ASSESSMENT OF THE VOLUME OF SEAFOOD WASTE GENERATION, UTILIZATION AND MANAGEMENT SYSTEM FROM SELECTED SEAFOOD PROCESSING COMPANIES IN GHANA: A CASE STUDY

Asiamah E[1]*, Oduro-Yeboah C[1], Mboom FP[1], Atter A[1], Idun-Acquah NN[1] and J Nkansah[2]

Ebenezer Asiamah

*Corresponding author email: e.asiam@yahoo.com
ORCID ID: https://orcid.org/0000-0003-0177-596X

[1]Council for Scientific and Industrial Research Institute-Food Research Institute, P.O. Box M20, Accra, Ghana

[2]Ghana Standard Authority, P.O. Box MB 245, Accra, Ghana

https://doi.org/10.18697/ajfand.112.21745   **20924**

ABSTRACT

Seafood waste has gained attention globally due to its increasing demand and negative impact on the environment. Survey work was conducted because Ghana has a significant number of commercial seafood processing industries but documentation on seafood waste is limited. The objective of this survey was to gain an insight into the volume of seafood waste generation, utilization and management system in seafood processing companies. Specifically, the study was to identify bottlenecks in the reuse of waste from seafood processing companies, quantify the seafood waste and determine the composition of the seafood waste generated. This study evaluated seafood waste from ten seafood processing companies situated in Tema, Effutu, Takoradi and Accra Metropolis in Ghana. Production and Quality Assurance managers from on-shore seafood processing companies were interviewed using a semi structured interview schedule (SSIS). These seafood processing companies have been in existence for between one to forty years. The highest proportion (40%) of the companies have been in existence for six to ten years. The companies which were in operation for a period of twenty to twenty-five years accounted for 20%. Most (80%) of these processing companies processed prawns, octopus, lobsters, grouper, catfish, whereas a minority (20%) processed tuna seafood. A majority (80%) of the surveyed processing companies did not process the waste generated. The remaining percentage occupied a production volume ranging from 10-50 tons of raw fish production. A large portion of the waste generated was from grouper (60%) with the least being tuna (11%). Survey results revealed that the companies did not process their seafood waste because of the unavailability of processing equipment and lack of knowledge on the seafood waste value-added products. Another challenge confronting seafood waste management was the absence of management policy to regulate it. It can be concluded that the 60% of the surveyed companies generated seafood waste and there is a need for steps to be taken to reduce it. The study revealed that there were no laws in Ghana that controlled the reuse of seafood waste. It is recommended that a holistic seafood waste reduction approach must be established between actors in the fishing and seafood processing sector. This study could be a driving tool to improve the seafood waste management system in Ghana.

20925

INTRODUCTION

There is an increasing global trend of interest towards Circular Economy to develop new approaches to transform the value chain in food systems, especially in supply chain management. This concept will enhance the efficiency of resource utilization to ensure sustainability, reduce economic, environmental and social burdens [1-2]. As a result, diversified end products are produced through recycling and re-use of organic wastes and biomass sources [3], which include among others biopolymers, fuels and seafood [4].

Seafood is reported to play an important role in global food security, nutritional quality and other socioeconomic indicators [5]. In the global market, its import value amounted to US$ 148 billion in 2014 [6]. This is the largest contribution to foreign exchange earnings and the labor market in many developing countries [6].

Seafood is a highly perishable commodity that demands processing immediately after harvest. During harvesting and processing, a significant amount of waste is generated. The rate of processing is dependent on the fish species and the intended end-product such as fish oil, fish meal and fish sausage. Some waste generated from seafood includes trimmings, fins, heads, skins, guts, scales and viscera [7-8]. In this study, seafood waste was defined as left-overs which are as follows: visceral, bones, tails, caudal fin, skins, scales, head, and gills. Global records indicated that about 1.3 billion tonnes of food produced annually are wasted [8]. The significance of this global challenge is highlighted in the United Nations Sustainable Development Goals (SDGs), where goal two is designed to reduce food waste by 2030 [9-10]. This is because demand for seafood has increased worldwide, affecting both environment and human health negatively because of the waste generated [11].

Improved use of seafood waste through consistent product recovery programs could reverse the negative impact posed on biodiversity and human health. To do this, the flow or chain of activities in seafood such as harvesting, production, marketing and consumption must be streamlined. About 70% of seafood undergo unit operations like descaling, gutting, trimming and filleting which are reported to generate as much as 55% of fish parts being lost because they are regarded as inedible [12].

