

**OCCUPATIONAL HEALTH HAZARDS ASSOCIATED WITH GARI
PRODUCTION AND THE POSSIBLE ENVIRONMENTAL EFFECTS OF THE
RESULTANT EFFLUENT**

BY

ADABIE, DEREK FIIFI

(10272513)

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DECLARATION

I hereby declare that, with the exception of specific references which have been duly acknowledged, this study is as a result of my own research and it has not been submitted either in part or whole for any other degree elsewhere.

Signature:

Derek Fiifi Adabie
(Student)

Date

Signature:

Prof. Paa Nii T. Johnson
(Principal Supervisor)

Date

Signature:

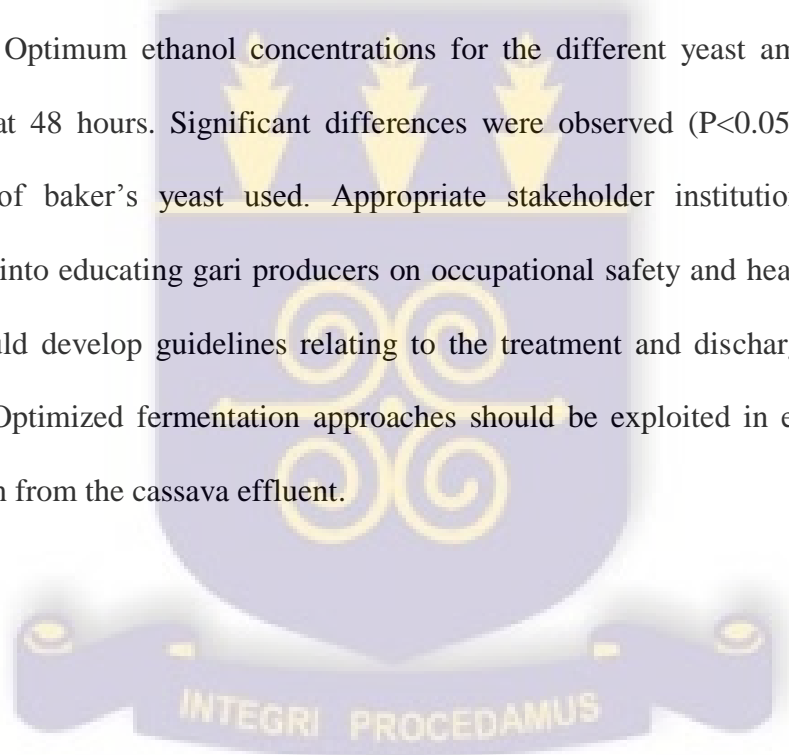
Dr. (Mrs.) Benedicta Fosu-Mensah
(Co-Supervisor)

Date

ABSTRACT

Cassava (*Manihot esculenta*, Crantz) is primarily grown for its starch containing tuberous roots, which are a major source of dietary energy in the tropics. It is highly perishable and begins to degenerate shortly after harvest. Cassava in the fresh form contains cyanide, which is extremely toxic to humans and animals. These factors make the processing of cassava into a dry form a necessity. Processing is essential for the removal of cyanides from cassava roots. This post-harvest necessity via gari production is coupled with several disturbing occupationally-related hazards. Exposure to volatile cyanide and smoke makes the frying stage of gari making the most dangerous. Effluent derived from gari production is noted to have a devastating effect on vegetation, as vegetation is hardly observed in areas where effluents are discharged. It also causes the eutrophication of surface water. This research aimed at determining processors' awareness of occupational health hazards relating to their line of work, and their awareness of the environmental hazards associated with the discharge of untreated cassava effluent. The study further sought to determine the quality of cassava wastewater, and the possible generation of ethanol from the liquid waste using *Saccharomyces cerevisiae* in varying amounts. Processors from three gari producing districts in Ghana served as respondents. These gari-producing districts were; Awutu Senya, Central Tongu and Ayensuano Districts. Cluster sampling of each district was used in selecting the respondents. Ninety (90) gari producers served as respondents. Processors acknowledged health related hazards associated with their line of work, coupled with a low usage of protective clothing. Processors indicated several undesired effects the discharge of the effluent had on their immediate environment. Effluents obtained from these districts were assessed for

wastewater quality, which showed values far outside EPA accepted limits; with the exception of $\text{PO}_4\text{-P}$ (0.125 mg/L) and $\text{NO}_3\text{-N}$ (0.070 mg/L), which were within acceptable limits. Mean values of the other quality parameters measured were; pH (4.02), Conductivity (12223.3 $\mu\text{S/cm}$), TSS (2078.3 mg/L), TDS (41597 mg/L), COD (60335 mg/L) and BOD (23493 mg/L). These very high wastewater quality parameters indicate that cassava effluent has a strong potential of being deleterious to vegetation and aquatic life. Optimum ethanol concentration (3.25%w/v) was obtained in baker's yeast at 0.6%w/v. Optimum ethanol concentrations for the different yeast amounts used were obtained at 48 hours. Significant differences were observed ($P < 0.05$) in the different amounts of baker's yeast used. Appropriate stakeholder institutions should invest resources into educating gari producers on occupational safety and health. The EPA and WRI should develop guidelines relating to the treatment and discharge of the cassava effluent. Optimized fermentation approaches should be exploited in enhancing ethanol production from the cassava effluent.



DEDICATION

This work is dedicated to my wonderful parents, Mr. Joseph Adabie and Mrs. Doris A. Adabie.



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LIST OF ABBREVIATIONS

APHA	-	American Public Health Association
AS	-	Awutu Senya District
AWWA		American Water Works Association
AY	-	Ayensuano District
BOD	-	Biochemical Oxygen Demand
CCOHS		Canadian Centre for Occupational Health and Safety
CDC	-	Centre for Disease Control and Prevention
COD	-	Chemical Oxygen Demand
CSIR	-	Council for Scientific and Industrial Research
CT	-	Central Tongu
DO	-	Dissolved Oxygen
EC	-	Electrical Conductivity
FAO	-	Food and Agriculture Organisation
FAS	-	Ferrous Ammonium Sulphate
GP	-	Gari Production
HCN	-	Hydrogen Cyanide
IITA	-	International Institute of Tropical Agriculture

ISSER	Institute of Statistical, Social and Economic Research
MoFA -	Ministry of Food and Agriculture
MSU -	Mississippi State University
NYSDOH	New York State Department of Health
OSH -	Occupational Safety and Health
RTIP-	Root and Tuber Improvement Programme
TDS -	Total Dissolved Solids
TSS -	Total Suspended Solids
USGS -	United States Geological Survey
WAAPP	West African Agricultural Productivity Programme
WEF -	Water Environment Federation
WRI -	Water Research Institute
WSDOE	Washington State Department of Ecology

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Cassava (*Manihot esculenta*, Crantz) is primarily grown for its starch containing tuberous roots, which is a major source of calories for roughly two out of every five Africans (Nweke, 2003). Cassava is a dietary staple in much of tropical Africa (IITA, 2009). It is highly perishable (explained by its high moisture content) and begins to degenerate shortly (2 – 3 days) after harvest. The bulky roots contain much moisture (about 70%), making their transportation from rural areas difficult and expensive (Bani, 2008). Cassava in the fresh form contains cyanide, which is extremely toxic to humans and animals. These factors make the processing of cassava a necessity. Processing the tubers into a dry form reduces the moisture content and converts it into a more durable and stable product with less volume, which makes it more transportable (IITA, 1990). Cardoso *et al.* (2005) noted that, processing is essential for the removal of cyanides from cassava tubers.

In Ghana, majority of cassava tubers are processed into ‘gari’, cassava dough (agbelima), cassava flour and starch. The tubers are also prepared into readily eaten foods such as ‘fufu’, ‘kokonte’ and ‘attieke’ (also spelt ‘acheke’). Gari is one of the most shelf-stable cassava-processed foods, with a moisture content of 8 – 10% (IITA, 1990). It is prepared to be used over a very long period of time; unlike some other derived foods, which are to be utilized immediately or within a relatively short period after being processed. Gari has a long shelf life, a year or more as long as it is not exposed to moisture (Nweke, 2003).

This study would focus on gari, a toasted granule derived from cassava. Gari is a grated, fermented and roasted cassava food product. Cassava processing into gari involves several unit operations which include peeling, washing, grating, pressing and fermenting, sieving and frying.

The activities and conditions present in small-scale gari production leaves processors exposed to several occupational-related hazards. As with most, if not all occupations and trades, gari production (especially on the small-scale traditional level) has its inherent occupational related hazards (Adenugba and John, 2014). These health hazards include inhalation of cyanide and smoke (Howeler *et al.*, 2000; Adenugba and John, 2014). Adenugba and John (2014) reported that gari producers identified several occupational hazards (associated with their work) such as; ‘knife cuts’, ‘ergonomic hazards’, eye irritations, and exposure to intense heat and smoke.

One by-product of cassava processing into gari (as with all forms of cassava processing) is the generation of liquid waste, derived from the dewatering stage. Despite it being a waste (usually not utilized), its indiscriminate and continuous disposal could have dire consequences on the environment (Bengtsson and Triet, 1994; Howeler *et al.*, 2000, Arimoro *et al.*, 2008).

1.2 Problem Statement

Conditions under which processors operate and activities carried out during gari production tend to predispose processors to health risks (Adenugba and John, 2014). Processors (mainly women and children) producing gari in ill-ventilated sheds, are often exposed to high levels of hydrogen cyanide (HCN) liberated during frying (Howeler *et*

al., 2000). Skin irritation (itchiness) has been reported among gari producers, and this was reported to be caused by the cyanide present in the cassava, when it comes into direct contact with the skin (Adenugba and John, 2014). Exposure to cyanide could prevent human cells from using up oxygen, leading to the eventual death of these cells (CDC, 2013). Smoke from the furnace could be irritating to the eyes, nose and throat (NYSDOH, 2013) of the processor; and cause a likely shortness in breath (WebMD, 2014). Inhaling carbon monoxide (present in smoke) could decrease the body's oxygen supply (NYSDOH, 2013). Also, the heat being emanated (alongside the smoke) from the furnace could lead to increased irritability and loss in concentration and ability to do mental tasks (CCOHS, 2014).

Several environmental problems could arise with the indiscriminate discharge of the effluent as, sufficient volume of cassava wastewater discharge can cause eutrophication of slow moving water systems (Howeler *et al.*, 2000), leading to oxygen depletion and death of aquatic life. Arimoro *et al.* (2008) reported the decline and total elimination of some benthic macroinvertebrates, as they were intolerant to the effects of the cassava-mill effluents. Bengtsson and Triet (1994) indicated possible harmful effects of the wastewater on the young stage of cultivated rice and vegetables. Olorunfemi *et al.* (2008) observed cassava effluent to be inhibitory to seed germination and seedling growth of *Zea mays*, *Sorghum bicolor* and *Pennisetum americanum*. Continuous application of the effluent resulted in the withering of the plants (Olorunfemi *et al.*, 2008). Ogundola and Liasu (2007) also noted that vegetation was hardly observed in areas where effluents were discharged.

1.3 Justification

Health and safety hazards encountered by processors need to be identified, as little information is available on the health predicaments faced by processors present in the gari value chain in Ghana. In so doing, expedient measures could be put in place to resolve the distressing and disturbing issues of occupational safety and health. Toxicity of the cassava-mill effluent resulting from this postharvest necessity (gari processing) would have to be investigated, and subsequently, appropriate mitigation measures developed. Making use of the effluent for something other than discharging into the environment would be beneficial. The possibility and the use of cassava-mill effluent for the production of alcohol could provide additional income generation for the processors. This would further enhance livelihood diversification options available to the rural settlers, through which they could contribute more to the economic capital of their households and improve their standards of living. With the use of unsophisticated methods and technologies, the processors and rural folks should easily relate to this value addition option, hence, a likely high adoption rate. The findings of this study will inform decisions with regards to the handling and usage of the generated effluent.

1.4 Objectives

This study aimed at assessing the potential effect of the effluent from gari production, and the provisions made by gari producers in minimizing occupational-health related issues.

The specific objectives were to;

- Assess processors' level of awareness of occupational health hazards associated with cassava processing into gari, and environmental hazards of the generated effluent.
- Determine quality of the generated (untreated) cassava-mill effluent, and identify the possible effects of the effluent on soil and water quality.
- Determine ethanol concentration that could possibly be derived from the cassava-mill effluent via fermentation with *Saccharomyces cerevisiae*.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Cassava

2.1.1 Crop Origin, Culture and Ecology

Cassava (*Manihot esculenta* Crantz) is a perennial woody shrub with an edible root, which grows in tropical and subtropical areas of the world. It belongs to the family Euphorbiaceae (spurge family). Though it is a perennial crop, it is grown as an annual crop. Cassava originated from tropical America and was first introduced into Africa in the Congo basin by the Portuguese around 1558 (IITA, 2009). O’Hair (1995) states that, cassava specifically originated from Brazil and Paraguay. Presently, it is a dietary staple in much of tropical Africa (IITA, 2009). Today it has been given the status of a cultigen with no wild forms of this species being known (O’Hair, 1995). Cassava cultivation is done in the tropical and subtropical regions of the world.

It is extensively cultivated for its edible starchy tuberous root. It is rich in carbohydrates, calcium, vitamins B and C, and essential minerals (IITA, 2009). However, nutrient composition differs according to variety and age of the harvested crop, and soil conditions, climate, and other environmental factors during cultivation (IITA, 2009). Though the roots are very starchy, the young leaves are a good source of protein (Bradbury and Holloway, 1988).

Cassava is propagated from stem cuttings. Roots can be harvested between 6 months to 3 years after planting (IITA, 2009). This is usually based on the variety, growing conditions and what the crop is to be used for. For human consumption, harvesting usually takes

place at about 8 to 10 months; for industrial uses, a longer growing period generally produces a higher root and starch yield (FAO, 2013). It takes 18 or more months to produce a crop under adverse conditions such as cool or dry weather (O’Hair, 1995). In the tropics, plants can remain unharvested for more than one growing season, allowing the storage roots to enlarge further (O’Hair, 1995). However, as the roots age, the central portion becomes woody and inedible (O’Hair, 1995). Its wide harvesting window allows it to be used as a famine reserve, harvested on a meal to meal basis (Nweke, 2003).

