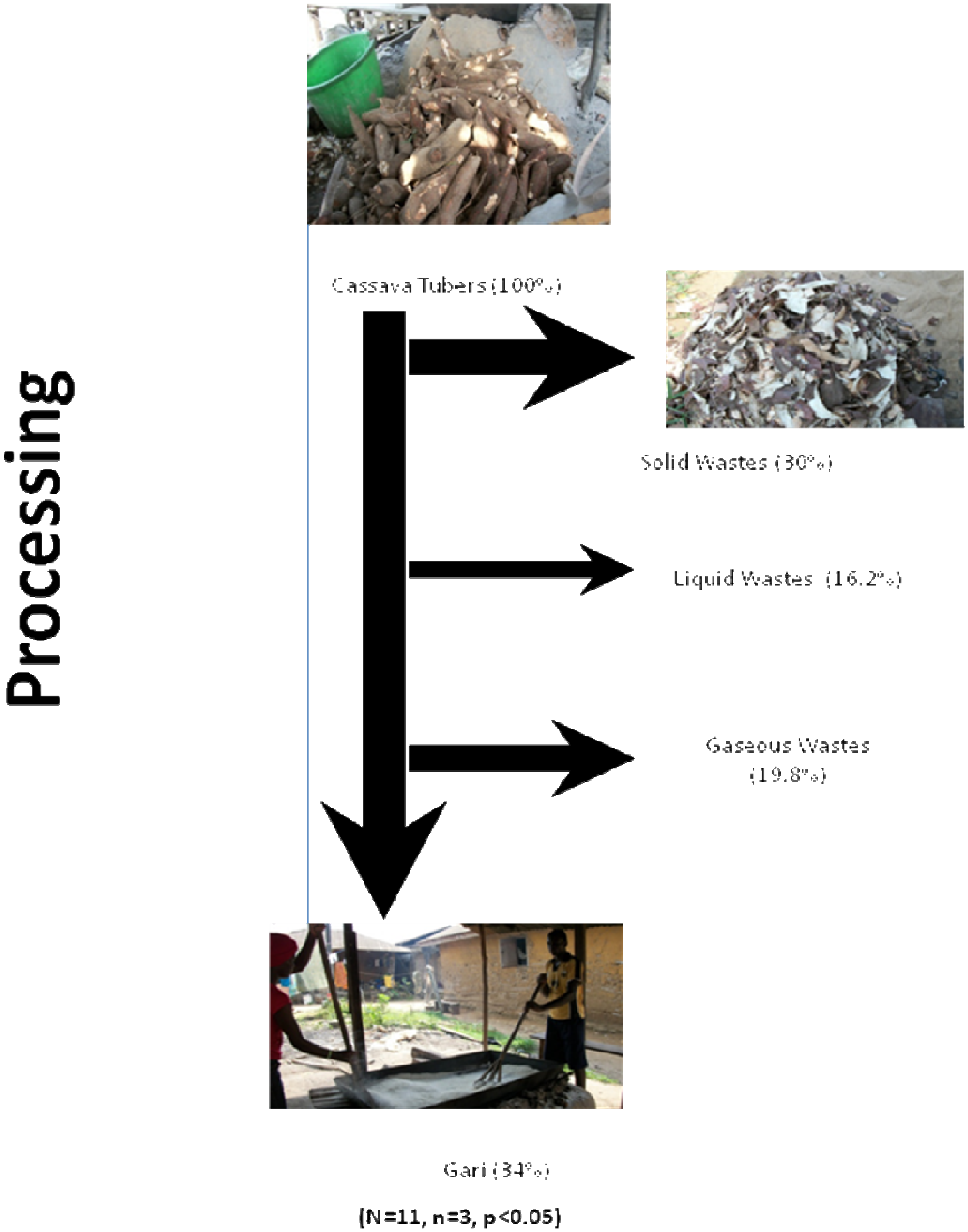

Fig 3: Summary of waste streams generated during the conversion of Cassava tubers to Gari.

CONCLUSION

Smallholder cassava processors dominate cassava processing in Wilberforce Island and Nigeria at large. There are about 7 – 8 steps in the processing of cassava to gari. Most of these steps are mechanized except peeling and frying. The peeling phase is the most labour and time consuming phase. The yield of gari is only 34%, while wastes including solid, liquid and air emissions accounted for the rest. With Nigeria being the largest producer of cassava in the world, and the majority of cassava being converted to gari, a large amount of wastes is typically produced annually, amounting to about 30 million tonnes. This is highly significant. The cassava process wastes are not utilized in Nigeria, but freely discharged into the environment causing environmental pollution. We therefore conclude that the traditional processing of cassava to gari in Nigeria is extremely wasteful.

In order to prevent environmental impacts arising from the huge waste streams generated during cassava processing, we suggest the various waste should be gathered and converted to useful products including fuel ethanol (Akpan et al., 1988; Opoku and Uraih 1983; Kosugi et al., 2009), animal feeds (Balogun and Bawa, 1997; Phillips et al., 2004), biogas and electricity (Ofoefule and Uzodinma, 2009; Plevin and Donnelly, 2004), bio-surfactants (Barros et al., 2008) and raw materials for several industrial applications for the production of mushrooms, single cell protein, enzymes, organic acids, amino acids and other buck chemicals (Pandey et al., 2000; Sriroth et al., 2000).

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