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Full Length Research Paper

Nile perch fish processing waste along Lake Victoria in East Africa: Auditing and characterization

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Worldwide, fish industry wastes are an important contaminant having an impact on the environment. The recovery of value added products from these residues constitutes an important waste reduction strategy for the industry. In East Africa, Nile perch fish processing into chilled fish fillet for export along Lake Victoria generate large proportions of both solid and liquid wastes. However, no thorough auditing and characterization of the waste has been done that would guide potential value addition through bioconversions and waste management. Auditing by surveying and mapping the fish processing industries was conducted along the lake. Waste quantification was done using specific guidelines for assessment of fish wastes. Analysis of the waste was carried out using standard methods. Annual solid waste and wastewater generation was estimated at 36,000 tonnes and 1,838,000 m^3, respectively. The wastewater generated was high strength with a total chemical oxygen demand of 12,400 mg/l and solid content of 5,580 mg/l. The wastewater contained 6,160 mg/l of lipids and 2,000 mg/l of protein. The Nutrient content was 20 mg/l of total phosphorous, 340 mg/l organic nitrogen and 61 mg/l of ammonia nitrogen. The current fish waste management systems in place were found to be neither efficient nor profitable, thus profitable options of fish waste utilization and waste reduction strategies are imperative. Modern and economically viable options of fish waste value addition, decision scheme and waste reduction strategies have been highlighted in this paper. In conclusion, large amounts of fish waste generated are a rich source of lipids and proteins, which could be utilized for production of value added products through bioconversions.

Key words: Nile perch, fish waste, auditing, characterization, value addition, utilization.

INTRODUCTION

Industrial fish processing generates large amounts of waste or residues of high nutrient content which, if not properly utilized or treated, is likely to be deposited in the environment creating pollution and health problems (Hwang and Hansen, 1998; Kotzamanis et al., 2001). Fish processing residues include scales, viscera, fish scrap, fat solids, proteins, fish rejects, and liquid stick wastewater (UN Report, 1997; Hwang and Hansen, 1998; McDonald et al., 1999). The solid fish wastes make up 30 - 40% of the total production, depending on the species processed.

In East Africa, fish processing industries comprise an important segment of the economy. There are over thirty fish processing industries along the shores of Lake Victoria employing thousands of people (LVFO, 2007). The nature of fish processing wastewater suggests that they have high biological oxygen demand (BOD) together with inorganic compounds from detergents and disinfect-tants used in these factories. These wastes are not suffi-ciently treated leading to eutrophication of the lake, which may result into changes in species composition, and even loss of species (Muyodi et al., 2004). Besides, all these fish processing factories are located in areas with no land for building conventional centralized wastewater treatment systems like stabilisation ponds or wetland. In

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the long run, the fish industry in East Africa will not be sustained due to water pollution (LVEMP, 1995). The prospects of generating value added products from fish processing waste will encourage factories to utilise their wastes before discharge. This approach will be in line with the 7th Millennium Development Goal number seven that emphasises sustainable development and reversal of loss of environmental resources. The most important environmental-friendly and profitable options for utilizetion of fish waste for the recovery of marketable by products and production of value added products through bioconversions has been recently reviewed by Arvanitoyannis and Kassaveti (2008). These include production of animal feed such as swine and poultry feed, monogastric animal feed supplements, aquaculture feed, fishmeal and oil production, fish silage production, production of renewable energy in form of biodiesel and biogas, composting for production of organic fertilizer, extraction of natural pigments and extraction of novel and industrial enzymes like proteases. Furthermore, Arvanitoyannis and Kassaveti (2008) reported the potential of fish waste for production of biochemical products for use in food, cosmetics and pharmaceutical industries such as collagen, fish protein hydrolysate, fish bone extracts, collagen and polyunsaturated fatty acids. Other options for utilizetion of fish waste reported by Hwang and Hansen (1998) and Arvanitoyannis and Kassaveti (2008); include production of short-chain organic fatty acids, substrates for microbial culture media, production of attractants for economically important flies of agricultural crops, chro-mium immobilization and use of fish scales as natural adsorbents and organic wastewater coagulant for sedimentation of small particles. Furthermore, Wasswa et al. (2007) reported that Nile perch fish skins and bones are a good source of gelatin and amino acids.