Cassava is easy to grow, yields well in good conditions and even in poor soils (IITA, 2009). Formerly regarded as a resource-poor farmer’s crop and as a food security crop, cassava was generally neglected by researchers (Plucknett *et al.*, 2000). Cassava was often relegated to marginal lands due to competition with higher-value crops (Plucknett *et al.*, 2000). Cassava is of increasing importance particularly in arid and semi-arid areas because of its hardy, drought-resistant nature, that can give acceptable yields even in low-fertility soils and in low rainfall conditions (FAO, 2013) and with limited labour requirements (IITA, 2009). The ability of cassava to produce reasonable yields on poor soils, in areas with low rainfall, and under low management levels makes it a suitable and attractive crop for poorly resourced farmers in the tropics (FAO, 2013). It tolerates a wide range of soil pH 4.0 to 8.0 and it is most productive under high light intensity (O’Hair, 1995). The crop has long been used as a famine reserve and food security crop (Plucknett *et al.*, 2000) The importance of cassava is embodied in the Ewe (a language spoken in Ghana, Togo and Benin) name for the plant, ‘agbeli’ meaning ‘there is life’.

In sub-Saharan Africa cassava is mainly a subsistence crop, grown for food by small-scale farmers who sell the surplus (IITA, 2009). Ghana has an estimated 790,000 Ha of

land under cassava cultivation, which produces an output of 9.6 million metric tons of cassava per annum (Dziedzoave, 2008).

2.1.2 Constituents of the Tuber and its Utilization

Roots of the cassava plant form large starchy tubers, somewhat similar to sweet potato, with a dark brown fibrous covering and white flesh. It has been reported that raw cassava tubers consist of up to 70% water (Plevin and Donnelly, 2004). The cassava tuber is an energy-dense food, with a high carbohydrate content ranging from 32 - 35% on a fresh weight basis, and 80 – 90% on a dry matter basis (Montagnac *et al.*, 2009). Cassava tubers are rich in calories but low in protein, fat, and some minerals and vitamins (Montagnac *et al.*, 2009). Cassava tubers have a crude protein content of about 1.5% (Montagnac *et al.*, 2009). IITA, (2009) noted that the tubers are also high in calcium and vitamin C. The nutritional value of the tuber is, however, lower than those of cereals, legumes, and some other root and tuber crops (Montagnac *et al.*, 2009).

Cassava tubers also contain linamarin and lotaustralin (two cyanogenic glycosides), which are formed from amino acids. The cyanogenic glucosides are hydrolysed to cyanide in the presence of linamarase (an enzyme present in the cassava) (O’Hair, 1995). Formerly, cassava was categorized as either sweet or bitter, signifying the absence or presence of toxic levels of cyanogenic glucosides (O’Hair, 1995). Sweet and bitter cultivars were related with low and high cyanogen levels, respectively. Sweet cultivars can produce as little as 20 mg of hydrogen cyanide (HCN) per kg of fresh roots, while bitter ones may produce more than 50 times as much (O’Hair, 1995). The bitterness is identified through taste and smell, but this is not a totally valid system, since sweetness is not absolutely correlated with HCN producing ability (O’Hair, 1995). A more appropriate

and useful guide based on total root cyanide content was used by Bourdoux *et al.* (1982): innocuous <50ppm, moderately poisonous 50 – 100ppm and dangerously poisonous >100ppm. The unsafe nature of very high cyanide varieties is emphasized by the name of one variety in Nigeria, referred to as ‘chop and die’ (Cardoso *et al.*, 2005). Intake of cyanide aggravates goitre and cretinism in iodine deficient areas (Delange *et al.*, 1994).

Apart from being a food staple, the cassava tuber is a very versatile commodity; its derivatives and starch are applicable in many types of products and industries such as foods and confectionery, sweeteners, glues and adhesives, plywood, textiles, paper-making, biodegradable products, monosodium glutamate, pharmaceutical drugs, high fructose syrup and alcohol brewery (O’Hair, 1995; IITA, 2009).

Dried tubers can be milled into flour; maize may be added during the milling process to provide protein to the flour. Cassava flour may be used as partial substitute for wheat flour in making bread (O’Hair, 1995). Bread made wholly from cassava has been marketed in the U.S.A. to meet the needs of people with allergies to wheat flour (O’Hair, 1995). In the culinary arts, fresh roots can be sliced thinly and deep fried to make a product similar to potato chips (O’Hair, 1995). They can be cut into larger spear-like pieces and processed into a product similar to French fries (O’Hair, 1995). Cassava is now a preferred material for making biofuels, and also used for laundry starch, which is used in clothing and laundry industries. IITA (2009) also notes that cassava chips and pellets are used in animal feed. Unpeeled roots can be grated and dried for use as animal feed (O’Hair, 1995).

2.1.3 Postharvest Issues of Cassava

Though, cassava cultivation requires less labour and resources, its post-harvest phase calls for considerable amounts of post-harvest labour (IITA, 2009). This is because the cassava tubers are highly perishable and must be processed into storable form within a day or two after harvest. This was confirmed by over two-thirds of local (Ghanaian) cassava farmers in a survey, where they credited post-harvest loss as a major risk factor in the production of cassava (NRI, 1992). The rapid post-harvest deterioration of cassava restricts the storage potential of the fresh root to a few days (Wenham, 1995). In addition to direct physical loss of the crop, postharvest deterioration causes a reduction in root quality, which leads to price discounts and contributes to economic losses (Wenham, 1995).

Cassava is much more perishable than the other major root and tuber crops (Wenham, 1995). This is attributed to the fact that the tuber (being the storage organ) has no dormancy (Wenham, 1995). Primary (or physiological) deterioration of the tuber is the initial and major cause of the qualitative and quantitative post-harvest loss, while secondary deterioration can become more important later (Wenham, 1995). Physiological deterioration in cassava roots appears to share many of the common characteristics of plant wound responses (Wenham, 1995). Physical damage which is an inevitable consequence of harvesting cassava roots, initiates the chain of events leading to physiological deterioration, which usually precedes the opportunistic invasion by microorganisms (Wenham, 1995). Cassava tubers are highly susceptible to physical injury (Bani and Josiah, 2008). Fresh tubers can suffer serious physiological deterioration within 24 hours after harvest (Bani and Josiah, 2008). Physiological deterioration, in

most cases, develops from sites of tissue damage and is initially observed as blue-black discoloration of the vascular tissue, referred to as vascular streaking.

Secondary deterioration occurs when pathogens penetrate through wounds and bruises inflicted during the harvesting and handling of the tuber (Wenham, 1995). Microbial activity is the most common cause of secondary deterioration, although fermentation or root tissue softening can also occur (Wenham, 1995). In some situations, secondary deterioration may be the initial cause of loss; and in these instances, symptoms of vascular streaking frequently occur ahead of the rots (Wenham, 1995). Storage at high humidity encourages fungal rotting, but high humidity is also necessary for effective wound healing (Wenham, 1995). The use of a microbial protectant is therefore often required with preservation methods that are favourable for root curing (Wenham, 1995).

Avoidance of rapid post-harvest deterioration and reduction of cyanide levels are traditionally the main reasons for processing cassava into different food products (Wenham, 1995). Effective processing removes naturally-occurring toxins in the roots, reduces the product's weight for transport, decreases post-harvest losses, and extends shelf life (IITA, 1990; Wenham, 1995; Bani, 2008).

One common practice of avoiding loss, employed by most farmers, is to store or leave the roots in the soil, past the period of optimal root development, until they can be immediately consumed, processed or marketed (Wenham, 1995). The setbacks with this practice are that: land is occupied and thus unavailable for further agricultural production (opportunity cost of land), roots lose some of their starch content, and palatability declines as roots become more fibrous (Rickard and Coursey, 1981).

A number of other cultural practices could come in handy in reducing the rate of deterioration. Harvesting and handling of cassava roots should be done with care (Bani and Josiah, 2008). Minimize damage at harvest by harvesting while the soil is wet, an ideal situation would be after a rainfall. Retain only roots that show no or little signs of injury, since curing will not be effective on tubers with extensive damage (Wenham, 1995). O’Hair (1995) notes that, removal of the leaves two weeks before harvest lengthens the shelf life to two weeks. Dipping the roots in paraffin or a wax, or storing them in plastic bags reduces the incidence of vascular streaking and extends the shelf life to three or four weeks (O’Hair, 1995). To reduce impact and compression damage, the tuber could be harvested with 2 – 3 cm of stem attached (Bani and Josiah, 2008). Some traditional methods include packing the roots in moist mulch to extend shelf life (O’Hair, 1995). Storage of cassava roots under moist conditions, as encountered in soil reburial methods, can promote the healing of wounds in roots damaged at harvest (Wenham, 1995). Curing of cassava tubers at high humidity levels also improves potential storage life (Bani and Josiah, 2008). Conditions favourable for wound healing/curing are 30°C to 40°C, and 90% to 95% relative humidity for 2 to 5 days (Bani and Josiah, 2008).

Cassava tubers store fairly well under refrigeration (Bani and Josiah, 2008). Cassava is the only root that tolerates low temperatures, and can be stored at 0 – 2°C for up to 6 months (Bani and Josiah, 2008). In storage, the tubers could last for 1 – 2 weeks at 5.5 – 7°C, and 85 – 90% relative humidity (Bani and Josiah, 2008). Refrigerated storage slows down the physiological and pathological processes that lead to deterioration (Bani and Josiah, 2008). Precooling of the tuber by hydrocooling or forced air is recommended for refrigerated long-term storage (Bani and Josiah, 2008). Cassava is not susceptible to

chilling injury, as are other tropical root crops if held at too low temperatures (Bani and Josiah, 2008).

Cassava traders usually arrange purchase and sale of their produce in advance to minimize their risk. Assemblers will sometimes buy standing crops in order to increase flexibility in timing the fresh tuber deliveries to urban markets (Wenham, 1995). Furthermore, the quantities handled by cassava traders are usually low, since retailers buy and sell limited volumes in order to assure a rapid turnover of the produce (Wenham, 1995).

To demonstrate the freshness of the tuber, retailers often take extreme measures (Wenham, 1995). Freshness is demonstrated by cutting the roots to show its non-deteriorated internal tissue and traders also deliberately wound certain parts of the roots to cause latex exudation, which is produced only by fresh cassava (Wenham, 1995).

Table 2. 1: Strategies along Food-Chain to Prevent Rapid Deterioration of Cassava Tubers

Channel Member	Strategy
Farmers	Delayed harvest Traditional storage Processing of roots into storable products Processing of old unused root
Traders	Low quantities traded High margins to compensate for risk Purchase of standing crops Highly integrated markets Storage technique (including traditional techniques and transferred technology) Processing of old unsold roots
Processors	Production and processing are in close proximity Small-scale processing in rural areas Processing into broad range of products (for human consumption, industrial use and animal feed) Production for new export markets
Consumers	Substitute fresh cassava with processed foods and cereals, unless cheap fresh roots are available Improved storage techniques, such as refrigeration

Source: (Wenham, 1995).

2.2 Cassava Processing to Gari

2.2.1 Why Process Cassava?

Cassava is well known for the presence of free and bound linamarin and lotaustralin, and are converted to HCN in the presence of linamarase (O’Hair, 1995). The tuber has to be processed to eliminate the naturally occurring toxicant, cyanide (Cardoso *et al.*, 2005). The roots are thus rendered edible through processing. Avoiding rapid post-harvest deterioration is the other major reason for processing cassava into different storable food forms. Effective processing removes naturally-occurring toxins in the roots, improves palatability, reduces the tubers' weight for transport, minimizes post-harvest losses, and extends shelf life (IITA, 1990; Wenham, 1995; Cardoso *et al.*, 2005; Bani, 2008). Urbanization has also led to an increase in the consumption of already-processed foods, thereby, reducing demand for perishable commodities (Wenham, 1995).

2.2.2 Contribution of Gari to the Ghanaian Economy and Its Profitability to the Producer

The largest market for cassava in Ghana is ‘cassava being used as food’, while industrial utilization is still limited but with potential for expansion (WAAPP, 2009). Gari is the most commercialized of all cassava products in Ghana (WAAPP, 2009). Since 1997 to 2008, price/kg of gari generally increased at a faster rate annually than that of maize (a major staple in Ghana), and in 2008, price of gari increased by 8.5 times, while that of maize increased by about 7.3 times. WAAPP (2009) suggested that the increased gari prices during this period could be attributed to increased urban demand and increased export market potential of the commodity.

Export price of gari in 2008 was US\$ 443 per tonne, and that same year Ghana was able to export 3404 tonnes of gari. In 2008, Ghana earned an amount of US\$1,679,719 from the export of gari (WAAPP, 2009).

Ghana was able to export 4,197 tonnes of gari in 1997. This dropped to 1266 tonnes the following year, but since then the quantity exported has been increasing (WAAPP, 2009). The value per tonne of gari (for the export market) has been highly volatile, inconsistent and unreliable. For example, after a steady increase from 2005 – 2007, the export price of gari dropped by more than 30% from US\$ 746 per tonne in 2007 to US\$ 493 per tonne in 2008 (WAAPP, 2009). Commenting on the volatility of prices of Ghana's non-traditional export commodities, ISSER (2007) noted that 'volatility in price of gari' does not make for good policy planning, and that Ghana appears to be mainly a price-taker in the global market for non-traditional export commodities. However, Ghana's potential to enter into world market is limited by high domestic prices of raw materials, inability to supply large orders and lack of grades and standards for Ghana cassava products (WAAPP, 2009).

Quaye *et al.* (2009) found that, benefit-cost ratios for gari production at the small scale level in the Suhum-Krabo-Coaltar, Awutu-Efutu-Senya and Ho Districts were 1.10, 0.95 and 1.06, respectively. WAAPP (2009) reported that gari-cassava price ratio ranged from 2.9 – 3.9. Yidana *et al.* (2013) also noted that the average net profit per month for gari processors in the Central Gonja District was about 50% of the total monthly revenue; and concluded that cassava processing (into gari and cassava dough) was profitable and contributed to the standard of living of the cassava processors in Central Gonja.