Realistic actions have been proposed to reduce the waste generated into more valuable products such as gelatin, fish oil, animal feeds, hydrolysates, bioactive peptide and dietic products (chitosan) and cosmetics [13]. These actions could reduce waste from the seafood industry, increase profitability and stress on the marine environment [14]. The steps to reduce seafood waste produced must be estimated and quantified [11].

Seafood and seafood products provide a substantial portion of animal protein which is reported to be about 50-80% [16]. The yearly per capita seafood consumption is estimated at 28 kg [16]. The sector also contributes approximately 10% of the labour force and 4.5% of the Gross Domestic Product (GDP) [15].

The fish and fishery sector is widely reported to contribute to environmental and health problems especially in Africa due to the waste generated after processing of seafood. The potential impacts are expressed through environmental indicators such as carbon dioxide (CO_2) which contribute to climate change which subsequently affects human health and the ecosystem [17]. Furthermore, the large biomass of seafood waste could increase energy consumption and financial cost which could contribute to economic losses [18]. To streamline the activities of seafood waste from the seafood industries, there should be the availability of precise data on waste generated. The availability of seafood waste data is non-existent in Ghana. Therefore, this study sought to gain an insight into the volume of seafood waste generation, utilization and management system in seafood processing companies.

The study objectives were: (i) to quantify seafood waste from seafood processing companies in Ghana, (ii) to determine the composition of seafood waste generated, and (iii) to identify the bottlenecks in the reuse of seafood waste from ten seafood processing companies using a survey approach. The companies were located in Tema, Accra, Winneba and Takoradi metropolis. The findings from this study can support future research and policy aimed at developing strategies to mitigate seafood waste generated and further increase seafood waste value addition.

MATERIALS AND METHODS

Study area
The seafood processing companies which took part in the survey were located along the coastal areas in the Atlantic ocean of Ghana. The purposeful sampling technique was adopted based on the criteria that they processed seafood for the case study. The selected on-shore processing companies are situated in Takoradi Metropolitan Assembly (TaMA), Accra Metropolitan Assembly (AMA), Effutu Municipal Assembly (WMA) and Tema Metropolitan (TMA) companies as shown in (Figure 1).
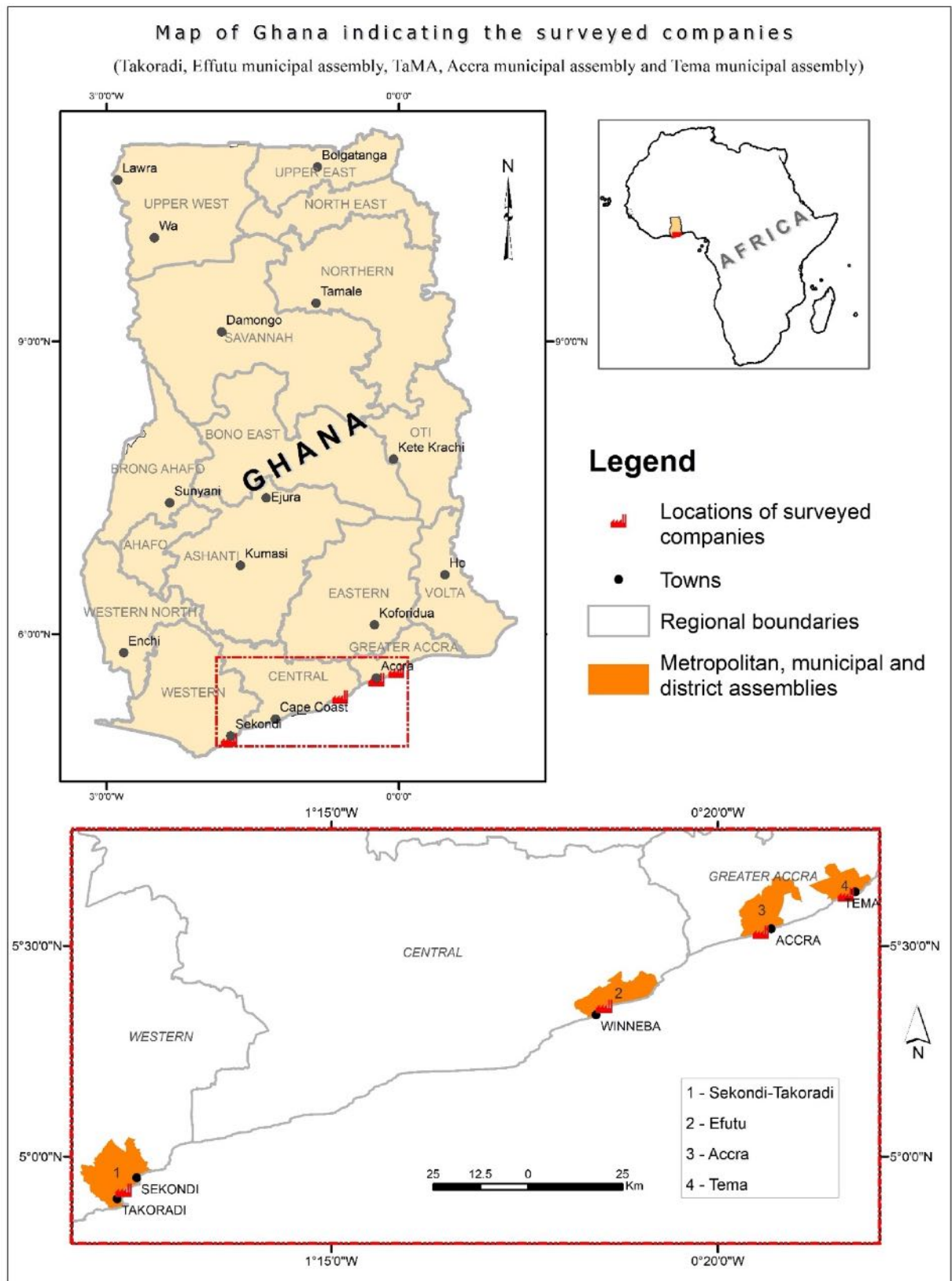
Figure 1: Map of Ghana indicating the surveyed companies: Takoradi, Effutu, Accra and Tema