A detailed description and characterisation of the fish waste is an essential precondition for the consideration of alternative strategies to waste value-addition. Hence, fish waste audit is the first step in planning for the reduction of waste volume through utilisation and overcoming pollution problems. It involves a detailed analysis of the Industry's processes and waste generated. Generally, a fish waste audit is done through observing, measuring and recording process-related data, asking questions around the plant and collecting and, analyzing waste samples (OWMC, 1993; Newenhouse and Schmit, 2000). Auditing of fish wastes generate information that can be used as a basis for fish waste management, waste value-addition and design of cost-effective and adequate waste treatment facilities (Del Pozo et al., 2003). Nevertheless, information on thorough mapping, quantification and characterisation of Nile perch fish processing waste as a potential resource for recovery of marketable by-products, and production of value added products along Lake Victoria is non-existent.

Since various options for the recovery of marketable by-products and production of value added products from fish wastes exist, fish processors must make right decisions with regard to efficient, low-cost and appropriate waste utilization and management options. The decisions need to be based on economics in order to ensure that all costs associated with waste management are considered along with opportunities to reduce those costs. Moreover, fish waste disposal per se is no longer a viable option with dumping or land filling prohibited with stringent legal penalties (Pfeiffer, 2003). Some options may only become viable in conjunction with other waste producers such as farms and agro-industries (for anaerobic digestion), forestry (for composting) or other food processors (for economies of scale).

This paper presents the results from the auditing of fish waste generated by the fish processing industries along the Lake Victoria, assesses the alternative management options and evaluation of their potential for value-addition through bioconversions.

MATERIALS AND METHODS

Auditing of fish processing waste

Fish processing solid waste and wastewater were audited by surveying and mapping all the fish processing industries along the shores of Lake Victoria in Tanzania, Uganda and Kenya. Waste quantification and characterization was done by integration of qualitative methods with quantitative methods and laboratory analysis. Information regarding the nature and type of processing, quantity and quality of waste generated, and current fish waste management methods was collected through a guided survey along the processing line and entire plant, filling a questionnaire, open-ended interviews, photography and laboratory analysis of wastewater samples (Masse' and Masse, 2000; Newenhouse and Schmit, 2000; Del Pozo et al., 2003). Since all the industries were basically dealing with filleting process of Nile perch (*Lates niloticus*), wastewater samples for physico-chemical parameter analysis and other investigations were based on one of the fish processing industries in Mwanza City, in Tanzania (Figure 1).

Sampling

The fish processing wastewater samples investigated in the study were collected from a selected fish processing industry. The wastewater samples were a mixture of components from different processing sections in the plant. The samples were transported in cool boxes to the laboratory for analysis at the University of Dar es Salaam in Tanzania. Upon arrival, the samples were analysed immediately while other portions frozen until required in the subsequent studies. Sampling was done five times (Masse' and Masse, 2000) at an interval of three months for one year; between January and December 2007.

Analytical methods

Wastewater samples were analysed in triplicates for physico-chemical parameters namely temperature (°C), pH, electrical conductivity (EC), total chemical oxygen demand (TCOD), total solids (TS), total volatile solids (TVS), total suspended solids (TSS), ammonium nitrogen (NH_4-N), total Kjeldahl nitrogen (TKN), total phosphorus (TP), dissolved phosphorus (DP), total organic carbon (TOC), total lipids, carbohydrates (Total sugars) and protein concentration. Temperature (°C), pH and EC were measured *in situ* directly using