2.2.3 Gari Production and Occupational Health Hazards

Small and medium-scale gari processing in Ghana can hardly be differentiated from the homes and living quarters of processors. Such processing is mostly carried out by household units or co-operative groups. Due to lack of financial and technological resources, gari producers cannot maximize their efforts into producing and sustaining large scale production (Yidana *et al.*, 2013).

Gari is a grated, fermented and dehydrated cassava food product, obtained in a dry crispy granular form (IITA, 1990). Processing cassava into gari, known as garification, involves several unit operations such as peeling, washing, grating, pressing and fermenting, sieving and frying. In gari making, fresh roots are peeled, washed and grated (IITA, 1990; Bani, 2008). The grated pulp is put in sacks, and placed under heavy stones or pressed with a hydraulic jack between wooden platforms (Bani, 2008). The grated pulp is pressed for about 3 – 4 days to express moisture present in the pulp (Bani, 2008). During the dewatering stage, fermentation of the pulp takes place (Bani, 2008). It is this fermentation process that is responsible for the taste and aroma of gari (Odunfa, 1985). The dewatered and fermented lumps of pulp are crumbled by hand and some fibrous materials picked out (Bani, 2008). The pulp is then sieved and roasted in an iron pan over fire (Bani, 2008). Palm oil is sometimes added during roasting in order to prevent burning of the pulp (Bani, 2008). The palm oil also imparts a light yellow colour to the final product (Bani, 2008). Palm oil contains a substantial quantity of vitamin A, thus making ‘yellow gari’ more nutritious (Bani, 2008). The garification process is complete when dry crisp granules are obtained (IITA, 1990).

Gari should preferably have a moisture content of 8 – 10% (IITA, 1990). The conversion rate of fresh cassava roots to gari ranges from 14 – 26% (Bani, 2008). This value varies with variety, time of harvest, age of plant and other environmental factors (Bani, 2008).

Processors work on large numbers of tubers at a time, resulting in long sitting sessions. Washing of the tuber is done with bare hands, and in some cases with the feet to march the peeled tubers against each other (Adenugba and John, 2014). The gari worker bends for long periods to do the washing by hand. The frying stage is characterized by long seated sessions, with processors seated close to the fire place.

As with all trades and professions, gari production also comes with its occupational health issues. The various stages involved in cassava processing expose the processor to various occupational health hazards and conditions of ergonomic importance (Adenugba and John, 2014). Aches, cuts and bruises, and fatigue are usually sustained during the execution of manual operations (Adenugba and John, 2014). Peeling of cassava is done manually with the use of clean and sharp knives, and less care could result in cuts (Adenugba and John, 2014). Skin irritation (itchiness) has been reported among gari producers, and this is reported to be caused by the cyanide present in the cassava, when it comes into direct contact with the skin (Adenugba and John, 2014).

Conditions of ergonomic importance include; backache from standing and bending, prolonged bending of the vertebral column and uncomfortable sitting posture during manual operations (Kolawole *et al.*, 2011). The skeletal and muscle systems are the most threatened parts of the human body during cassava processing (Adenugba and John, 2014). Sitting in a particular position over a long period of time (which occurs in the

peeling and frying stages of gari production) results in aches in the back, lower back and the waist (Adenugba and John, 2014).

The occupational hazards also include eye irritation, exposure to smoke from frying the gari, and exposure to gaseous or volatile cyanide (Howeler *et al.*, 2000; Adenugba and John, 2014). The processing of cassava leads to discharge of HCN into the atmosphere (Howeler *et al.*, 2000). Processors (mainly women and children) producing gari in ill-ventilated sheds, are often exposed to high levels of hydrogen cyanide (HCN) liberated during frying (Howeler *et al.*, 2000). Workers involved in such industries are under constant exposure to HCN via inhalation, skin contact and possibly oral intake. Cyanide is a toxic asphyxiant, and its presence in cells affects mitochondrial functioning (Ghosh, 2010). Exposure to cyanide could prevent human cells from using up oxygen, leading to the eventual death of these cells (CDC, 2013). Cyanide exposure can be treated initially with 100% oxygen therapy (Ghosh, 2010). Definitive therapy would have to do with inhalation of amyl nitrite or intravenous sodium nitrite (Ghosh, 2010).

During the frying stage, the processor sits next to the oven or traditional stove to stir, and this becomes unbearable for the worker after some time due to the heat and smoke from the oven (Adenugba and John, 2014). Occupational heat exposure not only threatens the health of the worker when heat illness occurs, but also undermines productivity (Lucas *et al.*, 2014). The heat generated could lead to increased irritability and loss in concentration and ability to do mental tasks (CCOHS, 2014). Smoke from the furnace could be irritating to the eyes, nose and throat (NYSDOH, 2013) of the processor; and causes shortness in breath (WebMD, 2014). Inhaling carbon monoxide (present in smoke) could

decrease the body's oxygen supply (NYSDOH, 2013). Adenugba and John (2014) noted the frying stage to be the most dangerous in the entire gari production exercise.

Better ventilation of processing areas would help safeguard the processors from cyanide inhalation (Howeler *et al.*, 2000). Likewise, wearing protective clothing, such as the overall coat and nose mask, will go a long way in reducing the level of exposure of workers to cyanide at the various cassava processing stages (Adenugba and John, 2014). However, occupational contexts that involve hot and humid climatic conditions, heavy physical workloads and/or protective clothing create a strenuous and potentially dangerous thermal load for the worker (Lucas *et al.*, 2014). Thermal comfort is a key issue in the use of protective clothing (Bishop *et al.*, 2013). The design of most protective industrial clothing reduces the rate of heat dissipation (Bishop *et al.*, 2013). Protective clothing can create a serious heat stress problem, as it can have no or low moisture permeability and high insulating properties (Lucas *et al.*, 2014). Thus, protective clothing can compromise performance and comfort (Bishop *et al.*, 2013), making its use an impractical approach in addressing some occupational health hazards inherent in gari production.

2.3 Cassava-Mill Effluent

2.3.1 Cassava Milling and Effluent Generation

Effluent is generated from the various cassava processing methods, ranging from processing into starch, flour, notwithstanding that of gari. The process of washing, and dewatering by pressing, results in the production of liquid residues. Liquid residue derived from washing is of little impact to the environment (Howeler *et al.*, 2000). Whereas the press water (obtained from draining out the moisture present in the cassava

mash), though produced in relatively low volumes, causes much harm to the environment (Howeler *et al.*, 2000). Reportedly the press water contains a high contaminating load of biochemical oxygen demand (BOD) (Howeler *et al.*, 2000).

2.3.2 Effects on the Environment

Cassava mill effluents have low pH (Plevin and Donnelly, 2004; Olorunfemi and Lolodi, 2011), and when discharged into soils or surface water could lead to lowering of soil pH and water pH. When soil becomes acidic, there is low availability of elements such as calcium, magnesium and phosphorus; and increased solubility of aluminium (Al), iron (Fe) and boron (B) (Kennelly *et al.*, 2012). High levels of these nutrients (Al, Fe and B) can induce toxicity symptoms in plants (Kennelly *et al.*, 2012). Solubility (amount that can be dissolved in water) and biological availability (amount that can be utilized by aquatic life) of heavy metals in water bodies is determined by pH (WSDOE, 1994). In surface water with high acidity, heavy metals become soluble, thus they become available but deleterious to aquatic life (WSDOE, 1994).

Sufficient volume of cassava wastewater discharge could lead to eutrophication of slow moving water systems (Howeler *et al.*, 2000). Oxygen present in the water body would be utilized in the decomposition of the organic content of the cassava wastewater, resulting in oxygen depletion (Howeler *et al.*, 2000). This would render the surface water incapable of supporting aquatic life, leading to detrimental effects on aquatic life forms in the water body (Howeler *et al.*, 2000).

Onyedineke *et al.*, (2010) reported LD₅₀ values of 0.4786%, 0.311% and 0.2818% of cassava effluent concentrations for 24, 48 and 96 hours respectively, in *Strandesia prava*

(a crustacean ostracod). The LT_{50} values recorded were 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 concentration respectively.

Olorunfemi *et al.* (2008) observed cassava effluent to be inhibitory to seed germination and seedling growth of *Zea mays*, *Sorghum bicolor* and *Pennisetum americanum*. Continuous application of the effluent resulted in the withering of the plants (Olorunfemi *et al.*, 2008).

Olorunfemi and Lolodi (2011) studied the physiological and biochemical response of onion bulbs to cassava-processing effluents and concluded that the effluents induced root malformations. Effluents concentrations at 0%, 0.2%, 0.4%, 0.8% 1%, 2%, 3%, 4% and 5% induced slow growth of roots (Olorunfemi and Lolodi, 2011). Strong growth retardation was observed in onion roots growing at high concentrations, while total inhibition in root growth was observed at 20% effluent concentration (Olorunfemi and Lolodi, 2011). At higher concentrations of 1% and 10%, the types of root malformations included root tips bent upwards resembling hooks (crochet hooks), c-tumors (abnormalities appearing as swellings of the root tips) and twists (Olorunfemi and Lolodi, 2011). The roots were pale at these concentrations. At 20% effluent concentration, the roots were dark brown or black in colour (Olorunfemi and Lolodi, 2011). Olorunfemi and Lolodi (2011) further indicated that the toxic compounds in the cassava wastes can be reduced by water dilution.

Adeyemo (2005) reported 20% mortality after 96 hours in *Clarias gariepinus* injected with 5 mL of cassava wastewater and 50% mortality in those injected with 10 mL

cassava effluent. There was 100% mortality after 96 hours in those injected with 15 mL of cassava effluent. Haematological changes observed by Adeyemo (2005) in the catfish included anaemia, and a significantly higher white blood cell (WBC) count. Reduced swimming by the catfish was also observed. *C. gariepinus* injected with higher dose (10 mL) of effluent showed severe necrosis, hypertrophy and vacuolation of hepatocytes (Adeyemo, 2005).

Adekunle *et al.* (2007) noted that acute exposure of *Clarias gariepinus* and *Oreochromis niloticus* to cassava effluent after 96 hours yielded LC₅₀ values of 0.45% and 0.25% respectively. Chronic exposure to the cassava effluent caused reduced growth and poor blood quality. Fish body weights decreased by 3.1–6.7% for *C. gariepinus* and 2.6–8.9% for *O. niloticus*, with increasing cassava effluent concentration (Adekunle *et al.*, 2007).

Arimoro *et al.* (2008) stated that cassava effluents permitted the dominance of oligochaetes and dipterans (both being non-sensitive species) at impact sites of the effluent, but the effluents resulted in a decline and total elimination of other benthic macroinvertebrates, which were intolerant to the effects of effluents. They however concluded that macroinvertebrates have a great capacity to recover from the cassava effluent impact in terms of taxonomic diversity.

2.4 Ghana Environmental Protection Agency (EPA)

The Environmental Protection Agency is the leading public body for protecting and improving the environment in Ghana. It was established June 1974, with the name Environmental Protection Council, and later changed to its present name (EPA, 2014). The Environmental Protection Agency Act, 1994 (Act 490) transformed the

Environmental Protection Council into an Agency having, inter alia, regulatory and enforcement roles (EPA, 2014). The mission of the EPA is to co-manage, protect and enhance the country's environment, as well as seek common solutions to global environmental problems (EPA, 2014).

EPA provides guideline values to determine the quality of wastewater generated and discharged into water bodies (streams, dams, rivers and lakes). These are limits allowed by EPA for the discharge of wastewater into water bodies. Quality of wastewater to be assessed in this study would be determined using the EPA guidelines.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Perception of Gari Producers on Occupational Health Hazards, and on Environmental Effects of the Effluent

A survey was conducted in three cassava producing districts in Ghana; namely, the Awutu-Senya, Central Tongu and Ayensuano Districts; located in the Central, Volta and Eastern Regions of Ghana, respectively. These districts were selected based on their levels of cassava production and processing. Each district was segmented into three clusters, from which respondents were identified, and effluent samples collected. Ninety (90) small/medium-scale gari producers served as respondents, ten (10) respondents were randomly selected from each cluster.

The survey sought to investigate the level of processors' awareness to occupational health hazards, as well as to identify measures instituted by processors to mitigate occupational-related hazards. The survey further investigated the knowledge of the processors on the hazards posed to the environment by the disposal of the (untreated) cassava-mill effluent. Methods employed by the processors in treating and/or adding value to the effluent were also sought for.

3.2 Quality Parameters of the Cassava Effluent

3.2.1 Effluent Collection and Laboratory Analysis

Effluent obtained at the dewatering stage of gari production were collected, two samples of cassava wastewater were taken randomly from each cluster. Sampling of the effluents was done once. Effluent samples were stored in an ice chest and kept below 4°C using ice

blocks, and were transported to the laboratory for analysis. Effluent samples were analyzed at the Water Research Institute (WRI) of the Council of Scientific and Industrial Research (CSIR). Parameters analyzed were pH, electrical conductivity (EC), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total dissolved solids (TDS), total suspended solids (TSS), nitrate ($\text{NO}_3\text{-N}$), phosphate ($\text{PO}_4\text{-P}$), potassium, calcium and magnesium. These parameters were all measured using standard methods by APHA-AWWA-WEF (1998), as discussed below.

3.2.2 Quality Parameters of the Effluent Studied

3.2.2.1 pH

pH was measured using a pH meter and a combination electrode (a set of glass electrode and reference electrode). The electrode was first calibrated using pH buffer 4 and 7. The electrode was withdrawn and rinsed with deionised water. The electrode was immersed in the sample, stirred and reading allowed to stabilize (APHA-AWWA-WEF, 1998).

3.2.2.2 Electrical Conductivity (EC)

The determination of the electrical conductivity provides a rapid and convenient way of estimating the concentration of the electrolytes in solution. The Cyberscan PC510 conductivity meter was used. The conductivity cell and the beaker to be used were rinsed with the portion of the sample to be examined. The beaker was filled completely and the cell of the conductivity meter was inserted into the beaker. When the wastewater sample and the equipment reached the same temperature, the value indicated on the conductivity meter was recorded (APHA-AWWA-WEF, 1998).

