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Typology of Pork-Butcheries and Factors Determining the Sustainable Pork-Butcheries Waste Management in Southern Benin

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Abstract

The butcheries are growing in Benin with a number of animal slaughtered on the rise. This slaughter practices generates more waste whose mismanagement can be a serious danger to the environment and public health. The aim of the study was assess the environmental impacts of pork-butcheries according to the types of butcheries in southern Benin. Observation and individual interviews were used in 80 randomly selected pork-butcheries. The data collected were analyzed with the FactoMineR package to perform a Principal Component Analysis (PCA) and to identify the different types of pork-butcheries according to their socioeconomic, hygienic and environmental characteristics. A multi-nominal logistic regression was also used to test waste management modes. Results from the study revealed three types of pork-butcheries which used different models for waste management. The pork-butcheries of type 1 are all young employees not member to any professional pork butcher's association. They don't have any waste management system. The pork-butcheries of type 2 are all entrepreneurs or pork-butcheries responsible. They are also affiliated with waste collection companies for the management of plastic waste. The type 3 differentiated by their great interest in the respect of hygienic standards and their frequent medical visit for professional purposes. The professional experience or seniority in the pork-butchery's activity, formal education and membership to a professional butcher's association are determinant variables of waste management produced by pork-butcheries. The implications of these results are discussed with respect to environment and waste management strategies for pork-butcheries.

Keywords

Environmental Impact, Meat Waste, Pork-Butcheries, Waste Management, Waste Water

1. Introduction

The meat sector is recognized as one of the leading polluting sectors in the food industry [1]. Meat is one of the food products with the greatest environmental impact [2−4]. Pork meat is a key component of humans´ diet [5]. In Benin, production and consumption of meat and livestock products

has been growing rapidly with greatest growth observed in the pork sector. The study conducted by the International Livestock Research Institute (ILRI) in 2012 confirmed that pork is frequently consumed and consumption is highest during periods of low food availability, hence increasing its potential to contribute to nutritional security [6]. This growth is essentially driven by increase in population, urbanization and wealth, alongside improvements in animal health control and government projects promoting growth of the livestock sector [7]. This increasing of pork consumption in Benin is noted particularly in the southern regions of the country where religious bans have very little influence [8]. The proliferation of restaurants of pork meat in the departments of Ouémé-Plateau could not hide the importance of high consumption of pork in this part of the country. Because of this increasing of pork consumption, the waste produced by this sector become also higher and need a best waste management.

An important public health concern associated with butchers's impact on environment is the potential translocation or entrapment of pathogen cells, such as Articles universitaires correspondant aux termes Escherichia coli (E. coli O157:H7) through poor waste management [9]. Hygiene problems are not limited to slaughtering but are also associated with incorrect processing, marketing and other practices [10]. The general hygiene in the abattoir will encompass the sanitary state of the environment within which the slaughter takes place and within which the staff operate, the house, equipment and other facilities such as toilets and baths. The personnel hygiene comprises the quality of staff members and other casual workers in the abattoir. It includes their health, hygiene and habits [11]. By analyzing specific environmental aspects connected with the core and supporting processes in the meat chain, major environmental aspect are discharge of waste water and solid waste and consumption of water and energy [12, 13].

According to European and UN documents, the main environmental performance indicators in meat production are meat yield (share of lean meat in live animal and/ or in carcass), solid output (in farming, this is mostly manure; in slaughtering /deboning, this is the percentage of by-product such as offal, bones, fat and skin), energy consumption (electric and thermal) and energy-to-meat ratio, water consumption, waste water discharge and waste water load (mostly chemical oxygen demand and chemical usage)[14, 15]. The environmental impact of meat production varies because of the wide variety of agricultural practices employed around the world. Some of the environmental effects that have been associated with meat production are pollution through fossil fuel usage, and water and land consumption [16].

A number of papers analyzed through numerous approaches, the environment impact of the meat production [17-19] but studies focusing particulary on the impact of pork-butcheries and waste management, are presently lacking, especially in Benin Republic.

The aim of the study was to provide a first evaluation of the environment impact potentials of pork-butcheries in Benin. Other purposes were to elaborate conceptual model of pork-butcheries waste management in south-Benin and to outline the major data in the analysis.