20928

Seafood processing company located in TaMA was one, whereas two, six, and one companies were found in AMA, TMA and EMA respectively (Table 1). The companies were grouped into four areas which were alphabetically represented as A, B, C and D to represent Takoradi, Accra, Tema and Effutu respectively as indicated in Table 1. The largest seafood processing companies located in TMA and TaMA were surveyed. Seafood processing companies situated in TMA added value to some of their seafood waste generated unlike the other processing companies located in EMA, TaMA, and AMA. A total of ten active seafood processing companies were surveyed where questionnaires were administered to the Quality Assurance and Production Managers of the companies prior to the consentment of participant form.

Data collection and analysis
The survey data were collected from October to November 2020 using a Semi-Structured Interview Schedule (SSIS) method. Pretesting was conducted using four companies to assess the applicability of the questionnaire. The aim of the pretesting was to help modify the questionnaire to make it suitable as a research tool for gathering the relevant data. The names of the companies were anonymous as per the consent. The questionnaire collated information on the type of seafood processing companies, duration of operation (years), target species, the quantity of seafood waste generated per day, current seafood waste management methods, primary and secondary production of the waste into value-added products, expenses incurred in waste management and plans to invest in secondary utilization of seafood waste.

Analysis of data
Descriptive analysis was done using SPSS (version 21, IBM Corp., Chicago, USA). The demographic and seafood processing information obtained from the companies were expressed in frequency counts and the percentage of the total responses.

RESULTS AND DISCUSSION

Demographic factors
The surveyed seafood processing companies which had been in operation for one to five years denoting 10%, and those in existence for six to ten represented 40% as those demonstrated in Figure 2.
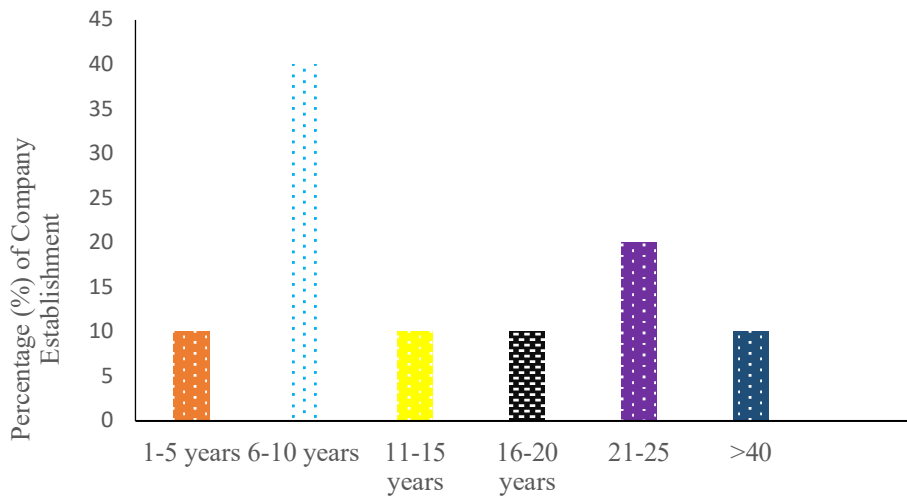
Figure 2: Years of operation of seafood processing companies in Ghana