3.2.2.3 Biochemical Oxygen Demand (BOD) (Winkler Azide Modification)

Effluent samples collected were diluted with aerated distilled water and incubated at 20°C for 5 days. Dissolved oxygen (DO) concentration was measured before and after incubation. The BOD was calculated from the difference between the initial and final dissolved oxygen.

An amount of 2 mL MnSO₄, followed by 2 mL Alkali-Iodide-Azide solution was added to the day one (DO) sample in BOD bottle. The bottle was corked carefully to exclude air bubbles and shaken thoroughly by inverting several times. Precipitate was allowed to settle. After precipitate had settled, 2 mL concentrated H₂SO₄ was added. The bottle was corked again and inverted several times to dissolve the precipitate, which gave an intense yellow colour. A hundred (100) mL of solution was titrated with Na₂S₂O₃ to a pale yellow colour. One (1) mL of starch was added as indicator. The titration was continued to the first disappearance of the blue colour (APHA-AWWA-WEF, 1998).

Calculation:

$$\text{BOD (mg/L)} = \frac{(D1 - D2)}{P}$$

Where;

D1 = DO of sample immediately after preparation

D2 = DO of sample after 5 day incubation at 20⁰C

P = Decimal volumetric fraction of sample used.

3.2.2.4 Chemical Oxygen Demand (COD) (Closed Tube Reflux Method)

Culture tubes and caps were washed with 20% H₂SO₄ before use, to prevent contamination. Samples were placed in culture tubes and digestion solution added. Sulphuric acid reagent was carefully run down the inside of the vessel to form an acid layer under the sample-digestion solution layer. Tubes were tightly capped and inverted several times to mix completely. Tubes were placed in a block digester preheated to 150⁰C, and refluxed for 2 hours behind a protective shield. The mixture was cooled to room temperature in a test tube rack. Culture tube caps were removed and small TFE-coated magnetic stirrer added, followed by 1 to 2 drops Ferroin indicator. The mixture was stirred rapidly while titrating with standard 0.1 M ferrous ammonium sulphate (FAS). The end point was a sharp colour change from blue-green to reddish-brown. In the same manner, a blank containing reagents and a volume of distilled water equal to that of the sample was refluxed and titrated (APHA-AWWA-WEF, 1998).

Calculation:

$$\text{COD (mg/L)} = \frac{(A - B) * M * 8000}{\text{mL sample}}$$

Where;

A = mL FAS used for blank

B = mL FAS used for sample

M = molarity of FAS

8000 = milli equivalent weight of oxygen × 1000 mL/L.

3.2.2.5 Total Suspended Solids (TSS) (Gravimetric Method)

Suspended solids are solids retained by a glass fibre filter 0.45 µm (or smaller) pore size under specific conditions. It works with the principle that a well-mixed sample is filtered through a weighed standard glass-filter. The residue that is retained on the filter is dried to a constant weight at 105°C. The increase in weight of the filter represents the total suspended solids (TSS).

The filtration apparatus were assembled. The filter was moistened with 10 mL of deionised water to seat it on the funnel. The sample bottle was vigorously shaken and 100 mL volume was transferred to the funnel. The filter was washed with three successive 10 mL volume of distilled water allowing drainage between washings and suction to continue for about three minutes after filtration. The filter was carefully removed from the holder and transferred into a petri dish (already weighed). The dish and the filter were dried for one hour at 105°C in an oven. The filter was cooled in a desiccator and weighed. The drying cycle was repeated until a constant weight was obtained (APHA-AWWA-WEF, 1998).

Calculation:

$$\text{TSS (mg/L)} = \frac{(A - B) * 10^6}{C}$$

Where;

A = weight of filter + dish + residue

B = weight of filter + dish

C = volume of sample filtered

3.2.2.6 Total Dissolved Solids (TDS) (Gravimetric Method)

The procedure followed the steps detailed for TSS. However, the filtrate left after the filtration process was evaporated on a water bath. The residue, obtained after filtration, was dried to a constant weight in an oven at 105°C. The increase in weight over that of the empty dish is the weight of the TDS (APHA-AWWA-WEF, 1998).

Calculation:

$$\text{TDS (mg/L)} = \frac{(A - B) * 10^6}{C}$$

Where;

A = weight of dish + dried residue

B = weight of dish

C = volume of sample filtered

3.2.2.7 Calcium (EDTA Titrimetric Method)

Fifty (50) mL of the wastewater sample was taken and 2 drops of 1 M NaOH solution was added. It was stirred and 0.1 – 0.2 g of the murexide indicator was added and titrated immediately. Ethylene diamine tetra- acetic acid disodium salt (EDTA) titrant was added slowly with continuous stirring until the colour changed from salmon to orchid purple. The endpoint was checked by adding 1 or 2 drops of the titrant in excess to ensure no colour change took place (APHA-AWWA-WEF, 1998).

Calculation:

$$\text{Ca (mg/L)} = \frac{A * B * 400.8}{\text{mL sample}}$$

Where;

A = mL of EDTA titrant used

$$B = \frac{\text{mL of standard calcium solution}}{\text{mL of EDTA titrant}}$$

3.2.2.8 Magnesium (Calculation Method)

Magnesium content was determined from magnesium hardness. Magnesium hardness is calculated from the difference between the total hardness and the calcium hardness. Magnesium content is then obtained by multiplying the magnesium hardness by 0.243 (APHA-AWWA-WEF, 1998).

Calculations:

- (i) From the calcium titration, calcium hardness was calculated

$$\text{Calcium hardness (CaCO}_3\text{)} = \frac{A * B * 1000}{\text{mL sample}}$$

Where;

A = mL titrant for sample

B = mg CaCO₃ equivalent to 1.0 mL EDTA titrant at the calcium endpoint

- (ii) Total hardness concentration was recorded (EDTA Titrimetric Method)

Total hardness is defined as the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate in milligrams per litre. Fifty (50) mL of the sample was pipetted into a conical flask. One milligram of the buffer solution was added to produce a pH of 10 ± 0.1 . A few crystals (0.1 – 0.2 g) of Eriochrome Black T indicator were added. The mixture was then stirred constantly and titrated with standard 0.01 M EDTA (ethylene diamine tetra-acetic acid disodium salt) until the last traces of purple disappeared and the colour turned bright-blue (APHA-AWWA-WEF, 1998).

Calculation:

$$\text{Total Hardness} = \frac{\text{mL EDTA} * B * 1000}{\text{mL sample}}$$

Where; B = mg of CaCO_3 equivalent to 1.0 mL EDTA titrant

- (iii) Magnesium hardness was calculated

$$\text{Magnesium Hardness} = \text{Total Hardness} - \text{Calcium Hardness}$$

- (iv) Magnesium concentration was calculated for

$$\text{Mg (mg/L)} = \text{Magnesium Hardness} * 0.243$$

Where;

$$0.243 = \frac{\text{atomic weight of Mg}}{\text{molecular weight of CaCO}_3}$$

3.2.2.9 Nitrate (Hydrazine Reduction Method)

Ten (10) ml of the sample was pipetted into a test tube, and 1.0 mL of 0.3 M NaOH was added and mixed gently. One (1) mL of reducing mixture (prepared by adding 20 mL copper sulphate (CuSO₄) working solution and 16 mL hydrazine sulphate to 20 ml of 0.3M NaOH) was added and mixed gently. The mixture was heated at 60°C for 10 minutes in a water bath and then cooled to room temperature, after which 1.0 ml of colour developing reagent was added. It was shaken to mix, and the absorbance was read at 520nm with the T60 UV/VIS spectrophotometer by PG Instruments. Absorbance read were used for a calibration curve. The calibration curve was used to determine the concentration of nitrate (APHA-AWWA-WEF, 1998).

3.2.2.10 Phosphate (Stannous Chloride Method)

One hundred (100) ml of sample free from colour and turbidity was taken and 0.05 mL (1 drop) phenolphthalein indicator was added. Strong acid was added to decolourise the sample and diluted to 100 mL with distilled water, and phenolphthalein indicator was added and discharged. Four (4.0) mL of molybdate reagent I and 0.5 mL (10 drops) stannous chloride reagent I (prepared from dissolving 2.5 g of fresh SnCl₂.H₂O in 100 mL glycerol) was added with thorough mixing after each addition. The absorbance was measured at a wavelength of 690 nm on the T60 UV/VIS spectrophotometer by PG Instruments after 10 minutes but before 12 minutes. The spectrophotometer was zeroed with a blank solution (prepared with 100 mL of distilled water). Absorbance read on the spectrophotometer were used for a calibration curve. The calibration curve was used to determine the concentration of (PO₄-P) in the samples (APHA-AWWA-WEF, 1998).

3.2.2.11 Potassium (Flame Photometric Method)

A digital flame analyser (Gallenkamp FGA-350-1) was used. It was calibrated with five (5) freshly prepared potassium (K) standards in the range of 1 – 10 mg/L to produce a straight line curve. It was operated using the wavelength of 768 μm . The sample was sprayed into the gas flame and excitation was carried out under careful, controlled and reproducible conditions. The desired spectral line was isolated by the use of interference filter. A phototube potentiometer then measured the intensity of light. The intensity of light at 768 μm is approximately proportional to the concentration of potassium in the sample. This method read the optical density, and the actual concentration in mg/L was read from a calibration curve (APHA-AWWA-WEF, 1998).

3.3 Fermentation of Effluent with Yeast

3.3.1 Sample Hydrolysis

Composite sample of effluent was sterilized in an autoclave for 15 minutes at 121°C, and allowed to cool to room temperature. The effluent was hydrolysed using α -amylase (with concentration of 75g/L). One (1) mL α -amylase was added per 100 mL of sterilized effluent. The sample was heated and kept at 60°C (in an incubator) for one (1) hour to facilitate enzyme catalysis.

3.3.2 Fermentation Process

The fermentation procedure was carried out at the Biotechnology lab of the Crop Science Department of the University of Ghana. Two hundred (200) mL of hydrolysate were dispensed into 500mL Erlenmeyer flask. The hydrolysates were then inoculated with baker's yeast at different amounts. These were incubated at $30 \pm 2^\circ\text{C}$ for 72 hours.

Fermentation was regarded as complete when ethanol concentration determined began to decline. Sampling was done at 24, 48 and 72 hours, to determine ethanol concentration.

3.3.2.1 Experimental Design and Treatments Used

A Complete Randomized Design (CRD) was used. Saf-instant® instant dry baker's yeast was used, and was added to the hydrolysates at varying quantities which served as treatments. Amounts of baker's yeast added were 0.2% (w/v), 0.4% (w/v), 0.6% (w/v), and a control sample (with no yeast inoculated). Each treatment had 3 replicates.

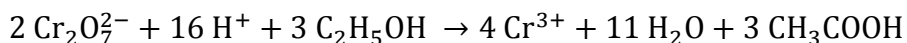
Table 3. 1: Treatments Used for the Fermentation of the Cassava Effluent

Treatment	Yeast concentration (g/100mL effluent; % w/v)
T1	0.2
T2	0.4
T3	0.6
T4	Control (no yeast)

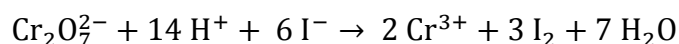
3.3.3 Ethanol Determination

3.3.3.1 Background

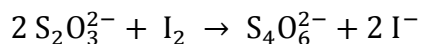
Redox titration was used in determining ethanol concentration derived. This involved ethanol being oxidized to ethanoic acid by reacting it with an excess of potassium dichromate in acid.



The amount of unreacted dichromate was then determined by adding potassium iodide solution, which is also oxidized by the potassium dichromate, forming iodine.



The iodine is then titrated with a standard solution of sodium thiosulphate and the titration results used to calculate ethanol content.



3.3.3.2 Setup

Acid dichromate solution (0.01 mol/L potassium dichromate in 5.0 mol/L sulphuric acid) was placed in flasks and the fermented samples suspended in a small holder (vial) above it and held in place with a cork (stopper). Blank preparations were made in same fashion, but with no samples suspended above the acid dichromate solution. The ethanol slowly evaporates and comes in contact with the dichromate; it first dissolves and then oxidized. Since this transfer is slow, it is necessary to leave the flask with the suspended sample in a warm place overnight. Flasks were kept in an incubator (at 30°C). The next morning the flasks were brought to room temperature, the stoppers loosened and sample holders discarded.

3.3.3.3 Titration Procedure

The redox titration was carried out at the Soil Science lab of the Soil Science Department of the University of Ghana. The flask was rinsed with distilled water, and 100mL of distilled water added, and 1mL of potassium iodide solution (1.2molL⁻¹) was added and swirled to mix. Each flask was titrated with sodium thiosulphate (0.03molL⁻¹) till the brown iodine colour faded to yellow. One (1) mL of starch solution (1.0% solution) was then added (which turned to dark blue). Titration continued till the blue colour disappeared and became clear.

3.3.3.4 Calculation for Ethanol Concentration

Volume of the sodium thiosulphate solution used for the sample titration was subtracted from the volume used for the blank titration. This volume of sodium thiosulphate was then used to determine the ethanol concentration. The number of moles of sodium thiosulphate in this volume (per litre) was calculated. Moles of ethanol were calculated from that of thiosulphate as; 1 mol of sodium thiosulphate is equivalent to 0.25 mol of ethanol. Moles per litre were then converted to percentage (g/100mL).

3.4 Data Analysis

3.4.1 Survey Analysis

The data obtained from the survey was subjected to descriptive analysis using the Statistical Package for Social scientists (SPSS®) version 17. Probit regression and Poisson regression were carried out on possible determining factors of some variables using Stata® version 13. Statistically significant relationships with the dependent variable were determined at ($p < 0.01$) and ($p < 0.05$).

3.4.2 Statistical Analysis of Effluent Quality Parameters

The relationships between the parameters were determined using correlation analysis. Analysis for all data points were carried out using Microsoft Excel 2010® and the nature of correlations between parameters were determined using the correlation coefficient (r).

3.4.3 Data Analysis on Ethanol Yield

Ethanol yield obtained were statistically analysed with Analysis of Variance (ANOVA), using Genstat® 12th edition software.. Differences between treatment means were determined using Least Significant Difference (LSD) at $p < 0.05$.

