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An Assessment of Indigenous Innovations in Wet *Fufu* Paste Production: Prospects, Constraints and Processing Risk Implications

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ABSTRACT

Immense opportunities in cassava-tuber value addition have resulted in the development and application of indigenous innovations by small and medium scale cassava processors across the country. This study examines the prospects and challenges faced by indigenous wet fufu paste processors; highlighting waste generation and handling, processing techniques and inherent processing risks. Data were collected using a structured questionnaire administered in 50 processing clusters scattered across the study area (Ifo, Ogun State, Nigeria). Target oral interviews were used to validate the questionnaire and elicit information on the processing clusters, adopted processing techniques, processing equipment, wastewater generation and disposal techniques, and processing risk factors. Wastewater quality parameters were also obtained to assess the level of compliance with permissible limits and the risk implications of disposed of effluent. Processing operations were entirely manual and dominated by young indigenous women working in organized groups of 2-6 people depending on the expected output. About 47% of the tested wastewater parameters were above local (NESREA - National Environmental Standards and Regulations Enforcement Agency) and international (WHO - World Health Organization) limits. Inorganic constituents like sodium, calcium, magnesium, phosphate and heavy metals were found in low quantities. However, heavy metals (cadmium, lead and chromium) exceed the permissible limits. Open land disposal (50%), nearby streams/rivers (13%) and open drains (37%) are the predominant wastewater disposal technique adopted by processors. The risk implications of these techniques were highlighted, and alternative solutions were proffered to mitigate the identified risks and encourage the development of improved innovations among processors.

Keywords: Cassava-tuber; Fufu processors; Wastewater disposal; Risk; Indigenous innovations

INTRODUCTION

CASSAVA-ROOT PRODUCTION AND PROCESSING: AN OVERVIEW

Cassava (*Manihot esculenta* Crantz) is a major source of food, feeding more than 800 million people worldwide. More than 70% of cassava is produced by subsistence farmers in rural and peri-urban areas of Africa, Latin America, and Asia. Africa produces about 147 million tonnes, with Nigeria leading with about 54 million tonnes annually; this is about 20% of global production (FAOSTAT 2013; Lawal et al. 2018). Its status as a subsistence agricultural crop is giving way to a more industrialized processing system that converts the tuber into diverse products used as raw material in animal nutrition and other industrial products (Avancini et al. 2007; Jansson et al. 2009; Lebot 2009 and Lei et al. 2012). It is known to be more perishable than other root and tuber crops and categorized as a sensitive species in terms of postharvest deterioration (Zainuddin et al. 2017). Cassava tissue postharvest deterioration accounts for 29% of post-harvest losses and has been reported to cause substantial qualitative and quantitative losses resulting in production and market risks in Africa (FAO 1995; FAO 2000; Djabou et al. 2017). The synthesis of toxic cyanide which is responsible for tissue deterioration is initiated within 48-72 hours from the spot of root damage during harvesting (Conn 1969; Ravi & Aked, 1996; Saravanan et al. 2016; Zainuddin et al. 2017). This threat engenders the need for prompt post-harvest processing.

Various indigenous processing techniques aimed at reducing the cyanide content of the processed tissue and add value to the final products have been developed in most cassava cultivating communities. These innovations often come with attendant risks resulting from sustained physical contact with the tubers during processing, tedious manual processing operations adopted by processors, low level of education/enlightenment and crude processing techniques.

CASSAVA PROCESSING ACTIVITIES, UTILIZATION AND WASTE GENERATION

The growing demand for high-quality cassava products has encouraged the establishment of medium to large scale processing factories which are mostly located in rural and peri-urban communities due to accessibility to fresh cassava tubers. In the past, the impacts of these factories are seldom noticed by regulatory bodies due to the low volume of generated waste with negligible environmental effects. The enormous waste currently generated by these factories is currently alarming due to massive environmental pollution and contamination of freshwater sources.