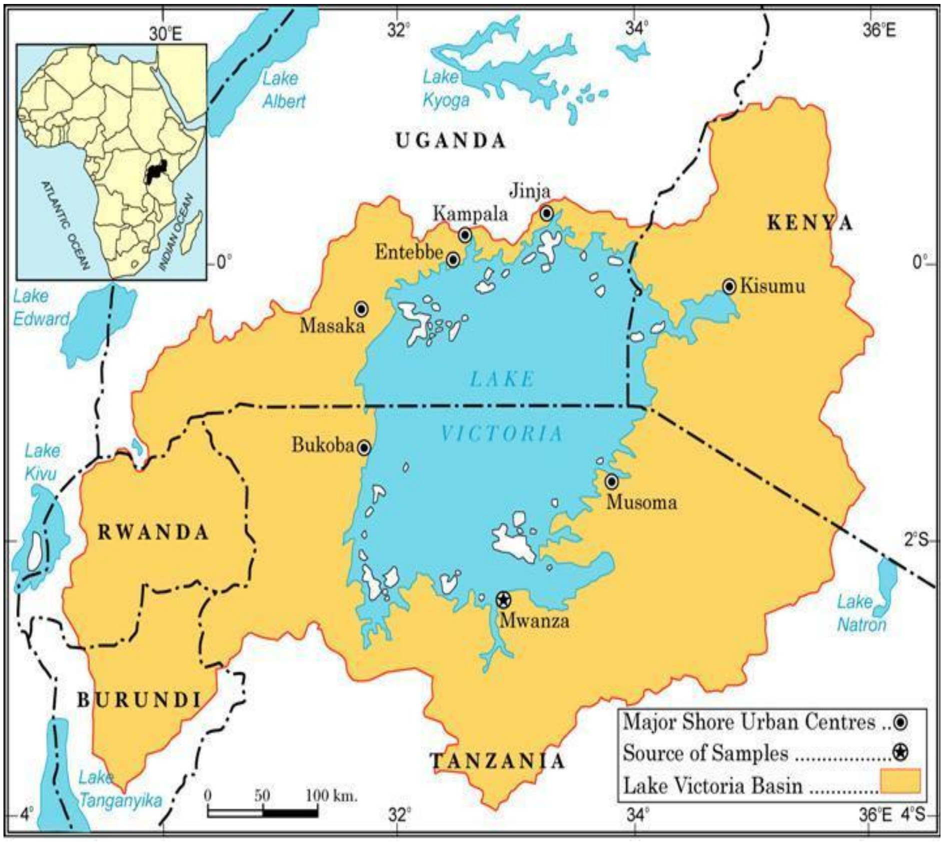

Figure 1. Map showing Lake Victoria Basin, Riparian countries and major shore urban centres and source of samples for laboratory experimentation.

a portable pH microprocessor probe and meter (HANNA-Italy). TS, TVS, TSS TVSS, TKN and TOC were measured according to the standard methods (APHA, 1998). TCOD, NH_4-N, TP and DP, and total sugars were determined colorimetrically using a DR 2010 spectrophotometer (Hach Co. Loveland, CO, USA) and standardized procedures in standard methods (APHA, 1998) according to Britz et al. (2000). Protein concentration was calculated by multiplying the difference between TKN and NH_4-N by 6.25 (AOAC, 2002). Total lipids were determined by gravimetric methods (APHA, 1998). Carbohydrates were determined as total sugars by Anthrone reagent method (Colin et al., 2007).

RESULTS

Surveys and mapping

Surveying revealed that generally all the fish processing industries along Lake Victoria are located in the major urban centers that are situated on the lake periphery mainly due to good transport network such as air ports/airfields, railway network and good roads that link these cities to market centres both locally and internationally. These urban centres include Mwanza in the South, Kisumu in the East, Kampala and Jinja in the North and Masaka in the West as shown in Figure 1. Other small centres include Bukoba, Musoma, Busia, Kasensero and Kalisizo. Through the survey, 31 fish processing industries were found to be located along the Lake shores. Their distribution per country and region is as shown in Table 1. All these industries are mainly dealing with Nile perch (*L. niloticus*) fish processing, filleting process in particular.

Nile perch waste quantification

Quantitatively, fish processing industries generated approximately 36,000 tonnes of solid waste and 1,838,000 cubic metres of wastewater annually (Table 1). Grouping these industries as per urban centre in their location, the variations in the fish waste emission is as shown in Figure 2, with Mwanza region taking the lead in both solid waste and wastewater emissions. The quantity of solid waste generated per urban centre is a function of the number of industries per region, amount of fish raw raw material processed (number of tonnes processed per day) and waste reuse/recycle ability while the quantity of wastewater generated at a particular industry was a function of water usage conservation. Tanzania generates more than 75% of the total solid waste emitted along the lake (Figure 3). This is attributed to high processing capacity of the industries along the Tanzanian side of the lake particularly in Mwanza municipality.