CHAPTER FOUR

4.0 RESULTS

4.1 Perception of Gari Producers on Occupational Health Hazards, and on Environmental Effects of the Effluent

4.1.1 Demographic Information of Gari Producers

Out of the respondents interviewed, 78.9% were females and 21.1% were males (Table 4.1). Results show that the majority (37.8%) of respondents were 40 – 49 years old. A sum of 60% of respondents fell within ages 30 – 49; whereas, 2.2% of respondents were 70 years and above. The education characteristic indicated that the majority (31.1%) of the respondents had no formal education. Only 7.8% and 2.2% of respondents had SHS and tertiary education respectively.

Table 4 1: Demographic Information of Gari Producers.

Variable		Frequency	Percent
Gender	Male	19	21.1
	Female	71	78.9
Age	20 – 29	12	13.3
	30 – 39	20	22.2
	40 – 49	34	37.8
	50 – 59	16	17.8
	60 – 69	6	6.7
	≥ 70	2	2.2
Formal Education	None	28	31.1
	Primary School	26	28.9
	Middle School/ JHS	27	30.0
	SHS	7	7.8
	Tertiary	2	2.2

4.1.1.1 Distribution of Male and Female Processors among Age Groups

Majority of male processors fall within the 40 – 49 age range (Table 4.2). This makes up 10.0% of the entire population, and 47.4% of males interviewed. Majority of the female processors also fell within the same age group of 40 – 49. They constitute 27.8% of the entire target population, and 35.2% of the female participants.

Table 4 2: Distribution of Gender among Age Groups of Gari Producers.

Gender		Age						Total
		20 – 29	30 – 39	40 – 49	50 – 59	60 – 69	≥ 70	
Male	%Male	15.8	15.8	47.4	15.8	5.3	0.0	100%
	%Total	3.3	3.3	10.0	3.3	1.1	0.0	21.1%
Female	%Female	12.7	23.9	35.2	18.3	7.0	2.8	100%
	%Total	10.0	18.9	27.8	14.4	5.6	2.2	78.9%

4.1.1.2 Respondents Participation in Gari Production

All respondents (100%) produced gari for commercial purposes (Table 4.3). A minority (8.9%) of participants interviewed had gari production as their sole occupation (Table 4.3), while 91.1% were involved in other economic activities besides gari production. Most of the respondents (44.5%) had been engaged in gari production for 6 – 15 years (Table 4.3). Some respondents (33.3%) processed an average of 2 – 5 bags of cassava mash per week (Table 4.3). Furthermore, 31.1% processed 6 – 9 bags per week, and 25.6% worked on 10 – 13 bags in a week.

Table 4 3: Respondents Participation in Gari Production

Variable		Frequency	Percent
GP for commercial purposes	Yes	90	100
	No	0	0.0
GP as sole occupation	Yes	8	8.9
	No	82	91.1
Years of GP	≤ 5	14	15.6
	6 – 15	40	44.5
	16 – 25	15	16.7
	26 – 35	15	16.7
	≥ 36	6	6.7
Average bags* of cassava mash processed in a week	< 2	2	2.2
	2 – 5	30	33.3
	6 – 9	28	31.1
	10 – 13	23	25.6
	14 – 17	4	4.4
	18 – 21	3	3.3

GP = Gari Production; *1 bag = 50 kg woven polythene sacks

4.1.2 Occupational Health Hazards Associated with Gari Production

4.1.2.1 Producers' Perception of Gari Production to be Hazardous

An overwhelming majority of 97.8% perceived gari production to be hazardous to processors' health (Table 4.4). Hazards mentioned by the processors included inhalation of smoke, intense heat from the furnace and boulder accident.

Table 4 4: Producers' Perception of Gari Production to be Hazardous

Response	Frequency	Percent
Yes	88	97.8
No	2	2.2
Total	90	100

4.1.2.2 Training on Occupational Health Hazards

Results indicate that only 5.6% of respondents had ever received some training on ways to mitigate occupational health hazards associated with gari production (Table 4.5). Respondents indicated that issues addressed during such trainings included; how to construct improved stoves, and putting up a good workplace and ideal working conditions. Only 2.2% of respondents received training on how to construct improved stoves.

Table 4 5: Training Received by Respondents on Occupational Health Hazards

Variable		Frequency	Percent	
Training on occupational hazards on GP	Yes	5	5.6	
	No	85	94.4	
	Total	90	100	
		Frequency	% Cases	% Total
Training received [multiple choice] (n = 5)	Good workplace and conditions	1	20	1.1
	Constructing improved stoves	2	40	2.2
	Minimizing exposure to burns, heat and smoke	4	80	4.4

GP = Gari Production

4.1.2.3 Measures Employed in Preventing/Minimizing Occupational Health Hazards

4.1.2.3.1 Preventing or Minimizing Cuts and Bruises

Majority of respondents (60.0%) exercised caution and attentiveness in preventing or minimizing the incidence of cuts and bruises (Table 4.6). Only 5.6% of respondents used strong and secured ropes (in dewatering the cassava mash) as a means of preventing cuts and bruises. These responses came from only the Central Tongu District. Some respondents (12.2%) used less sharp knives while peeling the tubers.

Table 4 6: Measures Adopted in Preventing/Minimizing Cuts and Bruises

(n = 90) [multiple choice]

Response	Frequency	Percent
No measure	34	37.8
Caution and attentiveness	54	60.0
Strong and secured rope	5	5.6
Less sharp knives	11	12.2

4.1.2.3.2 Preventing or Minimizing Skin Irritations

The majority of respondents (68.9%) did not employ any measures in avoiding skin irritations (Table 4.7). Some 16.7% of respondents wore clothing that covered arms and legs as a means to prevent or minimizing skin irritations.

Table 4 7: Measures Adopted in Preventing/Minimizing Skin Irritations

(n = 90) [multiple choice]

Response	Frequency	Percent
No measure	62	68.9
Caution	17	18.9
Clothes that cover arms and legs	15	16.7

4.1.2.3.3 Preventing or Minimizing Inhalation of Smoke

Majority of respondents (58.9%) employed no measure to prevent or minimize the inhalation of smoke from the furnace, while frying the gari (Plate 4.1; Table 4.8). Some of the respondents (10%) took time off in the course of the frying activity as a measure of preventing or minimizing the inhalation of smoke. A few respondents (7.8%) sat behind either tarpaulins or aluminium roofing sheets to prevent or minimize the inhalation of smoke during frying (Plate 4.2). Another 8.9% of respondents continually reposition their seats as a means of preventing or minimizing smoke inhalation. Some 17.8% of respondents fry gari behind a high mud wall partitioning the gari worker from the furnace (Plate 4.3), in order to prevent or minimize smoke inhalation.



Plate 4. 1: Gari Producers with No Measure against Exposure to Smoke from Furnace



Plate 4. 2: Usage of the Wind Barrier Measure

Source: Adenugba and John (2014)



Plate 4. 3: Mud Partition between Gari Producer and Furnace

Table 4 8: Measures Adopted in Preventing/Minimizing Inhalation of Smoke

(n = 90) [multiple choice]

Response	Frequency	Percent
No measure	53	58.9
Take time off	9	10.0
Wind barrier	7	7.8
Reposition seat	8	8.9
Partition between processor and furnace	16	17.8

4.1.2.3.4 Preventing or Minimizing Burns

Majority of gari producers (45.6%) exercised high level of caution and attentiveness as a means of preventing or minimizing burns (Table 4.9). A few gari producers (4.4%) placed rags at the rim of the pan in order to prevent or minimize burns. Another 3.3% utilized pans with rims that sunk into the mud stove. Some 8.9% of respondents regularly took breaks or run shifts (to manage fatigue) in order to prevent or minimize burns.

Table 4 9: Measures Adopted in Preventing/Minimizing Burns

(n = 90) [multiple choice]

Response	Frequency	Percent
No measure	39	43.3
Caution and attentiveness	41	45.6
Rags at rim of pan	4	4.4
Clothes that cover arms and legs	2	2.2
Take break/ run shift	8	8.9
Rim of pan sinks into stove	3	3.3

4.1.2.4 Awareness and Usage of Protective Clothing in Gari Production

4.1.2.4.1 Awareness of Protective Clothing

Majority of the respondents (68.9%) had no awareness on protective clothing as applicable to their line of work, whereas, 31.1% had such awareness.

4.1.2.4.2 Factors Influencing Processors' Awareness of Protective Clothing

Table 4.10 presents results of probit regression to determine factors that influence processors' awareness of protective clothing.

Table 4 10: Factors Influencing Processors Awareness of Protective Clothing

Variable	Coefficient	P-value	Marginal Effect
Gender	0.297	0.359	0.097
Age	-0.216	0.513	-0.071
Education	0.027	0.004**	0.038
Length of gari production	0.091	0.490	0.030
Consideration of gari production to be hazardous	1.812	0.003**	0.367
Training on occupational health hazards	0.291	0.031*	0.134
Visit to health facility relating to condition sustained at work	0.353	0.019*	0.115
Constant	-1.103	0.089	
Regression Diagnostics			
Log likelihood	-46.701		
Pseudo R ²	0.401		
LR chi ² (7)	18.20		
Prob > chi ²	0.011		

*indicates 5% significance level; **indicates 1% significance level

The pseudo R² of 0.401 implied that 40.1% of variation that occurred in the dependent variable (processors awareness of protective clothing) was jointly influenced by the independent variables in the model. The empirical results showed that educational level and consideration of gari production to be hazardous were both statistically significant at 1%; and positively influenced respondents' awareness of protective clothing. Training on occupational health hazards, and visit to health facility relating to a condition sustained at work were both statistically significant at 5%; and positively influenced processors'

awareness of protective clothing. Gender, age and length of gari production had no significant relationship with processors' awareness of protective clothing.

For each additional educational level, individuals were 3.8% more likely to be aware of protective clothing. Individuals who considered gari production to be hazardous were 36.7% more likely to be aware of protective clothing. Individuals who had had training (in one form or the other) on occupational health hazards associated with gari production were 13.4% more likely to be aware of protective clothing (than those who had never received such training). Respondents who had ever visited a health facility in relation to a health condition sustained at work were 11.5% more likely to be aware of protective clothing.

4.1.2.4.3 Usage of Protective Clothing

Only 3.3% of respondents utilized footwear (covering entire foot); and this was on a 'less often' basis (Table 4.11). None of the respondents made use of overall coats, but some 17.8% utilized an improvised means (long sleeve shirts with or without trousers). These respondents also utilized this improvised means on a 'less often' basis. None of the respondents used hand gloves and nose masks, neither in the actual form nor in an improvised way.

Table 4 11: Respondents' Frequent Usage of Protective Clothing

(n = 90)

Variable		Response			
		Always	More Often	Less Often	Never
Footwear (covers entire foot)	Frequency	0	0	3	87
	%Total	0.0%	0.0%	3.3%	96.7%
Hand gloves	Frequency	0	0	0	90
	%Total	0.0%	0.0%	0.0%	100.0%
Overall coat (improvised)	Frequency	0	0	16	74
	%Total	0.0%	0.0%	17.8%	82.2%
Nose mask	Frequency	0	0	0	90
	%Total	0.0%	0.0%	0.0%	100.0%

4.1.2.4.4 Factors Influencing the Wearing of Protective Clothing

Table 4.12 presents results of Poisson regression to determine factors that influence gari producers' decision to wear protective clothing while producing gari.

Table 4 12: Factors Influencing the Wearing of Protective Clothing

Variable	Coefficient	P-value	Marginal Effects
Location	-0.066	0.812	-0.003
Gender	-0.403	0.430	-0.158
Age	-0.168	0.440	-0.007
Education	-0.047	0.836	-0.002
Length of gari production	0.624	0.002**	0.024
Consideration of gari production to be hazardous	15.235	0.000**	0.055
Training on occupational health hazards	-16.420	0.000**	-0.098
Awareness of protective clothing	1.235	0.006**	0.065
Visit to health facility relating to condition sustained at work	0.906	0.010**	0.117
Constant	-17.862	0.000	
Regression Diagnostics			
Log pseudo likelihood	-37.243		
Wald chi ² (9)	1148.08		
Prob > chi ²	0.000		

**indicates 1% significance level

The empirical results showed that length of gari processing, consideration of gari production to be hazardous, training on occupational health hazards, awareness of protective clothing, and visits to health facility relating to condition sustained at work were statistically significant at 1%. Length of gari processing, consideration of gari production to be hazardous, awareness of protective clothing, and visits to health facility relating to condition sustained at work positively influenced the processors decision to wear protective clothing. Training on occupational hazards, however, had a negative

influence on the processors decision to wear protective clothing. Gender, age and education of the processors had no significant relationship with processors' decision to wear protective clothing.

For each increase in length of gari production, producers were 2.4% more likely to wear protective clothes. Respondents who considered gari production to be hazardous were 5.5% more likely to use protective clothing. Individuals with an awareness of protective clothing were 6.5% more likely to put on protective clothes. Respondents who had ever visited a health facility in relation to a health condition sustained at work were 11.7% more likely to wear protective clothes. However, individuals who had training on occupational health hazards associated with gari production were 9.8% less likely to make use of protective clothing.

4.1.2.4.5 Visit to Health Facility for Health Condition Sustained During Gari Production

Some respondents (43.3%) had visited a health facility at a point in time in relation to a health condition sustained at work (Table 4.13). These conditions included boulder accident, dizziness and induced fever.

Table 4 13: Visit to Health Facility Relating to Health Conditions Sustained in GP.

Variable		Frequency	Percent	
Ever been to a health facility relating to hazard sustained?	Yes	39	43.3	
	No	51	56.7	
	Total	90	100	
		Frequency	% of Cases	% of Total
Condition sustained?	Dizziness	11	28.2	12.2
[multiple choice] n = 39	Induced fever	25	64.1	27.8
	Severe aches and pains	22	56.4	24.4
	Induced diarrhea	3	7.7	3.3
	Deep cuts	3	7.7	3.3
	Boulder accident	1	2.6	1.1
	Eye irritation	3	7.7	3.3
	Skin rashes	1	2.6	1.1

GP = Gari Production

4.1.3 Environmental Hazards Posed by Effluent

4.1.3.1 Fate of Effluent

Majority of respondents (80%) discharged their effluent into the environment after generation (Table 4.14). All these respondents did not treat their effluent before discharge. Some respondents (20%) kept their effluent for later use. All such persons were identified in the Central Tongu District, and they constituted 60% of the respondents from Central Tongu (Table 4.15).