An understanding of the current indigenous processing techniques is needed to develop an effective processing system. Cassava processing technique and utilization varies in different parts of the world. In Nigeria, different forms in which processed cassava tissue exist include cassava bread, wet and dry chips, *elubo lafun* (fermented cassava flour), cassava starch, roasted/boiled cassava, *fufu* or *akpu* (wet fermented cassava paste) and *gari* (fermented and roasted cassava grit) (Westby 2002; Sobowale et al. 2016). The dominant activities in processing cassava-tuber into wet *fufu* paste have been consistent over time; however, minor improvements have been made due to increased public awareness. This has reduced the inherent processing risk and increased overall processing efficiency by reducing processing time, energy consumption and operation cost. While some of these indigenous innovations have helped to improve overall process efficiency and earned plaudits from researchers, they are largely characterized by manual activities and sustained contact with raw cassava root resulting in musculoskeletal disorders (MSDs) and contact-related risks.

Generally, the production of wet *fufu* paste is less time-consuming and less tedious when compared with other cassava processing activity in Nigeria. It involves manual peeling and submerging the peeled tubers in water for 3-4 days to soften and ferment. Retting of the soft tissue is done manually in large plastic/metallic drums or locally built concrete tanks. The fibre is left for about 24 hours to sediment after which the starchy water is decanted to obtain the final product as shown in the block flow diagram in Figure 1.

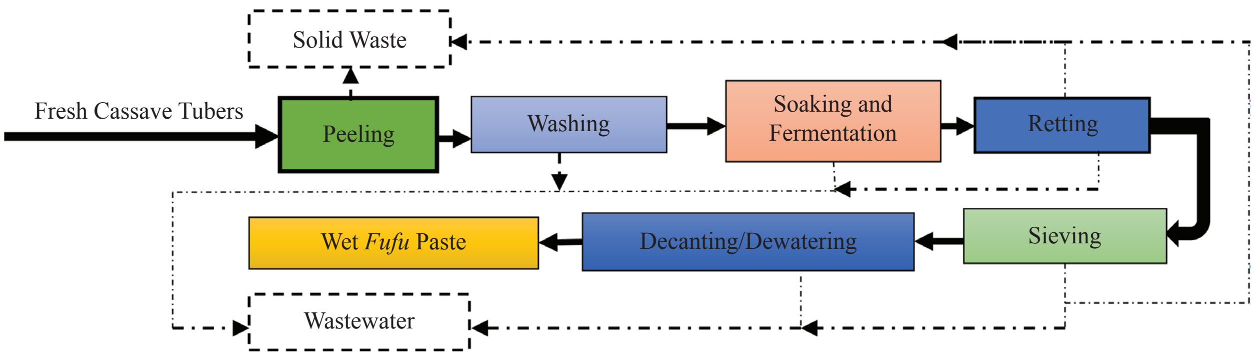

FIGURE 1. Block flow diagram of wet *fufu* paste production and waste generation

The mesh is dewatered by placing it in polyethylene sacks and allowing the residual water to slowly drain out overnight (Oyewole & Sanni 1995). The wastewater generated from the whole process is usually discharged into drains or uncultivated lands around processing clusters, causing stench and groundwater contamination as reported by Omotioma et al. (2013) and Nweke (1992). A holistic understanding of the techniques and risk factors is required to develop a sustainable solution that will mitigate the inherent risk and improve the current processing techniques. This study is the first step in a series of interdisciplinary research aimed at proffering sustainable solutions to the current environmental and health risks faced by processors. It seeks to assess the techniques, prospects and limitations of the current indigenous innovations with their inherent risks and suggest improved alternatives that will further promote innovativeness in wet *fufu* paste production among local processors.

METHODOLOGY

The study area (Ifo, Ogun State, Nigeria) was selected for its rich history in cassava cultivation and concentration of localized clusters engaged in processing cassava-tubers into wet *fufu* paste. Structured questionnaires were administered to obtain data from fifty randomly selected processing clusters with different processing capacities. Collected data were further validated using target oral interviews. The questionnaire was used to elicit information on the processing clusters, adopted processing techniques, processing equipment, wastewater generation and disposal techniques, and processing risk factors. The results are presented after statistical analysis. Biological oxygen demand (BOD_5), chemical oxygen demand (COD), pH, electrical conductivity (EC), turbidity, Magnesium, Calcium, Sodium and total coliform count were analyzed in triplicates from the wastewater samples collected from the processing clusters using Standard Methods (APHA 1998). Cyanide content was measured spectrophotometrically with Merck Spectroquant

14800 Kit as described by Colin et al. (2006). Atomic Absorption Spectrophotometer was used to determine the level of heavy metals in the wastewater samples. The total coliform count was determined by dispensing and diluting 1 ml of the wastewater sample into a sterile petri dish using a sterile pipette. 15-20 ml of sterile nutrient agar was mixed thoroughly by swirling gently. The mixture was incubated at 37°C for 24 hours after which the number of colonies growing in the agar plate was counted and recorded.