2. Materials and Methods

2.1. Study Area

The study was carried out in the Ouémé-Plateau area (6°22'–7°41'N and 2°28'–2°47'E) in southeastern Benin, West Africa (Figure 1). The area encompasses 14 municipalities of which 13 are rural (Kétou, Pobè, Adja-Ouèrè, Sakété, Ifangni, Adjohoun, Akpro-Missérété, Avrankou, Adjarra, Bonou, Dangbo, Sèmè-Kpodji, and Aguégués) and one is urban (Porto-Novo). Ouémé-Plateau is at the border between the Guineo-Sudanian and the Guineo-Congolese climatic zones of West Africa. It is characterized by a subequatorial climate, a bimodal rainfall pattern with average annual rainfall varying between 1100 and 1400 mm, and a dry period of up to five months. The daily temperature ranges from 22.7 to 35.8°C. The vegetation is dominated by forest, woodland, swamp, and tree and shrub savannas on different soiltypes including ferruginous, ferralitic, and hydromorphic[20]. The population is 1,625,603 with an average density of 358 inhabitants per km^2. Women are more abundant (52% of the total population) [21], and farming is the main occupation (51% farmers) involving mostly men. The major cultural groups are theGoun (26%), Nago (18%), Wémè (15%), and Toli (12%)[22], while the Adja, Toffin, Xoly, Yoruba, Fon, and Mahi cultural groups are minorities [22]. The size of the herd of pigs varies from 10.13 to 16.2 head per farmer [8].

2.2. Data Collection and Statistical Analysis

Eighty pork-butcheries in the Ouémé-Plateau departments were visited to determine the waste management practices set in place at each pork-butchery. Overall 80 pork-butchers were interviewed. First the interviewers established the contact with each participant interviewed and introduced the objectives of the study. The main objective of the interviews was to make a typology of pork-butcheries, understand waste management practices and safety of use and disposal of condemned products and elaborate conceptual model of pork-butcheries waste management. Data were collected using semi-structured interviews. So a semi-structured questionnaire was then developed and pre-tested on 10 pork-butchers operating in Ouémé-Plateau departments. The study used both quantitative and qualitative data collection techniques. The questionnaire was adjusted accordingly to make it clear and include the most relevant aspects of butchers. The final questionnaire had 36 questions and was divided into 3 sections; (i) demographic characteristics, (ii) environmental parameters of pork-butcheries, and (iii) sanitary and hygienic parameters of pork-butchers. The questionnaire was administered through face to face interviews. The interviews were individual and conducted in

the local language of the informants, with the researcher accompanied by a translator should the need arise.

A correlation analysis was carried out using the cor.test function on environmental, socioeconomic and hygienic variables to measure the correlations between the different variables. For quantitative variables, the Pearson coefficient was used. As for the qualitative variables Spearman coefficient was used. To identify the different types of pork-butcheries according to the actors of the waste management according to their role, a Principal Component Analysis (PCA) was performed using the FactoMineR package [23]. A multi-nominal logistic regression was also used to test whether waste management modes of pork-butcheries (dependent variable) were affected by the number of pigs slaughtered per day, the quantity of plastic waste and meat produced per day, the volume of waste water produced, the professional experience of butchers, the respect of hygienic standards by the pork-butcher, the types of used water collector, the disinfectant used, the final destination of the plastic and meat waste, the net income by day of pork-butcher (independent variables). All analyzes were done in the software R.3.3.2 (R Core Team, 2016). For multi-nominal logistic regression, a multinom function was used.

The group work with the different actors led to the construction of a model of interaction between the actors included in the management of pork-butcheries waste. The VENSIM PLE Version 6.2 software was used to represent the diagram of actors and management entities for pork-butcheries waste.

3. Results

3.1. Development of Typology of Pork-Butcheries

The first two axes computed by Simple Correspondence Analysis on the socio-economic, environmental and hygienic parameters of pork-butcheries (Figure 1) explained 63.43% of the information.