Table 4 14: Fate of the Effluent

(n = 90)

Variable	Frequency	Percent
Disposal	72	80
Treated before disposal	0	0
Kept for later usage	18	20

Table 4 15: Fate of the Effluent across the Various Districts.

(n = 90)

District		Disposal	Treated before disposal	Kept for later usage	Total
Ayensuano	Frequency	30	0	0	30
	%District	100.0%	0.0%	0.0%	100.0%
Awutu Senya	Frequency	30	0	0	30
	%District	100.0%	0.0%	0.0%	100.0%
Central Tongu	Frequency	12	0	18	30
	%District	40.0%	0.0%	60.0%	100.0%

4.1.3.2 Observed Effects of the Effluent

4.1.3.2.1 Observed Effects on the Environment

Majority of respondents (87.8%) reported bad odour at areas where the effluents are discharged (Table 4.16). Most respondents (96.7%) also reported of destruction of vegetative cover present in areas with effluent discharge. Some 10% of respondents discharged the effluent around the roots of trees, resulting in the death of these trees. Another 43.3% observed that such land space no longer supported plant growth. Majority

of respondents (62.2%) interviewed indicated that the disposal of their effluents did not end up in water bodies, as the water bodies were not in close proximity (over 6 km) to their processing sites. These respondents made up the ‘not applicable’ category.

Table 4 16: Observations Made on Effects of Effluent on the Environment

(n = 90) [multiple response]

Variable		Frequency	Percent
Atmosphere	Nothing noticed	11	12.2
	Bad odour	79	87.8
Vegetation	Nothing noticed	3	3.3
	Vegetative cover destroyed	87	96.7
	Trees destroyed	9	10.0
Land/ Soil	Nothing noticed	14	15.6
	Aesthetic damage	62	68.9
	Does not support plant growth	39	43.3
Water bodies	Not applicable	56	62.2
	Nothing noticed	22	24.4
	Salty	2	2.2
	Turns cloudy	11	12.2

4.1.4 Mitigation Options for the Generated Effluent

4.1.4.1 Treatment Options for the Effluent

All the respondents (100%) had no awareness of treatment options for the effluent obtained from the dewatering stage of gari production (Table 4.17).

Table 4 17: Respondents' Awareness of Treatment Options for the Generated Effluent.

Response	Frequency	Percent
Yes	0	0.0%
No	90	100.0%
Total	90	100.0%

4.1.4.2 Value Addition Alternatives for the Effluent

4.1.4.2.1 Gari Producers Who Keep the Effluent

Out of the 20% gari producers who keep their generated effluents (Table 4.14), 66.7%, 66.7% and 50% utilized the effluent in weed control, making of tapioca and starch, respectively (Table 4.18).

Table 4 18: Uses Respondents Derive from the Effluent

(n = 18) [multiple choice].

Uses	Frequency	% Cases	% Total
Starch	9	50.0%	10.0%
Tapioca	12	66.7%	13.3%
Weed Control	12	66.7%	13.3%

4.1.4.2.2 Gari Producers Who Always Discharge the Effluent

Majority of respondents (51.4%) who had no use for the effluent, however, were aware of its likely uses (Table 4.19). These included making starch and tapioca from the effluent (Table 4.20). Some 2.7% indicated that the effluent could be used to make a pregnancy-enhancing potion. This potion, has indicated by the respondent, could be applied over the

vulva, to trap semen from exiting the vagina after coitus; thereby enhancing the chances of fertilization of the ovum in human females.

Table 4 19: Awareness of Respondents on Effluent Uses Other than Disposal

(n = 72)

Variable		Awareness of Effluent Uses Other Than Disposing It	
		Yes	No
Effluent Disposal	Frequency	37	35
	% Cases	51.4%	48.6%
	% Total	41.1%	38.9%

Table 4 20: Awareness of Respondents on Effluent Uses Other than Disposal

(n = 37) [multiple choice]

Uses	Frequency	% Cases
Weed Control	10	27.0%
Starch	30	81.1%
Tapioca	16	43.2%
Coital Fertilization-Enhancing Potion	1	2.7%
Cassava Biscuit	3	8.1%
Chalk	2	5.4%

4.1.4.2.3 Factors Influencing Processors' Decision to Keep the Effluent for Later Use

Table 4.21 presents results of probit regression to determine factors that influence processors' choice to keep the effluent for later use.

Table 4 21: Factors Influencing Processors' Decision to Keep Effluent for Later Use

Variable	Coefficient	P-value	Marginal Effect
Location (Central Tongu)	0.426	0.047*	0.087
Gender	0.716	0.174	0.145
Age	-0.166	0.420	-0.034
Education	0.276	0.118	0.056
Length of gari production	0.404	0.029*	0.082
Observed effects of effluent discharge on the environment	0.745	0.042*	0.151
Awareness of value addition options	1.012	0.020*	0.181
Constant	-4.097	0.013	
Regression Diagnostics			
Log likelihood	-31.414		
Pseudo R ²	0.303		
LR chi ² (7)	27.24		
Prob > chi ²	0.0003		

*indicates 5% significance level

The pseudo R² of 0.303 indicated that 30.3% of the variation that occurs in the dependent variable (effluent kept for later use) was jointly influenced by the independent variables in the model. The empirical results showed that location of respondents, length of gari production, observed effects of effluent discharge on environment, and awareness of value addition options were statistically significant at (p<0.05); and positively influenced processors' decision to keep effluent for later use. Gender, age and education had no significant relationship with processors' decision to keep effluent for later usage.

Respondents located in Central Tongu were 8.7% more likely to keep the cassava effluent for later use than respondents from other locations. With an increase in length of gari production, processors were 8.2% more likely to keep the effluent for later use. Respondents who had observed environmental effects of the untreated effluent were 15.1% more likely to keep the effluent for later use. Individuals with an awareness of value added options for the effluent were 18.1% more likely to keep the effluent for later use (than those who were unaware of the effluent's use).

4.2 Quality of the Cassava Effluent

The physico-chemical parameters used to assess the quality of the effluents generated were pH, conductivity, total solids, total suspended solids, biochemical oxygen demand, and chemical oxygen demand, nitrate, phosphate, potassium, calcium and magnesium. The summary of the wastewater quality results are shown in Table 4.22.

The cassava-mill effluents were acidic, with pH values ranging from 3.79 – 4.25 (Table 4.21), and that from the Ayensuano District recording relatively low figures (3.79 – 3.95). The pH values obtained across the various districts were below the limits or standards of the Ghana Environmental Protection Authority (EPA), which puts it at a range of 6 – 9 (EPA, 2000). Electrical conductivity of the effluents also ranged from 8830 – 14680 $\mu\text{S}/\text{cm}$, which are extremely high compared to the maximum limit of 1500 $\mu\text{S}/\text{cm}$ set by the EPA (EPA, 2000). Total suspended solids (TSS) contained in the effluent ranged from 1700 – 2470 mg/L, with Ayensuano District recording 2020 – 2310 mg/L. The TSS figures recorded were all higher than the EPA maximum limits (EPA, 2000). BOD for the effluent from Awutu Senya ranged from 24480 – 24240 mg/L, whereas, that from Central Tongu ranged from 21680 – 25080 mg/L, and Ayensuano had BOD values of 19920 –

26080 mg/L. For phosphate, all samples from Ayensuano met EPA accepted limit, likewise for nitrate. Means of the entire samples for phosphate and nitrate (which are 0.125 mg/L and 0.070 mg/L respectively) were within EPA accepted limits.

Table 4 22: Cluster Means of Physico-Chemical Parameters of Gari Effluent across the Districts Surveyed

Location	Cluster	pH	Cond. (μ S/cm)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	PO ₄ - P (mg/L)	NO ₃ - N (mg/L)	TSS (mg/L)	TDS (mg/L)	COD (mg/L)	BOD (mg/L)
AS	C1	4.12	11160	3999	321	243	0.207	0.088	2470	35130	62974	22480
	C2	4.28	13770	3299	481	826	0.270	0.075	1710	55000	55688	24240
	C3	4.25	13360	2679	241	534	0.270	0.103	2370	42340	62974	23360
CT	C1	3.81	8830	3639	241	437	0.073	0.064	2140	40390	69927	23720
	C2	4.38	14680	5079	241	389	0.253	0.124	1700	45300	58811	21680
	C3	3.81	12400	2679	241	340	0.029	0.029	1730	35560	54127	25080
AY	C1	3.95	11950	2599	321	1409	ND	0.059	2310	44460	58811	24880
	C2	3.79	11910	3739	321	1020	0.010	0.035	2250	36460	59852	26080
	C3	3.79	11950	5039	241	291	0.010	0.050	2020	39730	59852	19920
Mean		4.02	12223.3	3656	294.3	610.4	0.125	0.070	2078.3	41597	60335	23493
EPA (2000)		6 – 9	1500	-	-	-	2	0.1	50	1000	250	50

ND = not detected (< 0.001); AS = Awutu Senya; CT = Central Tongu.; AY = Ayensuano

4.2.1 Relationship among Parameters

The correlation matrix among the various effluent quality parameters are shown in Table 4.23. There was a strong direct correlation between pH and EC ($r = 0.704$), pH and TDS ($r = 0.608$), and COD and TSS ($r = 0.576$). However, COD and EC showed a strong inverse relationship ($r = -0.702$). COD and pH showed a very weak inverse relationship ($r = -0.143$). There also existed no relationship between BOD and TDS ($r = -0.028$)

Table 4 23: Correlation Matrix of the Effluent Quality Parameters Measured

	TDS	TSS	BOD	COD	pH	EC
TDS						
TSS	-0.447					
BOD	-0.028	0.089				
COD	-0.252	0.576	-0.186			
pH	0.608	-0.186	-0.231	-0.143		
EC	0.499	-0.481	-0.120	-0.702	0.704	

4.3 Fermentation of Effluent with *Saccharomyces cerevisiae*

4.3.1 Ethanol Yield

Amount of ethanol produced (in the three yeast quantities used) increased progressively as fermentation duration increased to 48 hours (Figure 4.1). Optimum ethanol concentrations for the different yeast concentrations used were obtained at 48 hours. Afterwards, a gradual reduction was observed, with yeast at 0.4%w/v plateauing, indicating inability for further generation of ethanol. Optimum ethanol concentration obtained in yeast concentrations of 0.2%w/v, 0.4%w/v and 0.6%w/v were 2.77%w/v, 2.85%w/v and 3.25%w/v respectively. The amounts of ethanol produced in yeast (at 0.6%w/v and 0.4%w/v) at all given periods were higher than

that produced in yeast at 0.2% w/v. The ethanol concentration for the control sample remained constant throughout the fermentation period. Significant differences ($P < 0.05$) were observed for ethanol yield among the various treatments used (Appendix 2, 3 and 4).

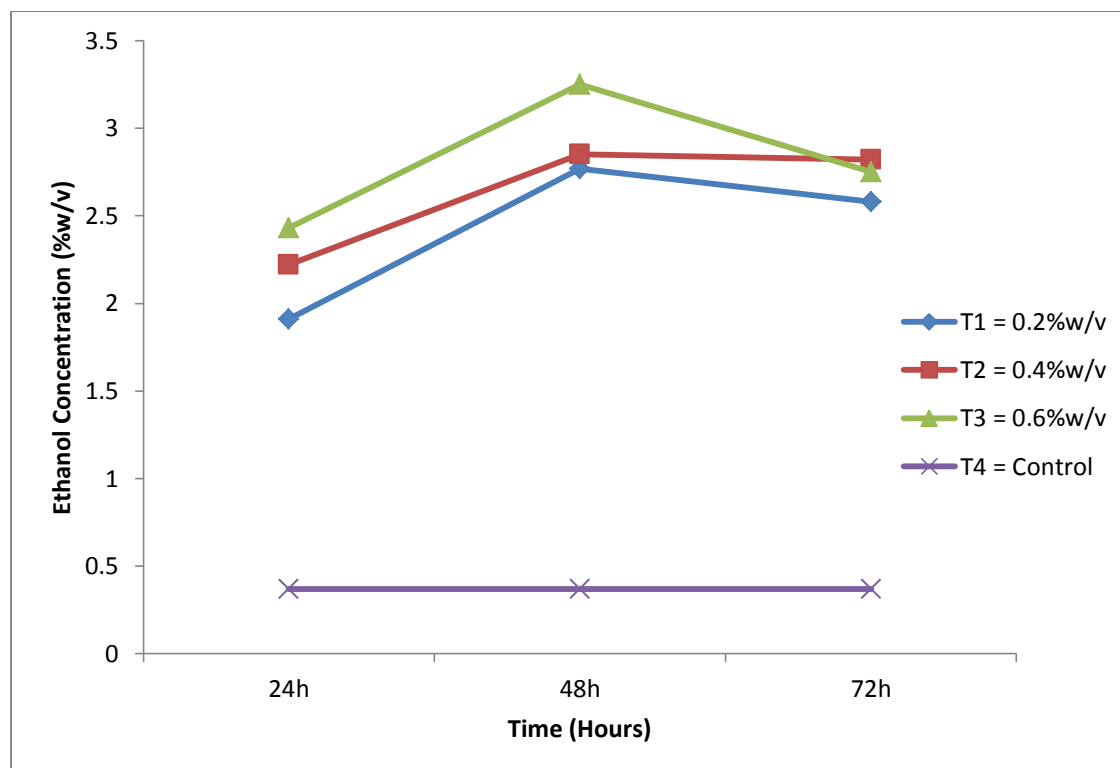


Figure 4 1: Ethanol Concentration of the Fermented Effluent by Different Concentrations of Baker's Yeast

CHAPTER FIVE

5.0 DISCUSSION

5.1 Perception of Gari Producers on Occupational Health Hazards, and on Environmental Effects of the Effluent

5.1.1 Demographic Information of Gari Producers

This study shows that 78.9% of the respondents were female, and this high percentage of females is consistent with findings of Quaye *et al.* (2009), who reports of an average of 94.5% female involvement in cassava processing. This is evidence of the fact that women play a principal role in food processing and the wholesomeness of food (Obeng-Ofori and Boateng, 2008). This high percentage of female involvement could largely be explained by the Ghanaian society's firmly rooted perception of food handling (processing and cooking) to be the responsibility of the female, as seen in many Ghanaian homes and eateries.