RESULTS AND DISCUSSION

CHARACTERISTICS OF CASSAVA WASTEWATER

The average physicochemical characteristics of collected samples are presented in Table 1. Effluent is basically generated from root washing, soaking/fermentation, retting and decanting. Samples were collected from 15 representative processing clusters scattered across the study area. Slight variations were observed for most parameters. Effluent pH ranged from 3.73 to 3.86. The low volume of fresh water used accounts for the high COD (32000 mg/l) and relatively low BOD (1837 mg/l) recorded. Heavy metal concentrations were all beyond local and international permissible limits. The level of indigenous processing technology, the variety of cassava tuber, and soaking duration account for the wide variations observed in the standard deviation values of some physicochemical parameters. This finding was also corroborated by Colin et al. (2006). Freshwater scarcity has been reported to influence almost all aspect of human existence (Teow et al. 2017). Cassava processing activity is mostly dependent on freshwater availability. Production capacity is drastically reduced during the dry season since freshwater is mostly obtained from boreholes and deep wells. The low water table during this period and the erratic power supply needed to power the borehole pumps is a major challenge faced by local processors. They are forced to minimize water usage and obtain water from other sources which undermine the product quality and largely account for the seasonal variations observed in the effluent pollutant levels (Zaiedy et al. 2016).

In this study, about 47% of the physicochemical parameters exceed local (NESREA) and international (WHO) limits. This could be detrimental to the environment if disposed of without appropriate treatment. An example is the reduction of pH and sunlight penetration which drastically impedes food availability to aquatic life.

TABLE 1. Biophysicochemical characterization of cassava processing wastewater

S/No.	Parameters[a]	Values		Values[b]	Maximum Permissible Limits	
		Min.	Max.		WHO	NESREA
1	pH	3.73	3.86	3.80 ± 0.07	8.5	9
2	Electrical conductivity	4.23	8.76	6.63 ± 1.90	400	NSc
3	Total dissolved solids	3200	5250	3973.33 ± 1113.84	50	500
4	CO_3^{2-}	ND	387	NS	500	200
5	TSS	2.5	9.28	2.63 ± 0.19	NS	25
6	COD	752.7	56000	32000 ± 21166.01	80	60
7	BOD	312.4	1889	1837 ± 75.82	40	30
8	Na2+	42.84	52.38	47.34 ± 4.80	0.4	200
9	Ca2+	35.4	47.28	42.84 ± 4.32	600	200
10	Mg2+	24.87	38.24	32.20 ± 6.78	NS	200
11	Phosphate	0.263	0.324	0.29 ± 0.03	-	3.5
12	Nitrate	0.147	0.86	0.16 ± 0.01	50	44
13	Oil and Grease	ND	0.386	0.13 ± 0.22	-	10
14	Cadmium	ND	0.07	0.03 ± 0.04	0.005	0.003
15	Lead	0.013	0.24	0.09 ± 0.13	0.001	0.05
16	Chromium	0.23	0.78	0.50 ± 0.28	0.05	0.1
17	Iron	0.27	0.56	0.39 ± 0.15	-	20
18	Sulphate	0.08	0.18	0.13 ± 0.05	-	250
19	Hydrogen Cyanide	0.26	0.64	0.46 ± 0.19	0.007	0.01
20	Turbidity	21.3	28.6	24.87 ± 3.65	5	5
21	Total Coliform	1.6×10^3	2×10^3	$1693.33 \times 10^3 \pm 368.96$	-	400

[a]All parameters are in mg/l except for pH; Electrical conductivity (μS/cm); Turbidity (NTU); and Total coliform count (CFU/100 ml). [b]Mean value was obtained from 15 processing clusters with all analyses in replicates. [c]NS=Not stated; ND= Not detected.