Majority (80%) of the seafood processing companies processed cuttlefish, octopus, lobster, prawns, barrucada, sardinella, tilapia, carranx, red mullet, grouper, thunnus (tuna) and squid. The seafood processing companies that processed tuna represented 20%. The findings of the study indicated that significant waste generated especially from lobster, cuttlefish, octopus and prawns occupied the second largest volume of production (Table 2) after tuna seafood production.

Quantification of waste generated from seafood processing companies
The quantification of seafood waste generated depended on several factors including processing capacity, end-product of seafood, target species and the kind of species harvested. The highest waste generated per weight of the product was obtained from grouper seafood (60 %). The least was produced from tuna seafood (11 %). Tuna waste was the only seafood waste processed for value added products. They are usually processed into fish oil and fish meal. The processing of sardinella and barracuda generated an average of 45% of the production volume, less than 10 tons of the production capacity as displayed in Table 2.

Processing of the seafood waste generated by the companies could save our environment and provide value-added products like fish oil, fish meal, protein hydrolysate and biofuel. Studies by [19] revealed that bio-diesel estimated at an amount of the 0.8 L could be extracted from 7 kg of seafood waste. There are, therefore, calls for an urgent improvement in the fishing industry for sustainability, effectiveness and environmentally friendly treatment technology among all the actors [20].

Production of raw seafood
Figure 3 displays the percentage production capacity of raw seafood caught from all the seafood processing companies. The majority of the processing companies (40%) produced 11 to 15 tons of raw seafood (Figure 3) whereas 10% produced 21 to 25 tons (Figure 3).
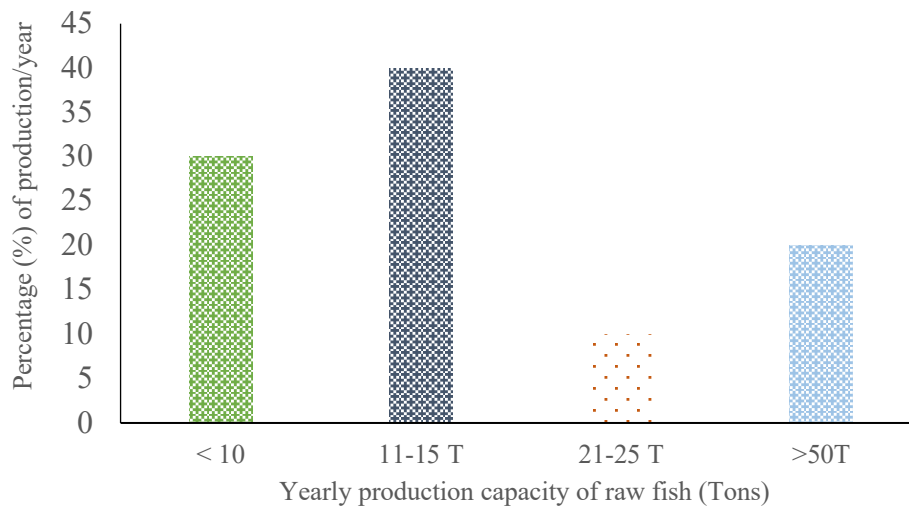
Figure 3: Production of harvested fish from inland and marine zones

Composition of seafood waste

A significant amount of this production (>50T) was from tuna fish followed by lobster, cuttlefish, octopus, prawns which had 21-25 tons production/year, squid, red mullet, grouper had 11-15 tons production volume and tilapia, catfish, sardinella, barracuda, carranx, thunnu, recorded <10 tons production/year. Most of the seafood waste generated (48-60%) was obtained from squid and red mullet (Table 3). On the other hand, the processing of tuna generated 11% seafood waste because the tuna processing companies had machinery to process the waste. The seafood companies improperly disposed off of their seafood waste which could lead to a serious environmental problem with subsequent effect on climatic stability [14].