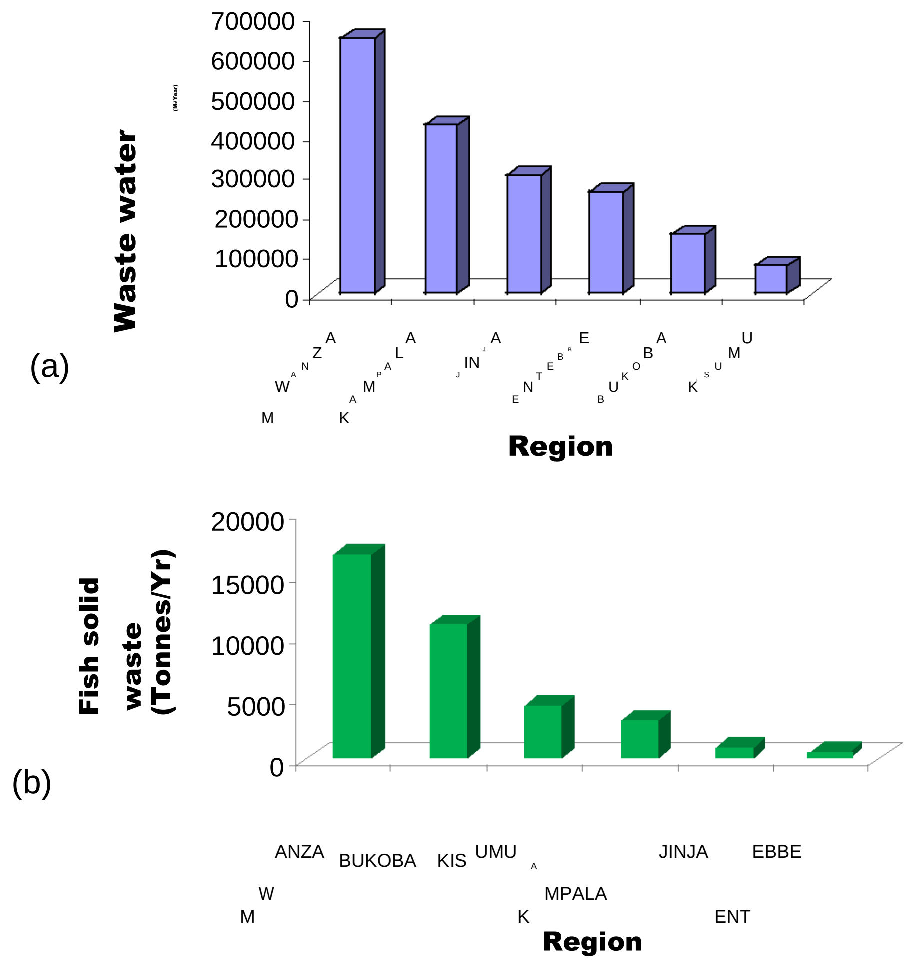

Figure 2. Fish processing waste generation per urban centre; (a) solid waste generation and (b) Wastewater generation.

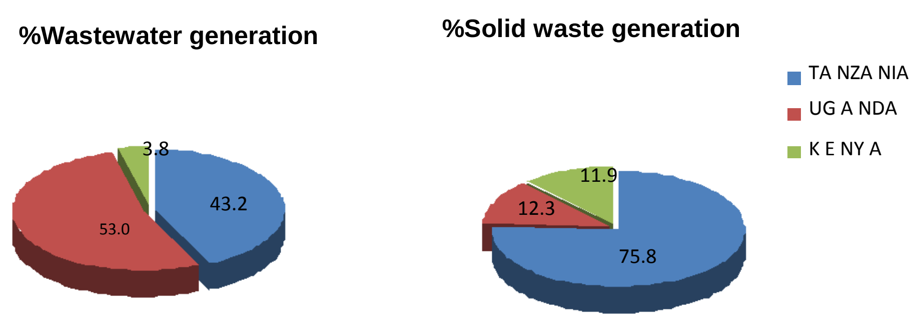

Figure 3. Percentage fish waste generation per riparian country.

Nile perch waste characterisation

The survey indicated that the solid fish waste consisted of viscera, skin, frames, chips, fins and constitute about 30 - 40% of the total production depending on the efficiency of the production process. The fish processing wastewater predominantly consisted of lipids, soluble proteineous material, chips, blood and scales. Wastewaters from the filleting section had most of the organic loads due to blood resulting from fish filleting activities. Other waste streams included those in the receiving section, by-product section, trimming and resizing section, grading and packaging section as shown in Table 2. The fish processing wastewater contained a very high concentra-

Table1. Fish processing industries along the shore of Lake Victoria and waste emissions.

Riparian state	Number of industries per country	Location				Wastewater generation (m^3/yr)	Solid waste generation (tonnes/yr)
		Region	Number of industries per region	Operating industries	Surveyed industries		
Tanzania	10	Mwanza	6	4	3	644,400	16,500
		Bukoba	2	2	2	149,400	10,800
		Musoma	2	2	0	na	na
Uganda	17	Entebbe	4	3	3	252,000	500
		Kampala	5	5	5	423,000	3,000
		Jinja	4	3	3	298,800	900
		Masaka	3	3	0	na	na
		Busia	1	1	0	na	na
Kenya	4	Kisumu	3	3	3	70,400	4,300
		Homa bay	1	1	0	na	na
Total	31		31	27	19	1,838,000	36,000

na: not audited.

Table 2. Major fish processing waste streams and their predominant waste fractions. Make a statement.