The contribution and representation quality of socioeconomic, environmental and hygienic parameters between the two axes was high for the age, education, experience, number of pork slaughtered, net income per day, wastewater, plastic and meat waste, waste management, medical visit of butcher, disinfectant used, frequency of washing, presentation or butcher's clothing.

The first factorial axis opposes on the one hand the group of pork-butcheries lead by young employees, with a few year experience in pork-butcheries activity, and poor waste management to the group of pork-butcheries manage by a butchers with a long professional experience, member of an professional associations and having good waste management. This axis represents the axis of socio-economic and environmental parameters.

The second factorial axis marked pork-butchers observing good hygienic practices and having frequently a professional medical visit. This axis represents the axis of the hygienic parameters.

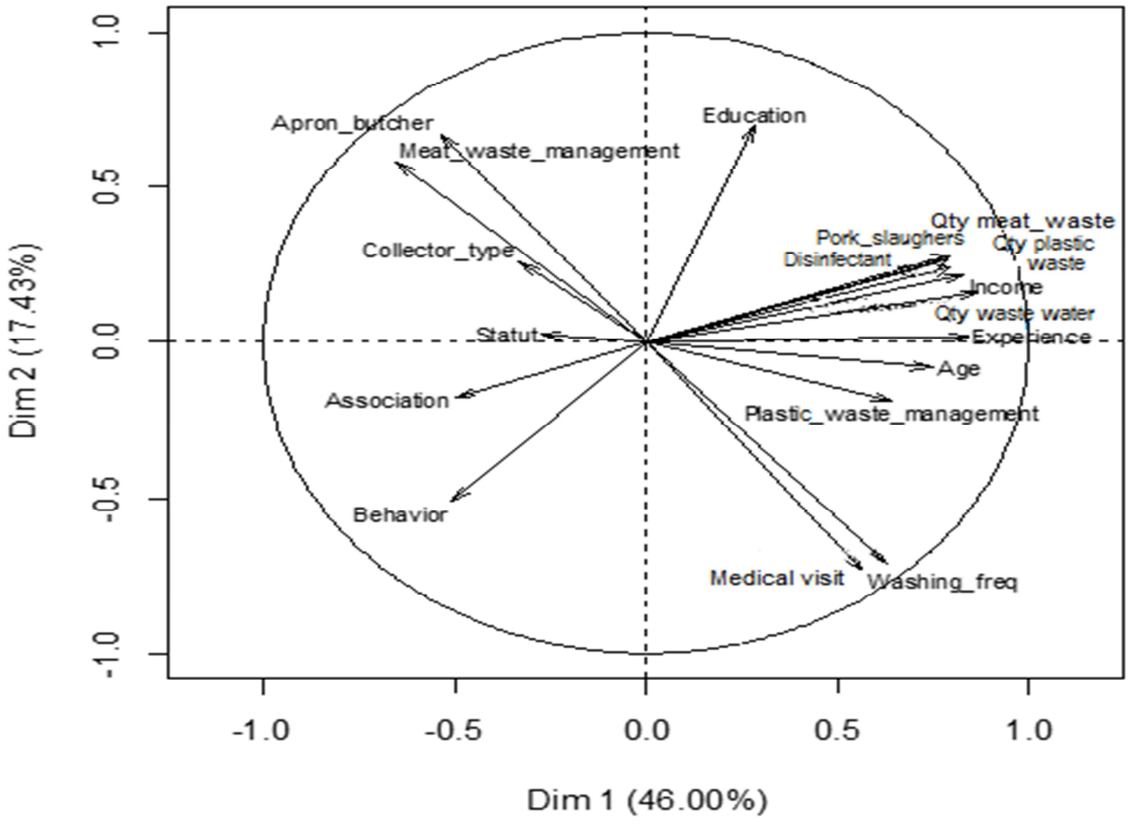

Figure 1. *Simple correspondence analysis computed on socioeconomics and environmental parameters of pork-butcheries.*

Three types of pork-butcheries can be identified, these are:

(1) Type 1: (43 pork-butchers or 53.75% of the sample)

The pork-butcheries of type 1 are all young employees (30.18 ± 6.68 years) not member to any professional pork butcher's association. They slaughter a small number of pigs (2.59 ± 1.41) per day. The Meat waste produced (10.50 ± 5.02) kilograms by this type of pork-butcheries are dumped in nature. As for the management of wastewater (433.56 ± 38.5) Liters. The quantity of plastic waste produced (7.00 ± 2.89) is lowest compared to other types of pork-butcheries. They use traditional open pits as collectors. They don't have any waste management system. About hygienic standards, these pork butchers don't wear protective clothes (aprons) and have many inappropriate behaviors (handled money while manipulate the meat, scratching the skin). Similarly, they do not use any disinfectant for cleaning the place.