Status of seafood processing companies in Ghana

The seafood processing companies produced primary and secondary by-products such as fish feed, fish meal, fish oil and seafood-based products. The survey results revealed that about 80% of seafood processing companies did not process their seafood waste (Figure 4).
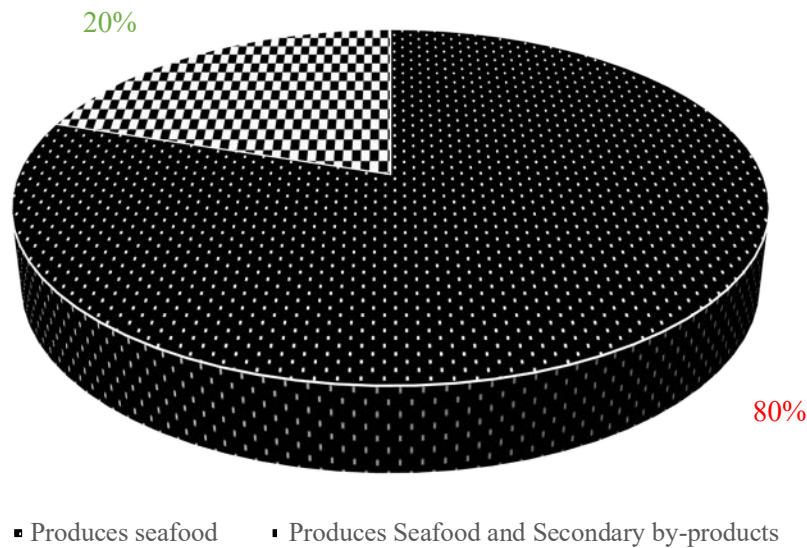
20%

80%

▪ Produces seafood   ▪ Produces Seafood and Secondary by-products

Figure 4: Total component of seafood production

Most of these companies sold the seafood directly to the end-users after harvesting and processing. A large proportion of these seafood wastes were discarded either by dumping or being buried. The seafood processing companies did not process the generated seafood waste because they were not interested. Most of the managers mentioned that the processing equipment needed for converting these wastes into useful products were not available. This is a serious problem in that seafood waste discarded into the sea by the companies could cause environmental pollution [21-23], reduction of oxygen level [24], generate new food chains for scavengers thereby creating an ecological distortion through organic enrichment of sediments [25-27]. About 20% of the seafood processing companies added value to their primary seafood waste.

An approach to increase seafood waste utilization is to convert most of this seafood waste into valuable products. The survey results indicated that two processing companies that generated 32% of value-added waste products further produced 11% of the seafood waste.

Bottlenecks in the reuse of seafood waste
Seafood waste management systems employed in seafood processing companies
The questionnaire was designed to gather information on the management practices employed by the seafood processing companies in Ghana. The survey results showed that about 20% of the seafood processing companies treated the generated waste. Out of the 10 companies surveyed, a majority (60%) disposed off their seafood waste into a dumping site. The rest, buried and disposed off the waste (solid and liquid) into the sea (10%) (Figure 5).
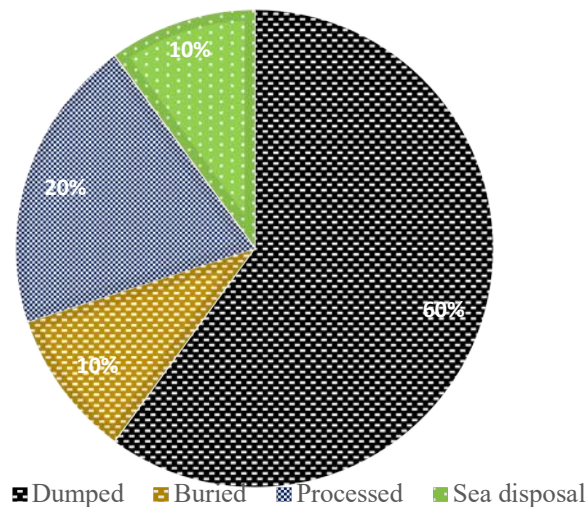
Figure 5: Seafood waste disposal methods employed in Ghana

Two out of the 10 processing companies which represented 20% utilized their waste for other products such as fish meal and fish oil. About 70% of the seafood processing companies spent as high as $12.8566-33.52.76 per day in managing their seafood waste (Table 4) which could raise the production cost by about $4631.23-12,035.08 annually. The remaining companies sold the generated seafood waste as animal feed.