Waste stream	Waste fraction emitted
Receiving section	Caucus/Fish rejects, Wash-off water,
Filleting section	Skin, Flame/Bony skeleton, Bloody water, caucus
Trimming	Chips, Fats, Fillet rejects, pieces of bones
By-product	Viscera, Fats Roes/eggs, Head, Breast, Bloody water
Headed & Gutted	Scales, Viscera, Bloody water, Fins
Grading & Packaging	Fillet rejects, deteriorated fillets

centration of lipids with very little carbohydrates determined as total sugars. Other physical-chemical parameters analysed are as shown in Table 3.

Current Nile perch fish waste management methods

A survey through these industries showed that more than 75% of these industries attempted to treat or utilize their solid wastes. However, these industries employed either preliminary or utmost primary treatment alone for treating high strength fish processing wastewaters and thereafter discharged. The wastewater disposal methods employed include undersized stabilization ponds and direct discharge of either raw or semi-treated wastewaters into the lake or channels that emptied into the lake. The methods that were employed in disposing the solid fish waste included dumping on the ground and burying under ground. The fish waste utilization methods mainly include-ed local sale of solid fish residues such as fish frames used as food by the local community. However, the residues were sold at low prices that could not pay off their handling costs as shown in Table 4. A few industries processed locally some of the fish waste fractions such as fish frames, skin and fins into fishmeal.

DISCUSSION

The pH of Nile perch fish processing wastewater varied from 6.0 to 7.8 (mean 6.9 ± 0.9). These values are similar to the ones reported for Trout-processing wastewater (Hwang and Hansen, 1998), and similar to 6.9; the pH value reported for slaughter house wastewater (Masse and Masse, 2000). This suggested that there was less use of chemicals such as detergents, which alter the effluent pH. Therefore, the waste was amenable to value addition through bioconversion. Furthermore, fish processing wastewater contained high solid content of which more than 95% were volatile. These values also tallied with the ones reported for trout-processing wastewater by Hwang and Hansen (1998). This indicated that most solids in the fish processing wastewater were of organic origin and have high energy production potential if efficiently biodegraded through anaerobic digestion.

The organic content obtained for Nile perch fish processing wastewater was as shown in (Table 3). The mean TCOD of 12,400 mg/l was comparable to 11,530 and

Table 3. Characteristics of Nile perch fish processing wastewater.

Parameter	Magnitude
pH	6.9 ± 0.9
EC (µs)	1,180 ± 500
Solid content	
Total solids (mg/L)	5,580 ± 790
Volatile solids (% of TS)	95.4 ± 2.5
Suspended solids (mg/L)	4,500 ± 640
Volatile SS (% of SS)	95.6 ± 3.8
Organic content	
Organic carbon (%)	52.5 ± 6.4
Organic nitrogen as TKN (mg/L)	340 ± 50
Protein (mg/L)	2,020 ± 290
Total COD (mg/L)	12,400 ± 140
Lipids (mg/L)	6,160 ± 140
Total sugars (mg/L)	0 ± 0
Nutrient level (mg/L)	
Ammonium-nitrogen	61 ± 21
Reactive phosphorous	9.2 ± 2.4
Total phosphorous	20 ± 6

Values are averages of the triplicate analyses ± standard deviation (SD).

Table 4. Local sale price of some fish waste fractions and potential use.

Waste fraction	Price (US $/ton.)	Use
Fish frames	40.3	Food
chips/trimmings	363.7	Food
Fat	378.5	Food and fuel
skin	54.6	Fuel
Roes/eggs	265.7	Food
Head	75.0	Food
Breast	378.0	Food

11,000 mg/l reported by (Masse and Masse, 2000) and (Johns, 1995), respectively. High TCOD in Nile perch fish processing wastewater is attributed to the high concentration of lipids (6,160 ± 140 mg/l). Kuang et al. (2002) reported that, the lipid content might vary between 1,200 and 1,700 mg/l in slaughterhouse wastewater, and between 2,000 and 3,000 mg/l in dairy effluents. The high lipid content of the Nile perch fish processing wastewater was mainly due to handling of viscera in the by-products section during sorting and washing of marketable by-products such as fish maws and fish roes. Viscera are major fat depots in the Nile perch. As shown in Table 3, the protein concentration of fish processing wastewater (2,020 ± 290 mg/l) was in the same range limits as values reported by Masse and Masse (2000) for slaughterhouse waste wastewater (444 - 2,775 mg/l). Fish processing wastewater did not contain carbohydrates (total sugars) and the 52.5% organic carbon was mainly due to high lipid content.