RISK IMPLICATIONS OF TRADITIONAL CASSAVA PROCESSING OPERATIONS

Wet *fufu* paste unit operations (peeling, washing, soaking and fermentation, retting, sieving, decanting/dewatering and packaging) have been associated with various processing hazards (Samuel & Adetifa 2018). The environmental and health risk of these operations has been reported by several authors as shown in Table 2. The risks reported in this study results from sustained exposure to raw cassava tubers, loading and unloading, repetitive motion and awkward posture adopted during processing. The accumulation of cassava peels and the indiscriminate disposal of high organic wastewater accounts for the environmental risks observed in the study area. These risks result from the disposal of untreated effluent into nearby streams and drainages, spillage of water from overflowing processing tanks and burning of cassava peels. Other negative impacts include environmental degradation, reduction of the aesthetic value of the surrounding as shown in Figure 3, offensive odour, and contamination of soils and groundwater. The flow of generated effluent into streams and rivers may affect aquatic plants and animals since polluting constituents like cyanide and heavy metals exceed permissible limits. Processors are also exposed to various occupational related ailments and ergonomic disorders as shown in Table 2. Sustained exposure to lower levels of cyanide have been reported as a significant cause of weakness and may result in permanent paralysis in extreme cases (Oyegbami et al. 2010). The impact of indiscriminate disposal of generated wastewater on the vegetative cover is shown in Figure 2 and 3.

FIGURE 2. Effect of raw cassava effluent on the vegetative cover

WET FUFU PROCESSING LIMITATIONS AND PROSPECTS

Despite extending the shelf life and market value of wet *fufu* paste by local processors using indigenous innovations (Dipeolu et al. 2001); the growing health concern associated with this process present researchers and equipment developers with immense opportunities to develop simple processing equipment that will eliminate the current sustained physical contact with the toxic tissue.

Currently, the production process is dominated by tedious manual operations. Peeling, as a critical processing operation

FIGURE 3. Environmental impact of cassava processing effluent on an open dumping site

was observed as the most tedious processing operation mostly done by women and children. Despite its importance, an efficient simple low-cost manual cassava peeler is yet to be developed. Previous efforts have been limited to research institutes and local fabricators. An abrasive cassava peeling machine was previously developed but this technology is limited to large-scale cassava processing industries and has not been widely circulated (Agbetoye 1999).

Rural and peri-urban centres where most processing centres are currently located are currently faced with infrastructural challenges ranging from unavailable or constant power outages, lack of adequate clean water and lack of modern wastewater treatment facilities. These challenges must be considered to develop an appropriate processing technology. An alternative to wet *fufu* paste was recently developed (dry *fufu* powder), but its acceptability is still low with limited producers due to the substantial initial investment cost required. Mechanical and hydraulic screw presses have also been developed for cassava mesh dewatering; since the amount of water expected to be drained from wet *fufu* mesh is minimal, its application is still limited to *gari* processing. Some wet *fufu* paste processing operations that currently requires urgent technological interventions include cassava peeling, retting/pulverization, packaging, and storage.

WASTEWATER GENERATION AND PROCESSING STRUCTURES

Similar to other agro-processing activities, cassava processing consumes enormous amount of fresh water. The peeled tubers are mostly soaked in frustum shaped concrete tanks with volumes ranging from 1.25 m^3-1.97 m^3. The concrete tanks are usually lined with polyethylene to prevent product contamination by sand particles eroding from the walls of the concrete structure (Figure 4).

This practice is consistent among all the processors visited. About 63% of the processors use plastic drums while very few (1%) use metallic drums lined with concrete. Product colouration resulting from rusted metallic drums and durability of the drums account for this low figure. About 31% of the processors use rafter reinforced frustum shaped concrete tanks lined with polyethylene (Figure 4 and 5). Few (5%) household processors use clay pots (Figure 6). Cassava

FIGURE 4. Cassava soaked in concrete tanks lined with polyethylene during retting

FIGURE 5. Rafter reinforced frustum shaped concrete tank

root washing accounts for about 39% of the generated wastewater while soaking/fermentation operation accounts for half (50%) of the generated effluent. Equipment clean up and other domestic activities account for the remaining 10.99% (Figure 7).

The quantity and quality of generated wastewater generally depend on the adopted technology, the quantity of cassava processed, the source of processing water and the amount of domestic activity in the processing plant.