(2) Type 2: (27 pork-butchers 33.75% of the sample)

The pork-butcheries of type 2 are all entrepreneurs or pork-butcheries responsible, with age (38.60 ± 4.75 years), a formal education, a professional experience or seniority in the pork-butcher's activity. They slaughter a high number of pigs (9.70 ± 2.99) and have an important net income per day. The quantity of meat waste produced by these type of pork-butcheries is (21.20 ± 7.03) Kilograms and the volume of wastewater is (632.40 ± 68.60) Liters. They have developed an interesting system of waste management. They have catch basins for collecting wastewater. They are also affiliated with waste collection companies for the management of plastic waste. Much of the organic waste produced by these pork-butcheries is recycled in agriculture (to product bio-organic fertilizer) and in breeding (to product maggots for poultry feeding). As hygienic practices, they use disinfectants.

(3) Type 3: (10 pork-butchers or 12.50% of the sample)

The pork-butcheries of type are a group of butcher's age (43.5 ± 2.75 years). This group differentiated by their great interest in the respect of hygienic standards and their frequent medical visit for professional purposes. They slaughter (9.50 ± 0.5) porks and produce a large quantity of plastic meat waste (17.0 ± 2.05), meat waste (23.25 ± 3.57) kilograms and a volume waste water (711.25 ± 26.88) liters. The average frequency of cleaning of butcher equipment is (6.25 ± 0.7) per day.