The nutrient level (organic nitrogen and phosphorous) of fish processing wastewater as shown in Table 3, was high and exceeded the industrial wastewater allowed discharge levels of 10 mg/l for total nitrogen and total phosphorous, (National Environmental Regulations, 1999). The concentration of ammonium-nitrogen was 61 mg/l, which was well below the toxicity level (3,000 mg/l) for the anaerobic biomass (Masse and Masse, 2000). This indicated that the wastewater was amenable to anaerobic digestion.

Despite the attempt by most fish processing industries to treat or utilize their fish wastes, the methods employed are compromised mainly due to the nature of the fish waste itself, limited land and low price when sold to the local market. Many industries which attempt to treat fish processing wastewater in conventional stabilization ponds use small sized ponds for treating high strength fish processing wastewater. This is attributed to the location of these industries in areas with limited land that is insufficient for construction of large sized stabilization ponds (Muyodi et al., 2004).

The high lipid content of fish processing wastewater leads to the formation of a thick layer of fats that covers the surface of the pond. This reduces the pond aeration that consequently lowers its efficiency. However, these fats can be removed for use in biodiesel production (Arvanitoyannis and Kassaveti, 2008). Furthermore, the scales and fats clog and block the screens that results into additional cost of employing manual labour to mechanically scoop off these scales and fats. Again, the scales were so semi-recalcitrant that they took long to decompose once dumped on the ground or buried underground. This poses a big challenge to this disposal method as it requires a large piece of land for sustained fish processing. Other typical challenges include the malodors from stabilization ponds, dumping grounds and unhygienic substandard of fishmeal plants. Fishmeal plants along Lake Victoria are limited, probably due to high cost of production especially in terms of energy inputs and low prices of the product. A fishmeal plant requires high energy in-put for drying fresh fish waste before milling (Arvanitoyannis and Kassaveti, 2008). As a result, there were few fishmeal plants along the lake shore, which were in turn discouraged by poor and substandard malodorous processing conditions that led to production of poor quality fishmeal products only limited to animal feed. Never the less, the local sale of fish processing residues is not the paramount solution to the management of fish waste along the lake. These residues are sold so cheaply that their economic value is undermined (Table 4). Moreover at some industries fish residues (fish wastes) are produced in more bulk than what can be sold locally and the excess is dumped. Strategies for fish processing waste reduction aim at reducing the level of waste generation with increased efficiency in usage of raw materials and other inputs such as water. The low efficiency in usage of water and recovery of marketable by-products accounts for the generation of