The waste generated from seafood poses negative impacts on the fishery sector especially marine ecosystems and the environment. This consequently creates unsustainable fishing which affects seafood actors in the fishing sector [9]. The United Nations (UN) through its sustainable development goals (SDGs) entreats society to engage in responsible food production and consumption to reduce seafood waste [28]. Results obtained from this study proved that majority of the seafood processing companies compromised on sustainable seafood waste management practices. Unfortunately, 70% of the seafood processing companies spent a huge amount of money to manage the waste which affected the cost of production and profit margin. Elsewhere in the world, other countries are successfully converting wastes into value-added products. For instance, in Thailand, sea bass, nile tilapia, and red tilapia skin and bone are used to produce fish gelatin [29], protein hydrolysates and lipids are successfully produced from sardine by-products [30].

Factors influencing seafood waste generation in Ghana are mainly due to lack of policy in addressing waste management and lack of knowledge on the importance of value-added seafood waste products.

The results from the survey indicated that there were no laws managing seafood waste in Ghana. This brings about difficulties in standardizing the definition of what seafood waste is. There are several definitions of seafood waste that exist in literature [10]. Based on the responses from the seafood processing companies interviewed, there is no

common definition of seafood waste. As a result, seafood waste considered to be waste by one company is not regarded as such by the other seafood processing companies. Additionally, there is no audit of seafood generated from the regulatory institutions like the Environmental Protection Authority. The proportion of seafood waste products recorded is based on estimates given by Quality Assurance and Production Managers during the survey. To address these issues, there should be an establishment, implementation and enforcement of national seafood waste legal instruments. Furthermore, the presence of an audit plan can identify the specific seafood species from which the waste was generated, the quantity of waste generated, value and relative hazard that the seafood waste will bring about. In that case, resorting to the seafood processing companies for such information, which could even affect the real situation on the ground.

Another challenge that contributed to the inability to process their seafood waste was the lack of knowledge of the importance of value-added seafood waste products.

Lastly, one significant challenge confronting the processing of seafood waste was the lack of equipment. From the results in (Figure 4), only 20% of the processing companies added value to the waste produced. A majority (80%) of the seafood processing companies did not process the seafood waste generated due to the unavailability of the processing equipment and skilled staff. To address this seafood waste menace, an amicable solution should be introduced. International organisations and Governments should liaise with these smaller seafood processing companies and invest in this area which could substantially reduce the waste generated. Although the Government of Ghana has a new turnkey fish processing plant aimed to reduce postharvest losses and add value to fishwaste, more effort should be put in place in acquiring more seafood waste processing plants to increase the utilization of the seafood waste generated in Ghana. For maximum output and sustainability of the seafood industry, processing plants should be established effectively to treat the seafood waste to reduce the loads and pressure on the ecosystem according to Shahidul *et al.* [30].

Majority of the surveyed companies (80) main interest was to harvest seafood and sell directly to the end-users or process it into end-products. The utilization of seafood waste by the seafood waste companies could go a long way to reduce the environmental problems in Ghana which will help in the sustainability of seafood.

CONCLUSION

Data on current seafood waste generated and managed by 10 seafood processing companies were obtained. It was evident that 60% of seafood waste was generated by seafood processing companies and there is a need for steps to be taken to reduce it. The study revealed that there were no laws in Ghana that controlled the reuse of seafood waste. Some of the seafood processing companies could not process their seafood waste generated because of inadequate knowledge on the importance of seafood waste value-added products, lack of equipment and skilled staff. Most of the seafood waste generated (60%) was obtained from grouper seafood with the least from tuna (11%).

The composition of seafood waste generated was visceral, bones, tails, caudal fin, skins, scales, head and gills. There is, therefore, the possibility to utilize seafood waste in the production of other low-cost value-added products like fish gelatin, chitosan, chitin, fish oil and protein hydrolysates.

It is recommended that a holistic seafood waste reduction approach must be established between actors involved in the fishing sector. In addition to this, seafood waste management laws should be established and enforced to regulate seafood waste. An independent audit firm should be established to identify the specific seafood species from which the waste was generated, the quantity of catch and waste generated, value and relative hazard obtained on a short and long time scale. Future studies should focus on the conversion factors of the seafood waste which could also be the basis for the quantification of the degree of waste generated.