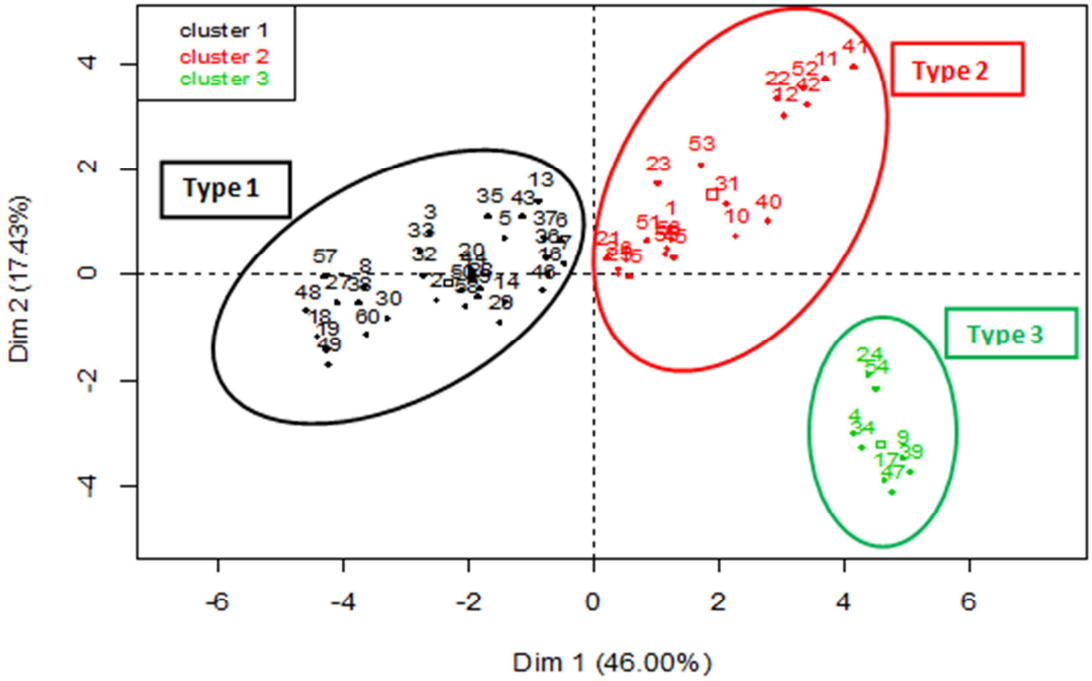

Figure 2. *Projection of pork-butchers surveyed on the factorial axes 1 and 2.*

3.2. Factors Determining the Management Modes of Waste Adopted by Pork-Butcheries

The table 1 and 2 respectively showed the correlations of the quantitative and qualitative variables relating to hygienic, environmental and waste management parameters produced by pork-butcheries. The correlation of the quantitative variables showed that there is a positive correlation between the number of pigs slaughtered and the quantity of waste produced (Table 1). The correlation of the qualitative variables showed that there are significant positive correlations between the type of disinfectant used and the professional experience of pork-butcher, as well as the type of disinfectant used and the net income per day. There are significant negative correlations between the adoption of a professional medical visit each year and the management of meat waste. There are also significant negative correlations between the adoptions of professional medical visit each year and the presentation or butcher's clothing. There is a positive correlation between the management of meat waste and the butcher's clothing (Table 2).

Table 1. *Correlations between quantitative variables.*

	Age	Equipment washing frequency	Number of pork slaughtered /day	Quantity of plastic waste	Quantity of meat waste	Volume of waste water
Age	1.000(0.0035)	0.440(0.0004)	0.581(<.0001)	0.553(<.0001)	0.591(<.0001)	0.493(<.0001)
Equipment washing frequency		1.000	0.297(0.0208)	0.284(0.0278)	0.280(0.0302)	0.379(0.0028)
Number of pork slaughtered /day			1.000(0.0272)	0.968(<.0001)	0.846(<.0001)	0.821(<.0001)
Quantity of plastic waste				1.000	0.838(<.0001)	0.835(<.0001)
Quantity of meat waste					1.000	0.887(<.0001)
Volume of waste water						1.000

Table 2. *Correlations between qualitative variables.*

	MPA	IB	DF	PMV	PE	PWM	MWM	ED	BC	NID	ST	WC
MPA	1.0000 (1.0000)	0.1093 (0.0177)	-0.4449 (0.0177)	-0.1307 (1.0000)	-0.4378 (0.0215)	-0.2915 (0.7867)	0.2325 (1.0000)	-0.1006 (1.0000)	0.1111 (1.0000)	-0.5246 (0.0010)	-0.0454 (1.0000)	0.2016 (1.0000)
IB		1.0000 (0.0124)	-0.4567 (0.0124)	0.0138 (1.0000)	-0.5045 (0.0022)	-0.3450 (0.2636)	-0.0013 (1.0000)	-0.1569 (1.0000)	-0.0117 (1.0000)	-0.4725 (0.0073)	0.3275 (0.3831)	0.1317 (1.0000)
DF			1.0000 (0.0005)	0.5416 (0.0005)	0.6235 (<.0001)	0.3483 (0.2491)	-0.4874 (0.0044)	0.3970 (0.0725)	-0.4603 (0.0112)	0.6767 (<.0001)	-0.1127 (1.0000)	-0.1208 (1.0000)
PMV				1.0000 (-)	0.4332 (0.0245)	0.4485 (0.0159)	-0.7761 (<.0001)	-0.1713 (1.0000)	-0.8498 (<.0001)	0.3848 (0.0983)	-0.1201 (1.0000)	-0.2737 (1.0000)
PE					1.0000 (<.0001)	0.5783 (<.0001)	-0.4570 (0.0124)	0.0497 (1.0000)	-0.3450 (0.2636)	0.5960 (<.0001)	-0.3900 (0.0869)	-0.3111 (0.5285)
PWM						1.0000 (0.0186)	-0.4428 (0.0186)	-0.1784 (1.0000)	-0.3812 (0.1063)	0.4826 (0.0052)	-0.1648 (1.0000)	-0.4788 (0.0059)
MWM							1.0000 (1.0000)	0.0258 (1.0000)	0.6511 (<.0001)	-0.4054 (0.0577)	0.1579 (1.0000)	0.1554 (1.0000)
ED								1.0000 (0.9321)	0.2803 (0.9321)	0.2232 (1.0000)	0.1849 (1.0000)	0.2898 (0.7904)
BC									1.0000 (0.3831)	-0.3270 (0.3831)	0.0454 (1.0000)	0.2326 (1.0000)
NID										1.0000 (1.0000)	-0.0376 (1.0000)	-0.2605 (1.0000)
ST											1.0000 (1.0000)	0.0570 (1.0000)
WC												1.0000 (1.0000)