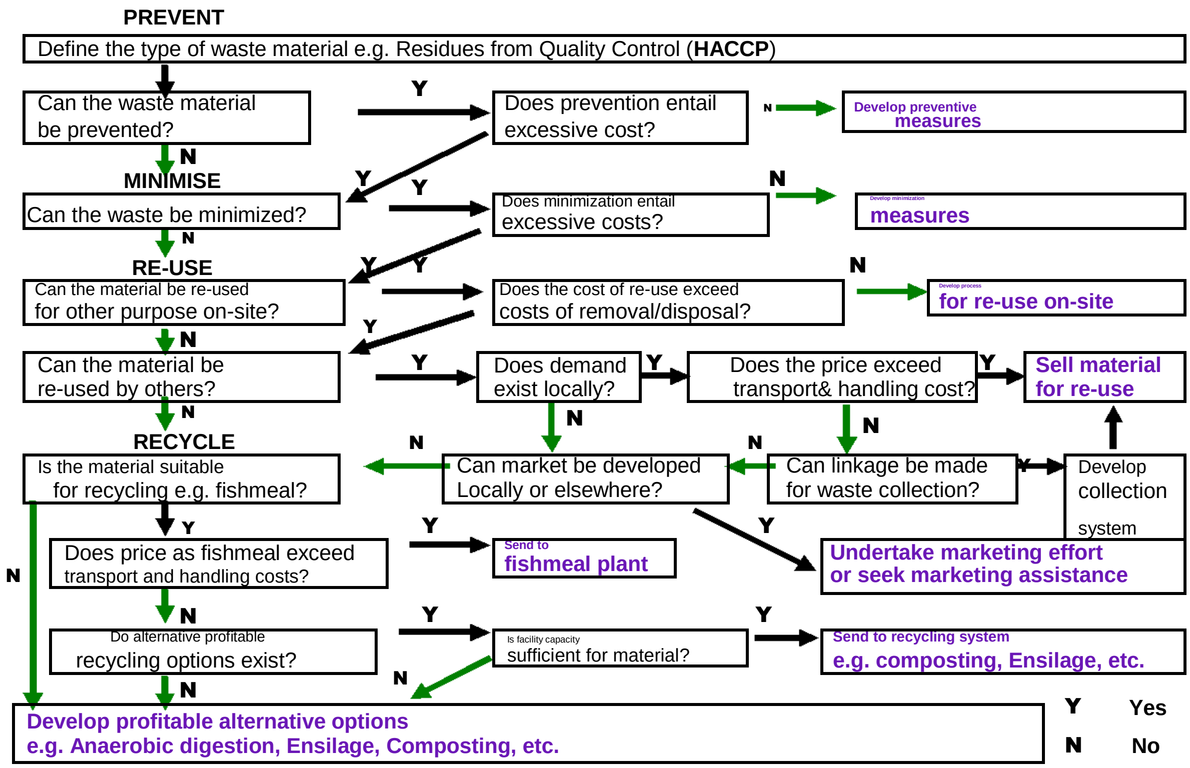

Figure 4. A decision scheme for fish waste utilisation and management.

more fish processing waste in one urban centre than the other. This study observed that Mwanza city generates most fish processing waste (Table 2) compared to other cities along the lake partly because it has the highest water usage among the industries surveyed. Again the recovery of marketable by-products from fish industries in Mwanza city is limited only to fishmeal production, which was also done at a small scale. Fish processing waste reduction options could include house keeping strategies, efficient water usage, process and product modifications, and input substitution. House keeping strategies focus at good management of raw materials and products to avoid contamination, deterioration and reduce fish rejects from the process stream. Raw material quality control is one of the key focal point in reducing waste production and profit enhancement. Although the theoretical fillet production per unit weight of fish is 42% (FAO, 2002), the actual fillet production in all the fish industries is less mainly due to post harvesting fishery losses like fish deterioration due to prolonged fish netting, inadequate freezing and on-boat and landing hygiene. Therefore among the key house keeping strategies, hygiene and adequate presser-vation of both raw material (fresh fish) and products are critically essential for profit maximization and waste reduction.

In fish processing industries, it is quite challenging to modify the product in favour of waste reduction because the former is controlled by market demands. However, the process can be modified to reduce waste generation and at the same time produce the same product. Process modifications include hygienic and fleshly collection of fillet trimmings as part of marketable by-products, screen-ing wastewater to make it low strength and easily treat-able, and restricting the use of detergents and soap so that fats recovered from wastewater stream can form part of the marketable by-product. Hypochlorite use could be minimized by using potable water treated by filtration and UV light treatment (McDonalds et al., 1999). Wasswa et al. (2007) and Arvanitoyannis and Kassaveti (2008) have recently reviewed modern and economically viable op-tions of fish waste value addition. A detailed proposed decision scheme on utilization of fish processing wastes is given Figure 4.

Fish processing wastewater can be reduced by minimis-ing water use while still maintaining hygienic conditions since hygiene is the axis of safety in the food processing industry. Three categories of water use per tonne of fillet produced have been defined according to Howard (1997) as: good (less than 6 m^3); average (between 6 and 15 m^3) and poor (greater than 15 m^3). However, fish Indus-tries along Lake Victoria have an average water usage of 20 m^3 per tonne of fillet produced which is a poor water usage based on Howard's scale. Therefore, fish pro-cessing industries need to minimise water use in order to reduce the volume of wastewater generated.

Conclusion

Along Lake Victoria, there are 31 fish processing Indus-tries located in the major urban centres and generate a lot of fish waste and large volumes of fish processing wastewater. The waste management methods employed is not efficiently treating the fish waste generated. With the currently limited options available for reuse or recycle fish wastes generated, businesses in the fish processing sector are losing out on potential revenue from by-products from fish waste and, waste disposal charges from perhaps unwittingly, illegal disposal of fish waste material. The wastewater effluents had characteristically high solid content and nutrient levels. The solids were highly organic with high COD values (12,400 ± 140 mg/L). The COD and high nutrient level are highly detrimental to the lake as they are likely to cause eutrophication.

There is an urgent need to employ modern fish waste management options to circumvent the voluminous generation and inefficient management of fish waste along Lake Victoria for not only waste emission minimization but also recovery of value-added marketable by-products and generation of renewable energy. Low cost potential options for utilization of fish wastes should be given first priority.

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REFERENCES

AOAC (2002). Official Methods of Analysis -17th ed. Association of Official Analytical Chemist, Maryland.

APHA (1998). Standard methods for examination of water and wastewater. 20 Edn. American Public Health Association, Washington, D.C.