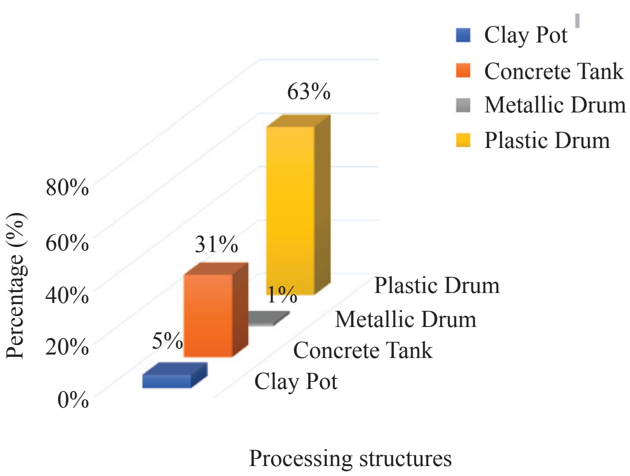

FIGURE 6. Cassava processing structures for wet *fufu* paste

This was also observed in a study on sour starch agroindustry in Colombia by Colin et al. (2006). It is expected that the wastewater generated from washing peeled cassava will contain less cyanide and other pollutants since the fresh water contact period with the tubers are relatively low. Retting of soft cassava tissue is done using lined metallic drums or concrete tanks after soaking for about 3-4 days to soften the tissue and reduce the toxic cyanide content of the roots.

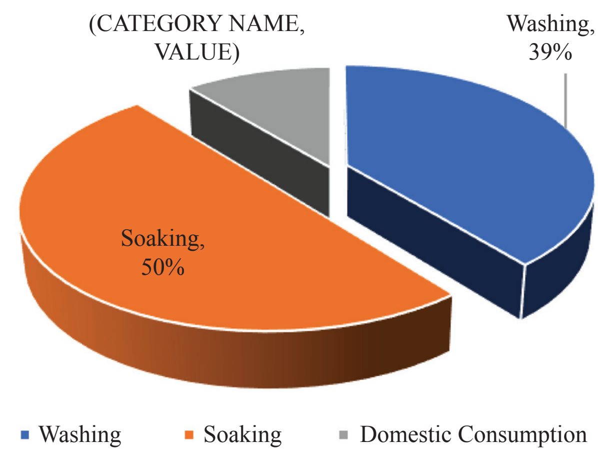

FIGURE 7. Water consumption during wet *fufu* paste production

Soaking/retting generates the highest quantity of high organic wastewater. Almost 50% of the processing clusters visited generate between 501-2119 litres of wastewater.

Processors obtain freshwater from four main sources: borehole (52%), public water supply (1%), stream/rivers (31%) and hand dug wells (16%). This is presented in Figure 8. These sources also impact on the quality of generated effluent as these sources are used without prior treatment.

The various wastewater disposal techniques practised in the study area are shown in Figure 9. These include open drains (37%), nearby streams/rivers (13%) and open uncultivated land (50%).

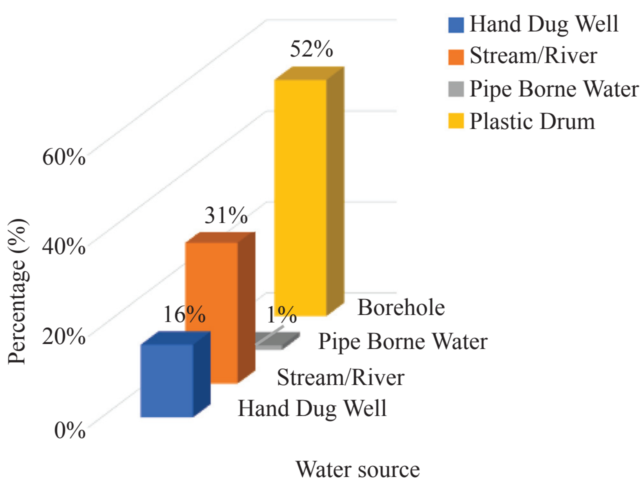

FIGURE 8. Processing water source

TABLE 2. Processing operations, occupational hazards, and risks associated with the traditional method of wet *fufu* paste production