Majority of respondents (73.3%) fell within the age range of 20 – 49, as this age interval is the most active of a person's life (in terms of productive manual labour). The age range of '60 and over' made up only 8.9%, as gari production involves much effort (labour-intensive) and exposure to health hazards (Adenugba and John, 2014). In such an advanced age, tolerance to such conditions is minimal, thus explaining the least involvement of this age group (≥ 60 years), as argued by Yidana *et al.* (2013).

Respondents making up 68.9% had one form of education, and this could signal prospects of effective adoption and integration of technologies, skills and information passed on to processors by stakeholder institutions. Bello *et al.* (2013) argued that low-level education of cassava processors had implications on the adoption of modern technology. Conversely, a higher-level education of the respondents could indicate

likely ease of understanding information laden with much technicality; as 10% of respondents had senior high and tertiary education. Though, not high a percentage (10%), this ‘high-level’ educated group could serve as focal points in the dissemination of information to individuals of the lesser educational levels.

The gari producers make use of livelihood diversification options which ensure that they are able to generate multiple streams of income to sustain themselves and contribute much better to the economic capital of the household, as 91.1% of respondents have other occupations other than gari production. From the interview session with the processors, several of them were involved in two or more economic activities other than gari production.

5.1.2 Gari Production and Occupational Health Hazards

5.1.2.1 Training on Occupational Health Hazards

Only 5.6% had ever received training relating to managing occupation health hazards. This small percentage is very unfortunate considering the effects gari production can have on the health of processors. This indicates that the stakeholder institutions have not given much attention or effort towards addressing issues of Occupational Safety and Health (OSH), through which processors would be equipped to safeguard against health hazards. Comparatively, much effort has been geared towards equipping farmers and processors with improved cassava varieties so as to maximize their outputs and profits (as with the Root and Tuber Improvement Programme [RTIP]) (Quaye *et al.*, 2009), while issues of Occupational Safety and Health seem marginalized.

5.1.2.2 Measures Adopted by Gari Producers against Occupational Health Hazards

The diverse responses given by the processors concerning measures they employ to prevent or minimize the occurrence of health hazards points to the fact that, gari producers are aware of some dangers they are exposed to. The high percentages of respondents with ‘no measures’ in minimizing the health hazards is indicative of the view that, little has been done by stakeholder institutions in disseminating appropriate information aimed at mitigating the health hazards. The efforts of the processors aimed at addressing such hazardous conditions cannot go without recognition. The processors in their own small ways have been pragmatic, and made attempts at managing some of these occupational health hazards (such as burns, cuts and inhalation of smoke). They attested to these measures as being effective in at least minimizing the intensity of the hazards they (the measures) were meant for. The response of a considerable number of respondents interviewed identified ‘caution and attentiveness’ as a popular measure in preventing or minimizing the health hazards, and this is consistent with the findings of Adenugba and John (2014). Adenugba and John (2014) reports that, gari producers attributed some hazards (such as cuts) to ‘faulty’ attitude to work; and further concluded that; careful attitude to work (gari production) was the best known way for reducing hazards that were inherent in the work design.

5.1.2.3 Awareness of Protective Clothing in Gari Production

Majority of respondents (68.9%) were not aware of protective clothing, and this goes to support the argument that little attention has been given to issues of Occupational Safety and Health by stakeholders.

5.1.2.4 Factors Influencing Processors' Awareness of Protective Clothing

Formal education had a positive significant effect ($p < 0.01$) on processors' awareness of protective clothing. This may be attributed to the fact that, the educated processors are likely to have a wider knowledge base, and are better placed towards acquiring new information.

Consideration of gari production to be hazardous, and visit to a health facility in relation to a condition sustained at work also had a positive significant relationship ($p < 0.01$) with processors awareness of protective clothing. This may be due to the fact that processors who find themselves in such situations would become aware of protective clothing (in an attempt to mitigate their predicaments).

Training received by processors on occupational health hazards had a positive significant relationship ($p < 0.01$) with processors awareness of protective clothing. This could be due to the fact that such training programmes have a high likelihood to make mention of protective clothing that may be utilized in mitigating some health hazards.

5.1.2.5 Usage of Protective Clothing in Gari Production

Respondents attributed the 'less often' usage of the long sleeve shirts to considerable discomfort. Issues of high atmospheric temperature coupled with intense heat emanating from furnace, hindered the frequent usage of this improvised measure (same for the overall coat proper). Usage of the long sleeve shirts is an attempt to mitigate the skin irritations that some processors experience when cyanide-laden cassava mash comes in contact with the skin, and also against burns on the forearms that could occur during the frying stage. However, the excuse for its infrequent usage cannot be disregarded. Ghana, being in the Tropics, experiences high intensity of sunlight, hot weather with a high degree of humidity. Lucas *et al.* (2014) reported that

occupational contexts that involve hot and humid climatic conditions, heavy physical workloads and/or protective clothing create a strenuous and potentially dangerous thermal load for the worker. Hot and humid climatic conditions create a thermal heat extreme as heat loss from the body to the environment becomes increasingly difficult (Lucas *et al.*, 2014). As noted by Bishop *et al.* (2013), thermal comfort is a key issue in the use of protective clothing. This conceivably explains the low usage of protective clothing recorded in the various districts.

5.1.2.6 Visit to Health Facility for Health Condition Sustained During Gari Production

A considerable percentage (43.3%) of respondents had visited a health facility at a point in time in relation to a health condition sustained at work, with most of these conditions being severe. This considerable percentage and the nature of their predicaments further confirm the hazardous nature of gari production, already pointed out by the processors themselves.

5.1.3 Respondents Perception about the Effects of the Effluent on the Environment

The various effects and changes to the environment as reported by the respondents (concerning the discharge of the untreated effluent) points to the fact that the generated effluent is harmful to the environment, and also, the gari producers are aware of some dangers posed to the environment. Some effects reported by respondents were supported by quality parameters measured in the effluent. Foul odour was explained by the high values of BOD, COD and TSS in the effluent. ‘Destruction of vegetation’ and ‘inability of receiving soil to support plant growth’ were also explained by the low pH and high values of TDS recorded in the effluent.

5.1.4 Mitigation Options for the Cassava-Mill Effluent

All respondents (100%) were not aware of treatment options for the wastewater. This, coupled with the fact that majority of respondents (80%) discharge the (untreated) effluent into the environment, makes the situation a disturbing one, considering the numerous gari or cassava processing activities all over Ghana and the consequential environmental effects. The 20% of respondents who made use of the effluent were all located in the Central Tongu District, and this gives an indication that usage of the generated effluent may not be widespread in the Ghanaian cassava processing industry. Several of the processors were engaged in farming, and have been able to harness the vegetation-destructive potential of the effluent to their advantage. They employed it in weed control on their farm lands. The effluent is mixed in its raw form with commercially-sold inorganic weedicides, and applied on the farm lands. This practice was only reported, and is considerably widespread in the Central Tongu District, with 40% of the Central Tongu respondents making use of this technology. The use of this mixture ensures quicker destruction of weeds and lengthier periods for re-emergence. A total of 60.1% of respondents were aware of value added products that could be derived from the effluent. This statistic consists of respondents that keep the effluent for later usage and those that always discharge their effluent (but are aware of its likely uses). This is indicative of a majority of processors being knowledgeable of value added options that could be derived from the cassava effluent. The 'low-level' or 'low-intensity' execution of the known value addition alternatives by the respondents could either be; a lack of drive to invest money and effort, or an oblivion of the extent of possible income that could be derived from bringing value to the waste. The value-added products mentioned by the respondents (Table 4.18; Table 4.20) do not require machinery or sophisticated technology in

producing them, thus this possibility (sophisticated technology) is ruled out as a likely reason for the ‘low-intensity’ execution (of adding value to the effluent) by respondents.

5.1.4.1 Factors Influencing Processors’ Decision to Keep Effluent for Later Use

The study showed that location of respondents had a positive statistically significant relationship ($p < 0.05$) with processors decision to keep effluent for later use. This was the case, as respondents from only Central Tongu were identified to make use of the cassava effluent.

Length (in years) of gari production also showed a positive significant effect ($p < 0.05$) on decision to make use of the effluent. With lengthier years in a trade, one gets to develop a deep knowledge and understanding of various issues related to his/her profession, and as such, processors with long years of gari production are much likely to be aware of possible uses for the effluent, which is likely to influence their decision to keep the generated effluent for later usage.

Observance of environmental effects of the untreated effluent, and the awareness of value addition options for the effluent both showed positive significant effects ($p < 0.05$) on the decision to keep effluent for later use. With the observance of environmental hazards associated with the discharge of the untreated effluent, processors may likely make attempts to mitigate such hazards. One important way of doing this, is to avoid the discharge of the untreated effluent. By so doing, processors may have identified ways of adding value to the effluent. With knowledge of possible uses for the effluent, processors are very much likely to exploit such knowledge, hence the positive significant relationship ($p < 0.05$) between awareness of value addition options for the effluent and processors’ decision to make use of the effluent.

5.2 Quality of the Cassava Effluent

Several physico-chemical parameters measured in the effluent samples were outside permissible limits set by the EPA (EPA, 2000). The pH values, which were very acidic, were lower or outside what had been prescribed (6 – 9) by EPA. The very high wastewater quality parameters indicate that cassava wastewater has a strong potential of being deleterious to vegetation and aquatic life.

5.2.1 Biochemical Oxygen Demand and Chemical Oxygen Demand

BOD and COD are important parameters used in examining waste water quality (as they indicate the organic load present in the liquid waste). Reynolds *et al.* (2002) defines BOD as the level of organic content in wastewater measured by the demand for oxygen that can be utilized by living organisms present in the wastewater, and Spellman (2003) explains that COD measures the amount of oxidizable matter present in wastewater. The degradation of such constituents (oxidizable matter) utilizes dissolved oxygen in the effluent causing its (dissolved oxygen) depletion, and the generation of foul odour (Monney *et al.*, 2013). Such foul odour was confirmed by respondents during the survey.

The very high levels COD and BOD found in the cassava waste water could be due to the high composition of organic substances present in the wastewater. BOD values obtained are similar to that reported by Arguedas and Cooke, (1982). They recorded BOD values of 25000 – 50000 mg/L in farinha (de mandioca) wastewater. Farinha de mandioca is a cassava product derived from processes same as gari (but with a shorter fermentation time); with arguments that freed slaves from Brazil, with their knowledge in farinha making, introduced African folks to gari production (Wenham, 1995). Plevin and Donnelly (2004) also recorded very high BOD value of 16000 mg/L, but slightly lower than that recorded in this study. Howeler *et al.* (2000) and Plevin

and Donnelly (2004) also reported high COD values of 15000 – 30000 mg/L and 32000 mg/L, respectively, in cassava waste water; but these COD values were slightly lower than that obtained in the study. The very high levels of BOD and COD (of the effluent) when introduced into receiving water bodies could have dire effects on life present in there. BOD present in the receiving water would increase (Arimoro *et al.*, 2008) and oxygen present in the water body would be depleted, and life forms present may die. Large amounts of oxygen would be needed to degrade the high content of organic compounds present, which would result in the oxygen depletion.

5.2.2 pH of Effluent

The pH of wastewater is also important in determining water quality, as it affects chemical reactions that possibly occur. The pH values of all samples were acidic, with a mean value of 4.02. The pH values obtained in this study are consistent with the findings of Plevin and Donnelly (2004), Olorunfemi *et al.* (2008), and Olorunfemi and Lolodi (2011); who recorded low pH values of 3.8 – 4.2, 4.6, and 4.0 – 4.6, respectively for cassava effluents.

The low effluent pH recorded in this study could alter or increase the acidity of receiving soils, and of receiving water bodies (Arimoro *et al.*, 2008). Though plants vary in their response and tolerance to soil acidity, acidic soils restrict root growth and facilitate stunting in plants, which leads to decrease in growth and yields (MSU, 2014). With low pH in soils, there is low availability of elements such as calcium, magnesium and phosphorus; and increased solubility of aluminum (Al), iron (Fe) and boron (B) (Kennelly *et al.*, 2012). High levels of these nutrients (Al, Fe and B) in low pH soils can induce toxicity symptoms in plants (Kennelly *et al.*, 2012). Effluent pH could thus explain the destruction of vegetation, as indicated by respondents.

The pH of water bodies determines solubility and biological availability of heavy metals (such as lead and copper) (WSDOE, 1994). Acidity of receiving surface water may possibly be increased with the discharge of this acidic effluent. Heavy metals tend to be more soluble (become toxic) at lower pH (WSDOE, 1994) and this could be deleterious to aquatic life.

Hydrogen cyanide (HCN) is widely speculated to be responsible for such low pH in gari wastewater, but that may not be the case. Hydrogen cyanide is known to be highly volatile (Howeler *et al.*, 2000; Ogundola and Liasu, 2007), and evaporates around room temperature of 25.6°C. It is also a weak acid, with pka of 9.2. With the high volatility and weak acidity of HCN, HCN may not be deserving of the scare associated with its presence in cassava wastewater. Though, cyanide is highly toxic and present in cassava tubers, it cannot possibly be responsible for low pH recorded in the wastewater.

During the fermentation process in the cassava mash (for gari making), activities of the bacterium *Corynebacteria manihot* results in the production of organic acids (lactic and formic acids) and the lowering of substrate pH (Nweke and Ezumah, 1988). The acidic condition present stimulates the growth of *Geotrichum candida*, which causes further acidification (Nweke and Ezumah, 1988). Okafor (1998) also reported the cassava effluent to contain a large amount of lactic acid. Low pH present may largely be as a result of these microbial activities (during the fermentation of the cassava mash) and not HCN.