Arvanitoyannis IS, Kassaveti A (2008). Fish industry waste: treatments, environmental impacts, current and potential uses. Int. J. Sci. Technol. 43: 726-745.

Britz TJ, Trnovec W, Fourie PC (2000). Influence of retention time and influent pH on the performance of an upflow anaerobic sludge bioreactor treating cannery waste waters. Int. J. Food Sci. Technol. 35: 267-274.

Colin X, Farinet JL, Rojas O, Alazard D (2007). Anaerobic treatment of cassava starch extraction waste water using a holizontal flow filter with bamboo as support. Biores. Technol. 98: 1602-1607.

Del Pozo R, Tas DO, Dulkadiroglu H, Orhon D, DieZ V (2003). Biodegradability of slaughterhouse wastewater with high blood content under anaerobic and aerobic conditions; J. Chem. Technol. Biotechnol. 78: 384-391.

FAO (2002). FAO fisheries statistical year book 2002. Food and Agricultural Organization of the United Nations, Rome pp. 27-39.

Howard G (1997). Water usage and minimization in fish processing. Paper 5, In: Proceedings of the Humber waste seminar, Sea fish Report SR505, Sea fish Industry Authority, Hull 1997.

Hwang S, Hansen CL (1998). Formation of organic acids and ammonia during Acidogenesis of trout-processing wastewater. *ASAE*. 41:151-156.

Johns MR (1995). Developments in wastewater treatment in the meat processing industry: a review. Biores. Technol. 54: 203-216.

Kotzamanis YP, Alexis MN, Andriopoulou A, Castritsi-cathariou I, Fortis G (2001). Utilization of waste material resulting from trout processing in gillhead bream (*Sparus aurata* L) diets. Aqua. Res. *32*: 288-295.

Kuang Y, Lepesteur M, Pullammanappalli P, Ho Ge (2002). Influence of co-substrates on structure of microbial aggregates in Long-Chain fatty acid –fed anaerobic digesters. Lett. App. Microbiol. 35: 190-194

LVEMP (1995). Report submitted to the World Bank for the establishment of Lake Victoria Environment Management Project (LVEMP), by the Government of Kenya, Uganda and United Republic of Tanzania.

LVFO (2007). Lake Victoria fisheries organization. Fish Processors and exporters, Report Thursday, 4th January, 2007.

Masse' DI, Masse L, Verville A, Bilodeau S (2001). The start-up of anaerobic sequencing batch reactors at 20 °C and 25 °C for the treatment of slaughterhouse wastewater. J. Chem. Technol. Biotechnol. 76: 393-400.

Masse' DI, Masse L (2000). Characterisation wastewater from hog slaughter houses in Eastern Canada and evaluation of their in-plant wastewater treatment systems. Canadian Agric. Eng. 42: 38-46.

McDonald C, Ince ME, Smith MD, Dillon M (1999). Integrated development for wastewater supply and sanitation; Fish processing in Uganda. Waste minimization. 25th WEDC Conference, Addis Ababa, 1999, pp. 52-55.

Muyodi FJ, Rubindamayugi MST, Semesi AK (2004). Effects of water Hyacinth on the distribution of sulphate reducing bacteria in sediments of Lake Victoria. Water SA.30: 421-425.

Newenhouse SC, Schmit JT (2000). Qualitative methods add value to waste characterization studies. Waste Manage.Res.18: 105-114.

OWMC (1993). Industrial waste audit and reduction manual: A practical guide to developing and conducting a manufacturing process survey for waste minimisation opportunities, Third edition. Ontario Waste Management Corporation, Canada. pp. 7-32.

Pfeiffer N (2003). Disposal and Re-Utilization of fish and fish processing wastes (including aquaculture wastes). Report: Marine Institute Galway Technology Park, Parkmore Galway Ireland. NDT Marine RTDI Desk Study Series. Reference: DK/01/003.2003, pp. 75-132.

National Environmental Regulations (1999). Standards for Discharge of Effluent into water or on Land. The Uganda Gazette No.7, Volume XCII, pp. 13-14.

Tritt WP, Schuchardt F (1992). Material flow and possibilities of treating liquid and solid wastes from slaughterhouses in Germany: a review. Biores. Technol. 54: 235-245.

UN Report (1997). Law of the sea-Report of the UN Secretary-General. Doc.No. A/52/487 and corr.1. 20 October and 29 December 1997, p. 73.

Wasswa J, Tang J, Gu X (2007). Utilization of fish processing by-products in gelatine industry. Food Rev. Int. 23:157-179.