S/No.	Processing Operation	Related Occupational Hazards	Risk Implications	References
1	Peeling	Knife cut/bruises, contact-dermatitis, and erythema. Eye irritation and redness due to the burning of accumulated cassava peels. Soft tissue injuries (risks around the wrist – carpal tunnel syndrome) and musculoskeletal disorders caused by sustained exposure to cassava roots, repetitive motion, and awkward posture.	Aesthetic and environmental degradation, odour, increase in soil and water microbial load which may lead to the destruction of vegetative covers. Work-related musculoskeletal disorders in the low back and upper back due to prolonged sitting.	Omueti, (2004); Oyegbami (2004); Oyegbami et al. (2010); Samuel and Adetifa (2013); Kolawole, 2014; Samuel and Adetifa (2018); this study.
2	Washing	Contact-dermatitis, erythema, skin irritation and pain lasting 15 to 30 minutes at the contact point and general body aches and weakness which may lead to paralysis in extreme cases.	Contamination of surface and groundwater sources, degradation of processing equipment due to rust, air pollution due to unrestrained disposal and destruction of vegetative covers.	Oyegbami (2004); Oyegbami et al. (2010); Kolawole et al. 2012; this study.
3	Soaking/ Fermentation	Back pain and skin irritation due to direct contact with raw cassava tissue.	Offensive odour from uncovered fermentation tanks attracts infestation of insects and rodents. Spilt water on uncemented processing floors results in soil and groundwater pollution.	Oliveira et al. (2001); Oyegbami (2004); Oyegbami et al. (2010); Okunade and Adekalu (2013); this study.
3	Retting	Direct skin contact with the cassava mash leads to contact-dermatitis and erythema, skin reactions and pain.	Generated waste tissue litters the processing environment and generates strong stenches. The untreated wastewater is the most significant source of environmental pollution affecting both plant and animal life.	Fajemilehin & Jinadu, (1992); Oyegbami (2004); Oyegbami et al. (2010); this study.
4	Sieving/sifting	Ergonomic disorders and backache due to prolong standing and bending of the vertebral column. Processors are also faced with the hazards mentioned in 2 and 3 above due to prolonged skin contact with the roots.	Accumulation of large hips of waste tissue litters the processing area, degrades the environment, and clogs drainages preventing the free flow of water. The "milky juice" generated also leads to surface and groundwater pollution.	Fajemilehin & Jinadu, (1992); Fellows (1997); Oboh (2004); Oyegbami (2004); Oyegbami et al. (2010); this study.
5	Dewatering	Skin irritation due to direct contact with wet cassava mesh. Over time, this also results in contact-dermatitis, erythema, skin irritation, and pains.	Damages to vegetation and structures. The highly toxic wastewater contaminates the soil, affects animals and contributes to groundwater pollution.	Fajemilehin & Jinadu, (1992); Fellows (1997), Oboh (2004); Oyegbami (2004); Kolawole et al. 2011; Kolawole, 2014; this study.
7	Packaging/Bagging	This stage exposes processors to skin irritation as mentioned in 2 and 3, musculoskeletal risks, lifting related ailments and ergonomic disorders such as backaches, pains, and fatigue.	Seepage from bagged products aid corrosion which may contaminate products with rust fungus. Corrosion of metallic parts also necessitates frequent repairs of transporting vehicles resulting in substantial transportation cost.	This study.

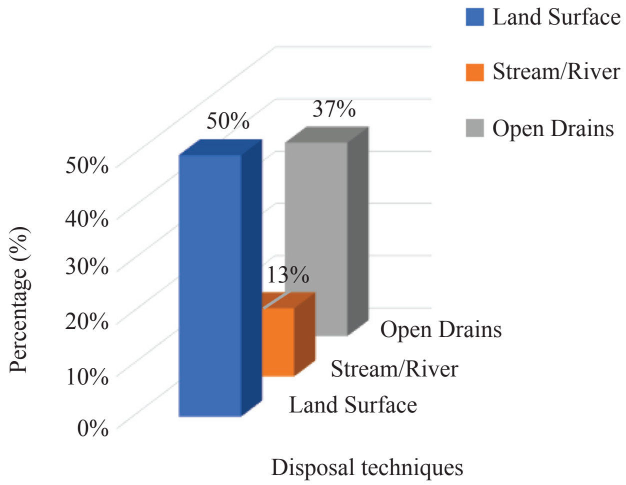

FIGURE 9. Wastewater disposal techniques

The environmental impact of these practices has been widely reported, but much has not been done to check this practice. The impact of this practice is presented in Figure 2 and 3. All the processing clusters visited lack necessary wastewater treatment facilities. The effect of this practice on the vegetative cover around processing areas is shown in Figure 2 and 3. Processing operations are mainly done on uncemented floors which results in groundwater pollution. spilt water from processing tanks also results in wet floors and unhealthy processing environment.