5.2.3 Electrical Conductivity (EC)

Electrical conductivity shows the ability of water to conduct electric current, and it relates to the amount of dissolved minerals or ions in the water. The high conductivity recorded in the effluent samples may be associated with high concentrations of

dissolved ions (Agyemang *et al.*, 2013). This is further confirmed by the high values of TDS recorded in the samples. This has the potential of altering the electrical conductivity of receiving surface water, which may lead to salinity problems and eutrophication (GWA, 2009).

The EC values recorded for this study, however, are in contrast to that reported by Bengtsson and Triet (1994); as Bengtsson and Triet (1994) recorded low EC values of 1150 – 1410 $\mu\text{S}/\text{cm}$ for cassava wastewater.

5.2.4 Total Dissolved Solids (TDS)

TDS is a measure of organic matter, inorganic salts and other dissolved materials in water. TDS directly relates to purity of water, since it accounts for anything present in water other than water molecules (H_2O) and suspended solids. The high TDS values recorded could be due to high levels of dissolved organic and inorganic molecules and ions present in the effluent (Sarkodie *et al.*, 2014). Rauscher (2015) notes that dissolved minerals cannot be removed by traditional filtration, but by reverse osmosis or distillation. Treatment of the high TDS values recorded would be cumbersome and expensive. In receiving soils, plant roots would have difficulty taking up nutrients (Rauscher, 2015), because of the very high concentrations of dissolved solids. This explains (in part) the vegetation-destructive nature of the effluent as reported by the gari producers.

Plevin and Donnelly (2004) also reported very high TDS value of 14,500 mg/L (in cassava wastewater), but relatively lower than the values recorded in this study.

5.2.5 Total Suspended Solids (TSS)

The TSS values recorded were very high and could have undesired effects on aquatic ecosystem of the receiving water body. The discharge of waste water with high

amounts of TSS can cause sludge deposition and anaerobic conditions in receiving water bodies (Hodgson, 2000). Weiner *et al.* (2003) indicates that the decomposition of the organic composition of TSS results in depletion of dissolved oxygen and unpleasant odour, as this was confirmed by respondents of the survey. The high organic content of the cassava wastewater if introduced into surface water has a high tendency of inducing eutrophication.

Though TSS values recorded in this study were above EPA permissible limits, this study's TSS values are in large contrast to that reported by Plevin & Donnelly (2004). Plevin & Donnelly (2004) reported TSS value of 15000 mg/L in cassava wastewater, and this value is relatively higher than that recorded in this study.

5.2.6 Phosphorus

Though phosphorus is a nutrient of great importance to plants, Spellman (2003) and Metcalf and Eddy (2003) indicate that phosphorus in surface water acts as a fertilizer, promoting the undesirable growth of algae populations. With the decomposition of phosphorus in receiving surface water, dissolved oxygen levels would decrease leading to a deleterious effect on fishes and other aquatic life species (Monney *et al.*, 2013). Since phosphorus measured (across all clusters and districts) were below the EPA maximum limit of 2 mg/L, this could explain why the above mentioned issue of 'algae growth on surface water' was not reported by respondents.

5.2.7 Nitrate

In excess quantities, nitrate leads to eutrophication in freshwaters (Horne, 1995), and excessive nitrate, just like phosphorus, stimulates growth in algae. But from the nitrate figures obtained in this study, and unlike the other eutrophication-inducing parameters talked about earlier, nitrate concentrations were very low. Mean nitrate

concentration of 0.07 mg/L recorded, was lower than EPA maximum limits. This low nitrate concentration in the effluent could be dependent on the low crude protein content (with a fraction being stored as nitrate) of the cassava tuber (Montagnac *et al.*, 2009).

5.2.8 Calcium and Magnesium

Calcium and magnesium are the two elements responsible for hardness in water (USGS, 2015). These two elements are naturally present in water. Olorunfemi *et al.* (2008) and Olorunfemi and Lolodi (2011) reported calcium values of 62.25 mg/L and 94.30 mg/L, respectively in cassava effluent, but these values are relatively lower than that recorded in the study. Olorunfemi *et al.* (2008) and Olorunfemi and Lolodi (2011) further reported magnesium values of 25.50 mg/L and 110.90 mg/L, respectively, but both values were also relatively lower than magnesium values recorded in the study.

Mean values of 294.3 mg/L and 610.4 mg/L for calcium and magnesium respectively were recorded. These figures are relatively high, and discharge of the wastewater into surface water may alter the water quality (in regards to hardness). As a result, such water may become unsuitable for domestic use. Calcium and magnesium (particularly calcium) form nearly insoluble salts with detergent and soap, thereby inhibiting their cleansing ability. There are no EPA limits for calcium and magnesium, possibly because toxicity induced by magnesium and calcium has not been recorded.

5.3 Fermentation of Effluent with *Saccharomyces cerevisiae*

The fermentation procedure was designed to keep all steps involved simplistic, so that with its success, gari producers and other rural folks (who could easily come by the effluent) can find ease with its adoption. All yeast treatments used achieved maximum

ethanol concentrations at 48 hours, after which a gradual reduction was observed. These preliminary data suggest that baker's yeast has the potential for ethanol production from cassava-mill (gari) effluent. The success of *Saccharomyces cerevisiae*, and subsequent rise in ethanol can be accredited to the ability of the yeast to utilize simple sugars, though they can metabolize various carbon substrates (Bekatorou *et al.*, 2006), in the presence of favourable broth conditions, and in the absence of other microbes. The relatively low concentration of ethanol obtained is possibly due to the non-optimized approach used for the fermentation. Optimization techniques would have to be developed to increase production of ethanol from the cassava effluent. Since the effluents are readily available and in large quantities, cassava wastewater could possibly be a cheap source of generating ethanol.

The 0.37% w/v ethanol observed in the control sample may likely have been generated during the fermentation and dewatering of the cassava mash. Sterilization of the control samples resulted in no additional ethanol being produced. This was because the control became void of microbes (after sterilization in an autoclave for 15 minutes at 121°C).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

Based on the study carried out the following conclusions have been made:

6.1.1 Perception of Gari Producers on Occupational Health Hazards, and on Environmental Effects of the Effluent

The gari production industry in Ghana is highly dominated by women. Due to the labour-intensive nature and exposure to distressing occupational hazards, involvement of elderly folks (above 60 years) is low. Traditional gari production is hazardous to the health of the processors, and the processors are much aware of this. Extent of training and education on occupational safety and health is very low. Efforts by stakeholders in addressing these work-related predicaments are apparently absent. Usage of protective clothing by processors in safeguarding against these hazards is very low.

The gari producers are aware of various effects that the generated cassava-mill effluent has on their immediate environment. Unfortunately, processors are unaware of treatment (detoxification) options for the generated effluent. Though processors may be aware of various uses for the effluent, making use of this waste water, or adding value to it is not widespread in the Ghanaian gari production industry. Processors have managed to harness the vegetation-destructive potential of the liquid waste, by employing it on their farm lands for the control of weeds.

6.1.2 Quality of the Cassava Effluent

Some effects of the effluent on the environment (as reported by the gari producers) were confirmed by the very high levels of some quality parameters measured in the

effluent, such as TDS, BOD and COD. Foul odour perceived by respondents was explained by the very high levels of BOD, COD and TSS. Destruction of vegetation observed by the respondents was also explained by the low pH and high TDS values recorded in the effluent. Effluents generated from gari production, according to EPA standards are not safe for discharge into the environment. The cassava wastewater, from the quality parameters determined, is toxic to the environment, and requires appropriate treatment before discharge.

High BOD and COD figures recorded for the effluent samples are likely factors responsible for the foul odour (emanating from the effluent) perceived by respondents. BOD and COD in receiving water may increase, leading to depletion of oxygen present in the water body and the likely death of life forms present. Low pH of the effluent may increase acidity of receiving soils, and this could possibly be responsible for the destruction of vegetation as reported by respondents, as soil nutrients become unavailable for plant uptake at low pH. Possible increase in pH of receiving surface water may lead to toxicity by heavy metals, and this is deleterious to aquatic life. High EC recorded for the effluent samples could also lead to eutrophication and salinity problems in receiving surface water. In receiving soils, plant roots may have difficulty taking up nutrients, due to a possible increase in TDS. High TDS value of the effluent is a likely contributor to the vegetation-destruction ability of the effluent. Decomposition of the organic components of the high TSS (recorded for the effluents) could be partly responsible for the foul odour of the effluents, as noted by respondents. The cassava effluents, with their high TSS, also have a tendency to induce eutrophication in receiving water.

6.1.3 Fermentation of Effluent with *Saccharomyces cerevisiae*

Saccharomyces cerevisiae exhibited the potential to metabolize the effluent to generate ethanol. With the use of a non-optimized fermentation procedure, ethanol concentration produced was relatively low. Significant differences ($p < 0.05$) were observed among the amounts of baker's yeast used for the fermentation, with the highest concentration of yeast (0.6% w/v) generating the highest ethanol concentration (3.25% w/v) at 48 hours.

6.2 RECOMMENDATIONS

Appropriate stakeholder institutions should invest efforts and resources into educating and training gari producers on Occupational Safety and Health (OSH).

Gari producers need to move from makeshift sheds, under which they usually work, to large working bays with good aeration. Gari producers should take advantage of improved facilities such as stoves that make use of chimneys, and long insulated spatulas (to keep the processor at a distance from the pan). Appropriate workspace structure and safe conditions for work cannot be overemphasized.

Research should be conducted on the synergistic impact that cassava-mill wastewater has with commercially available inorganic weedicides, in weed control.

The Water Research Institute (WRI) of the CSIR alongside the Ghana Environmental Protection Authority (EPA) should develop guidelines relating to the treatment and discharge of the cassava wastewater.

Optimized fermentation approaches need to be exploited in enhancing ethanol production from the cassava effluent.

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APPENDIX

Appendix 1: Questionnaire on Hazards Relating to Gari Production

This questionnaire is designed to find out gari producers' awareness of occupational health hazards associated with their line of work, and also environmental implications related to the disposal of cassava-mill wastewater (effluent). The questionnaire would further inquire about issues relating to the processors' treatment and addition of value to the resultant cassava-mill waste water. *(Please tick or fill in the blanks provided, where appropriate.)*

Demographics

Q1. Gender;

Male

Female

Q2. Age;

Q3. Education;

None

JHS

Adult Education

Primary School

SHS

Other(*specify*);

Q4. Do you produce gari for commercial purposes?

Yes

No

Q5. Is gari production your sole occupation?

Yes

No

Q6. If no, what other occupations are you engaged in?

Q7. How long have you been producing gari?

≤5yrs

16-25yrs

≥35yrs

6-15yrs

26-35yrs

Q8. What is the average number of bags of cassava mash that you process in a week?

.....

Occupational Health Hazards

Q9. Do you consider gari production to be hazardous?

Yes

No

Q10. If yes, what are the occupational health hazard(s) that you are aware of?

.....

Q11a. Have you ever had training on occupational hazard(s) in relation to your line of work?

Yes No

Q11b. If yes to Q11, what hazards did the training address?

.....

Q11c. What organization(s) provided the training?

Q12. What measures do you take in preventing or minimizing the following hazards?

Cuts and bruises

Skin irritations

Inhalation of fumes

Burns

Q13. Are you aware of protective clothing that could be used against some of the hazards?

Yes No

Q14. Indicate how often you use protective clothing while processing cassava to gari? (Please tick where appropriate.)

Protective clothing	Always	More often	Less often	Never
Footwear (covers entire foot)				
Hand gloves				
Overall coat				
Nose mask				

Q15a. Have you ever been to a health facility for a reason related to hazards sustained at work?

Yes No

Q15b. If yes, what conditions were those?

Observed Environmental Hazards

Q16. What is the fate of your generated cassava-mill liquid waste? (Please tick as many that may apply.)

Disposal

Treated before disposal

Kept for later usage

Q17. If you ticked 'Disposal' or 'Treated before disposal' in Q16, where do you dispose off the waste water?

.....
.....

Q18. How long have you been disposing effluent in this particular place?

.....

Q19. What are the changes and effects noticed with the disposal of the liquid waste in such a place?

Atmosphere

Vegetation

Land/ Soil

Water bodies

Treatment and Value-Addition Options for the Effluent

Q20. Are you aware of treatment option(s) for the liquid waste generated?

Yes

No

Q21. If yes, what are these waste water treatment option(s)?

.....
.....

Q22. If you chose 'Treated before disposal' in Q16, how do you treat the waste water?

.....

Q23. If you chose 'Kept for later usage' in Q16, what do you use it for?

.....
.....

Q24a. If you did not tick 'Kept for later usage' in Q16, do you know of anything that could be made of the waste water apart from disposing it?

Yes

No

Q24b. If yes, what are they?

Appendix 2: Analysis of Variance for Ethanol Concentration at 24 Hours

Variate: %24h

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	7.8440667	2.6146889	4753.98	<.001
Residual	8	0.0044000	0.0005500		
Total	11	7.8484667			

Tables of means

Variate: %24h

Grand mean 1.7333

Treatment	T1	T2	T3	T4
	1.9133	2.2167	2.4333	0.3700

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	8
s.e.d.	0.01915

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	8
l.s.d.	0.04416

Appendix 3: Analysis of Variance for Ethanol Concentration at 48 Hours

Variate: %48h

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	15.4620250	5.1540083	6376.09	<.001
Residual	8	0.0064667	0.0008083		
Total	11	15.4684917			

Tables of means

Variate: %48h

Grand mean 2.3108

Treatment	T1	T2	T3	T4
	2.7700	2.8533	3.2500	0.3700

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	8
s.e.d.	0.02321

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	8
l.s.d.	0.05353

Appendix 4: Analysis of Variance for Ethanol Concentration at 72 Hours

Variate: %72h

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	12.4894917	4.1631639	9251.48	<.001
Residual	8	0.0036000	0.0004500		
Total	11	12.4930917			

Tables of means

Variate: %72h

Grand mean 2.1308

Treatment	T1	T2	T3	T4
	2.5833	2.8167	2.7533	0.3700

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	8
s.e.d.	0.01732

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	8
l.s.d.	0.03994