DECLARATION OF COMPETING INTEREST
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Table 1: Seafood processing companies in various district assembly in Ghana

Company code	Number	Assembly
A	1	Takoradi
B	2	Accra
C	6	Tema
D	1	Winneba

Table 2: Production volume/day of harvested target species from the processing companies

Target species	Production volume (T)
Tuna	>50
Lobster, cuttlefish, octopus, prawns	21-25
Squid, red mullet, grouper	11-15
Catfish, sardinella, barracuda, carranx, Thunnus	<10

Table 3: Composition of seafood secondary by- products and seafood waste generated from seafood processing companies

Species	Seafood (%)	Secondary by-products (%)	Seafood waste (%)
Lobster (*Nephropidae)*	66	-	34
Cuttlefish (*Sepiida*)	75	-	25
Octopus (*Octopuda*)	75		25
Prawns (*Dendrobranchiata*)	100	-	-
Squid (*Teuthida*)	52	-	48
Tuna (*Thunnini*)	43	38	11
Red mullet *(Mullus sarmuletus*)	45	-	-
Grouper (*Epinephelinae*)	40	-	60
Sardinella (*Sardinella*)	45	-	55
Barracuda (*Sphyraena*)	60	-	40
Caranx (*Caranx*)	55	-	45
Thunnus	28	-	15

Table 4: Cost involved in waste management of seafood waste

Percentage of seafood companies involved in seafood waste management (%)	Cost of waste disposal/ (¢/day)
20	< 100
50	100-250
30	-

REFERENCES

1. **Silk D, Mazzali B, Gargalo C L, Pinelo MA, Udugama I and SS Mansouri** A decision-support framework for techno-economic-sustainability assessment of resource recovery alternatives. *J. Clean. Prod*, 2020; **266**: 121854. https://doi.org/10.1016/j.jclepro.2020.121854

2. **Udugama IA, Petersen LAH, Falco FC, Junicke H, Mitic A, Alsina XF, Mansouri SS and KV Gernaey** Resource recovery from waste streams in a water-energy-food nexus perspective: Toward more sustainable food processing. Food Bioprod Processing, 2020; **119**: 133–147. https://doi.org/10.1016/j.fbp.2019.10.014

3. **Gani R, Baldyga J, Biscans B, Brunazzi E, Charpentier J, Drioli E, Feise H, Furlong A, Van Geem K, Hemptinne J, ten Kate AJB, Kontogeorgis GM, Maneti F, Marin G, Mansouri SS, Piccione PM, Povoa A, Rodrigo MA, Sarup B, Sorensen E, Udugama IA and JM Woodley** A multi-layered view of chemical and biochemical engineering. *Chem Eng Res Des*, 2020; **155**: A133-A145.

4. **Perederic O A, Mansouri SS, Appel S, Sarup B, Gani R, Woodley JM and GM Kontogeorgis** Process Analysis of Shea Butter Solvent Fractionation Using a Generic Systematic Approach. Ind. *Eng. Chem. Res*, 2020; **59**: 9152–9164. https://doi.org/10.1021/acs.iecr.9b06719

5. **Hasselberg AE, Aakra I, Scholtens J, Overa R, Kolding J, Bank MS, Atter A and M Kjellevoid** Fish for food and nutrition security in Ghana: Challenges and opportunities. Glob. *Food Sec.* 2020; **26 (2020**): 1003802020.

6. **Zhang D and R Tveteras** A fish out of water? Survival of seafood products from developing countries in the EU market. Mar. Policy. 2019; **103:** 50-58.

7. **Kerton FM, Liu Y, Omari KW and K Hawboldt** Green chemistry and the ocean-based biorefinery. *Green Chem.* 2013; **15**: 860e871. https://doi.org/10.1039/c3gc36994c

8. **FAO.** Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication. FAO; 2015, Rome. Retrieved from. http://www.fao.org/3/ai4356e.pd *Accessed 14 January 2021.*

9. **Thyberg KL and DJ Tonjes** Drivers of food waste and their implications for sustainable policy development. *Resour. Conserv. Recycl.* 2016; **106**: 110–123. https://doi.org/10.1016/j.resconrec.2015.11.016

10. **V**an Herpen E, Van der Lans IA, Holthuysen N, Nijenhuis-de Vries M and **TE Quested** Comparing wasted apples and oranges: an assessment of methods to measure household food waste. *Waste Manag.* 2019; **88**: 71–84. https://doi.org/10.1016/j. wasman.2019.03.013

11.   **Love DC, Fry JP, Milli MC and RA Neff** Wasted seafood in the United States: quantifying loss from production to consumption and moving toward solutions. *Global Environ. Change*. 2015; **35**: 116–124. https://doi.org/10.1016/j.gloenvcha