CONCLUSION

Efforts to add value to cassava tubers and improve profitability through processing have engendered the adoption of various indigenous innovative processing techniques. These techniques and their inherent risks were assessed and extensively discussed. While these innovations should be applauded, they often come with attendant risks that have not been addressed. Despite efforts to improve these techniques, all the processing operations in wet *fufu* paste production are still being done manually, exposing processors to the various risks highlighted in this study. Huge opportunities, therefore, exist for researchers and equipment designers to develop sustainable systems and improved focused designs that will address the current challenges. Processing operations should be optimized to reduce contact with the tubers and enhance product quality and shelf life. Collaborative effort is needed to widely circulate research findings to relevant stakeholders to further improve on the current gains. Processors enlightenment should be intensified by relevant authorities to mitigate processing and environmental risks. Lastly, environmental laws should be strictly enforced and improved waste management facilities should be provided to properly manage generated waste.

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REFERENCES

Agbetoye, L.A.S. 1999. Developments in cassava harvesting mechanization. *West Indian Journal of Engineering* 22(1): 11-19.

American Public Health Association (APHA). 1998. *Standard methods for the examination of water and wastewater,* 20th edition, Washington DC. American Public Health Association.

Avancini, S.R.P., Faccin, G.L., Vieira, M.A., Rovaris, A.A., Podesta, R., Tramonte, R., de Souza, N.M.A. & Amante, E.R. 2007. Cassava starch fermentation wastewater: characterization and preliminary toxicological studies. *Food and Chemical Toxicology* 45(11): 2273-2278.

Colin, X., Farinet, J.L., Rojas, O. & Alazard, D. 2006. Anaerobic treatment of cassava starch extraction wastewater using a horizontal flow filter with bamboo as support. *Bioresource Technology* 98(8): 1602-1607.

Conn, E.E. 1969. Cyanogenic glucosides. *Journal of Agricultural and Food Chemistry*, 17(3): 519-526.

Dipeolu, A.O., Adebayo, K., Ayinde, I., Oyewole, O.B., Sanni, L.O., Pearce, D.M., Wandschneider, T.S., White, J.L. & Westby, A. 2001. *Fufu* marketing systems in South-West Nigeria. *NRI Resources Institute Report* R2626.

Djabou, A.S.M., Carvalho, L.J.B.C., Li, Q.X., Niemenak, N. & Chen, S. 2017. Cassava postharvest physiological deterioration: a complex phenomenon involving calcium signalling, reactive oxygen species and programmed cell death. *Acta Physiologiae Plantarum* 39(91): 1-10.

Fajemilehin, B.R. & Jinadu, M.K. 1992. Occupational health hazards associated with traditional methods of cassava processing in Nigeria. *Finnish Institute of Occupational Health African Newsletter* 2: 38-39.

FAO. 1995. Post-harvest deterioration of cassava A biotechnology perspective. *Plant production and protection paper 130.* FAO. Rome, Italy. http://www.fao.org/docrep/v4510e/V4510E09 .htm Accessed on: 1st August 2018.

FAO. 2000. The World cassava economy, facts, trends and outlook FAO. Rome Italy. 46.

FAOSTAT. 2013. Food and agricultural division of United Nations, statistics division. http://www faostat.fao.org/site/291/default.aspx Accessed on: 21st July 2018.

Jansson, C., Westerbergh, A., Zhang, J., Hu, X. & Sun, C. 2009. Cassava, a potential biofuel crop, in (the) People's Republic of China. *Applied Energy* 86(1): S95-S99.

Kolawole, O.P., Agbetoye, L.A.S. & Ogunlowo, A.S. 2011. Evaluation of cassava mash dewatering methods. *Journal of Bioinformatics and Sequence Analysis* 3(2): 23-30.

Kolawole, O.P., Agbetoye, L.A.S., Ogunlowo, A.S. & Samuel, T.M. 2012. Preventing occupational ailments and disorders associated with cassava mash dewatering techniques. *International Journal of Prevention and Treatment* 1(2): 27-30.

Kolawole, P.O. 2014. Cassava processing and the environmental effect. *The 4th World Sustainability Forum*, 1-7.

Lawal, N.S., Babalola, A.A., Adama, O.O., Sosanya, A.O. & Adebayo, A.A. 2018. Characterization of different cassava effluents and evaluation of processor on-site handling techniques in Ogun state, *Nigeria. Journal of Engineering and Engineering Technology* 12(2): 261-268.

Lebot, V. 2009. *Tropical Root and Tuber Crops: Cassava, Sweet Potato, Yams and Aroids.* CABI Publications.

Lei, S., Shungang, W., Zebin, Y., Yinghui, W. & Shuangfei, W. 2012. Anaerobic biological treatment of high strength cassava starch wastewater in a new type up-flow multistage anaerobic reactor. *Bioresource Technology* 104: 280-288.

Nweke, F. I. 1992. Traditional cassava processing in sub-Saharan Africa and research implication. *International Potato Center.*

Omotioma, M., Mbah, G.O., Akpan, I.J. & Ibezim, O.B. 2013. Impact assessment of cassava effluents on Barika stream in Ibadan, Nigeria. *International Journal of Environmental Science, Management and Engineering Research* 2(2): 50-56.

Oboh, G. 2004. Management of occupational hazards associated with traditional method of cassava processing. *Proceedings of a workshop on promotion of improved management technologies aimed at reducing occupational and environmental hazards associated with cassava processing in Ogun, Ondo and Oyo States*, 11-19.

Okunade, D.A. & Adekalu, K.O. 2013. Physico-chemical analysis of contaminated water resources due to cassava wastewater effluent disposal. *European International Journal of Science and Technology* 2(6): 75-84.

Oliveira, M.A., Reis, E.M. & Nozaki, J. 2001. Biokinetic parameters investigation for biological treatment of cassava mill effluents. *Water, Air and Soil Pollution* 126(3-4): 307-319.

Oyegbami, A. 2004. Social hazards associated with cassava processing and control management practices. *Proceedings of a workshop on promotion of improved management technologies aimed at reducing occupational and environmental hazards associated with cassava processing in Ogun, Ondo and Oyo States*, 33-37.

Oyegbami, A., Oboh, G. & Omueti, O. 2010. Cassava processors' awareness of occupational and environmental hazards associated with cassava processing in South-Western Nigeria. *African Journal of Food, Agriculture, Nutrition and Development* 10(2): 2176-2186.

Oyewole, O.B. & Sanni, L.O. 1995. Constraints in traditional cassava processing – the case of *fufu* production. *ORSTOM Editions*, 523-529.

Ravi, V. & Aked, J. 1996. Review on tropical root and tuber crops. II. Physiological disorders in freshly stored roots and tubers. *Critical Reviews in Food Science and Nutrition* 36(7): 711-731.

Samuel, T.M. & Adetifa, B.O. 2013. Assessing musculoskeletal risks in gari-frying workers. *Leonardo Journal of Sciences* 23: 61-76.

Samuel, T.M. & Adetifa, B.O. 2018. Prevalence of the risk of work-related musculoskeletal disorder in the stirring task of gari frying as a result of different sitting postures. *International Journal of Engineering Research in Africa* 37: 43-51.

Saravanan, R., Ravi, V., Stephen, R., Sheriff, T. & George, J. 2016. Post-harvest physiological deterioration of cassava (Manihot esculenta) – A review. *Indian Journal of Agricultural Sciences* 86(11): 1383-90.

Sobowale, S.S., Awonorin, S.O., Shittu, T.A., Oke, M.O. & Adebo, O.A. 2016. Estimation of material losses and the effects of cassava at different maturity stages on garification index. *Journal of Food Process Technology* 7(2): 1-5.

Teow, Y.H., Ghani, M.S.H., Wan Mohammad Hamdan, W.N.A., Rosnan, N.A., Mohamad Mazuki, N.I. & Ho, K.C. 2017. Application of membrane technology towards the reusability of lake water, mine water, and tubewell water. *Jurnal Kejuruteraan* 29(2)2017: 131-137.

Westby, A. 2002. Cassava utilization, storage and small-scale processing. *Cassava Biology, Production and Utilization* 14: 281-300.

Zaiedy, N.I., Karim, O.A. & Mutalib, N.A.A. 2016. Water quality of surface runoff in loop two attachment area in UKM. *Jurnal Kejuruteraan* 28(2016): 65-72.

Zainuddin, I.M., Fathoni, A., Sudarmonowati, E., Beeching, J.R., Gruissem, W. & Vanderschuren, H. 2017. Cassava post-harvest physiological deterioration: From triggers to symptoms. *Postharvest Biology and Technology* 142: 115-123.