12.   **FAO.** The state of food and agriculture. 2019a. Available from. http://www.fao.org/3/ca6030en/ca6030en.pdf Accessed *15 January 2021.*

13.   **Ghaly A, Ramakrishnan V, Brooks M and D Dave** Fish processing wastes as a potential source of proteins, amino acids and oils: a critical review. *J. Microb. Biochem. Technol*. 2013; **5**: 107–129. https://doi.org/10.4172/1948-5948.1000110

14.   **Erasmus VN, Kadhila T, Gabriel NN, Thyberg KL, Ilungu S and Machado T** Assessment and quantification of Namibian seafood waste production. *Ocean Coast Manag*. 2021; **199**: 105402.

15.   **FAO.** Fishery and Aquaculture Country Profiles. The Republic of Ghana. FAO 2016a; Rome. Fishery and aquaculture country profiles: Republic of Ghana http://www.fao.org/fishery/facp/GHA/en *Accessed 02 September 2019.*

16.   **Sumberg J, Jatoe J, Kleih U and J Flynn** Ghana's evolving protein economy. *Food Secur.* 2016.

17.   **Avadí A and I Acosta-Alba** Eco-Efficiency of the Fisheries Value Chains in the Gambia and Mali. *Foods* 2021; **10**: 1620. https://doi.org/10.3390/foods10071620

18.   **Coppola D, Lauritano C, Palma Esposito F, Riccio G, Rizzo C and D de Pascale** Fish Waste: From Problem to Valuable Resource. *Mar. Drugs* 2021; **19**: 116. https://doi.org/10.3390/md19020116

19.   **Yahyaee R, Ghobadian B and G Najafi** Waste fish oil biodiesel as a source of renewable fuel in Iran Renew. Sustain. *Energy Rev*. 2013; **17**: 312-319.

20.   **Kratky L and P Zamazal** Economic feasibility and sensitivity analysis of fish waste processing biorefinery. *J. Clean. Prod.* 2020; **243 (2020**): 1186772020.

21.   **Arvanitoyannis IS and A Kassaveti** Fish industry waste: treatments, environmental impacts, current and potential uses. *J. Food Sci.* 2008; Technol. 43, 726e745. https://doi.org/10.1111/j.1365-2621.2006.01513.x

22.   **Gumisiriza R, Mshandete AM, Rubindamayugi MST, Kansiime F and AK Kivaisi** Nile perch fish processing waste along Lake Victoria in East Africa: auditing and characterization. *Afr. J. Environ. Sci.* Technol. 2009; **3**: 13–20. https://doi.org/10.5897/AJEST08.149

23.   **Caruso G** Fishery wastes and by-products: a resource to be valorised. J Fisheries Sciences.com. 2015; **9**: 80–83.

24. **Onofri L and F Maynou** Unwanted catches, quota systems and the EU Landing 27 Obligation: an economic and econometric analysis. *Ocean Coast Manag.* 2020; **189:** 105159. https://doi.org/10.1016/j.ocecoaman.2020.105159

25. **Dayton PK, Thrush SF, Agardy MT and RJ Hofman** Environmental effects of marine fishing. *Aquat. Conserv. Mar. Freshw. Ecosyst.* 1995; **5**: 205–232.

26. **Connolly PL and CJ Kelly** Catch and discards from experimental trawl and longline fishing in the deep water of the Rockall Trough. *J. Fish. Biol.* 1996; **49 (Suppl. A):** 132–144.

27. **UNDP.** United Nations development programme, sustainable development goals. 2016. www.undp.org/content/undp/en/home/sustainabledevelopment-goals *Accessed 15 January 2021.*

28. **TInrAT S and M SIIA-ASuA** Optimization of Gelatin Extraction and Physico-chemical Properties of Fish Skin and Bone Gelatin: I's Application to Panna Cotta Formulas. *Curr. Res. Nutr. Food Sci.* 2017; **Vol (3):** 263-273.

29. **Batista I, Ramos C, Mendonca R and ML Nunes** Enzymatic hydrolysis of sardine (Sardinapilchardus) by-products and lipid recovery. *J. Aquat. Food Prod.* Technol. 2009; **18**: 120–134.

30. **Islam S, Khan S and M Tanaka** Waste loading in shrimp and fish processing effluents: potential source of hazards to the coastal and nearshore environments Md. Marine Pollution Bulletin **49 (2004)** 103–110.