MPA: Member of pork-butchers's, IB: Inappropriate behaviors, DF: Disinfectant, PMV: Professional medical visit, PE: Professional Experience, PWM: Plastic waste management, MWM: Meat waste management, ED: Education, BC: Butcher's clothing, NID: Net Icome/day, ST: Status, WC: Wastewater Collector

Ten models of factors determining the management modes of waste adopted by pork-butcheries were elaborated. Among these models, the first model has a very weak AIC. He is then the best model. Factors such as professional experience or seniority of the pork-butcher in the activity and the equipment washing frequency have significantly influenced the waste management methods adopted by pork-butcheries (Table 3).

Table 3. *Determinant factors of waste management mode adopted by pork-butcheries.*

Model number	Waste Management Models (WMM)	AIC	ΔAIC
1	WMM = Professional Experience +Equipment Washing Frequency	12	0
2	WMM= Equipment Washing Frequency + Quantity Plastic Waste	12.64	0.64
3	WMM = Equipment Washing Frequency + Number of Porks Slaughtered /day	14.77	2.77
4	WMM = Equipment Washing Frequency + Butcher's Clothing or Presentation	15.82	3.82
5	WMM = Professional Experience +Equipment Washing Frequency+ Net Income/ day	16.00	4
6	WMM = Equipment Washing Frequency+ Age	16.07	4.07
7	WMM = Equipment Washing Frequency+ Quantity Meat Waste	16.08	4.08
8	WMM = Professional Experience + Equipment Washing Frequency+ Types of Disinfectant Used	20	8
9	WMM = Professional Experience +Equipment Washing Frequency+ Education	24	12
10	WMM = Age + Association + Profession Medical Visit + Professional Experience +Equipment Washing Frequency+ Education + Number of Pork Slaughtered /day+ Butcher's Clothing or Presentation + Quantity Plastic Waste+ Quantity Meat Waste + Income/Day +Waste Water Collector +Types of Disinfectants+ Quantity Waste Water	72	60

Table 4. *Significativity of the variables describing the waste management mode (WMM) adopted by pork-butcheries.*

Variables of model	LR Chisq	Df	Pr (>Chisq)
Professional Experience	4.506	2	0.01051
Equipment Washing Frequency	37.412	2	7.52e-09

** p <0.001; *** p <0.0001. LR Chisq = Chi-Square likelihood ratio, Pr: Probability

3.3. Conceptual Model of the Pork-Butcheries Waste Management

The pork-butcheries produce three types of waste: plastic waste, liquid waste and meat waste. To ensure the management of this waste, pork-butcheries interact with several actors. Thus, some production companies of maggots, composts production and some poultry farms negotiate the use of meat waste with the butchers of the departments of Ouémé-Plateau. Liquid waste produced by pork-butcheries is often used by market gardeners in the department of Ouémé-Plateau to fertilize their crops. While garbage collection companies are interested in plastic waste. Plastic waste is subsequently recycled by other companies to produce goods to the community. Model analysis shows that plastic and meat waste produced in pork-butcheries is of interest to several actors. While liquid waste is less valued. Pork-butcheries are an interesting resource; their treatment can become a profitable activity that could lead to the establishment of sustainable management of the sector in the department of Ouémé-Plateau. It is also important to point out the remarkable absence of local authorities and decentralized structures in the management of pork-butcheries wastes. So, the intervention of the private sector, the development of an integrated management of the sector and the improvement of recycling methods are avenues to be explored in order to meet the challenge of the sustainable management of pork-butcheries wastes in the department of Ouémé-Plateau.

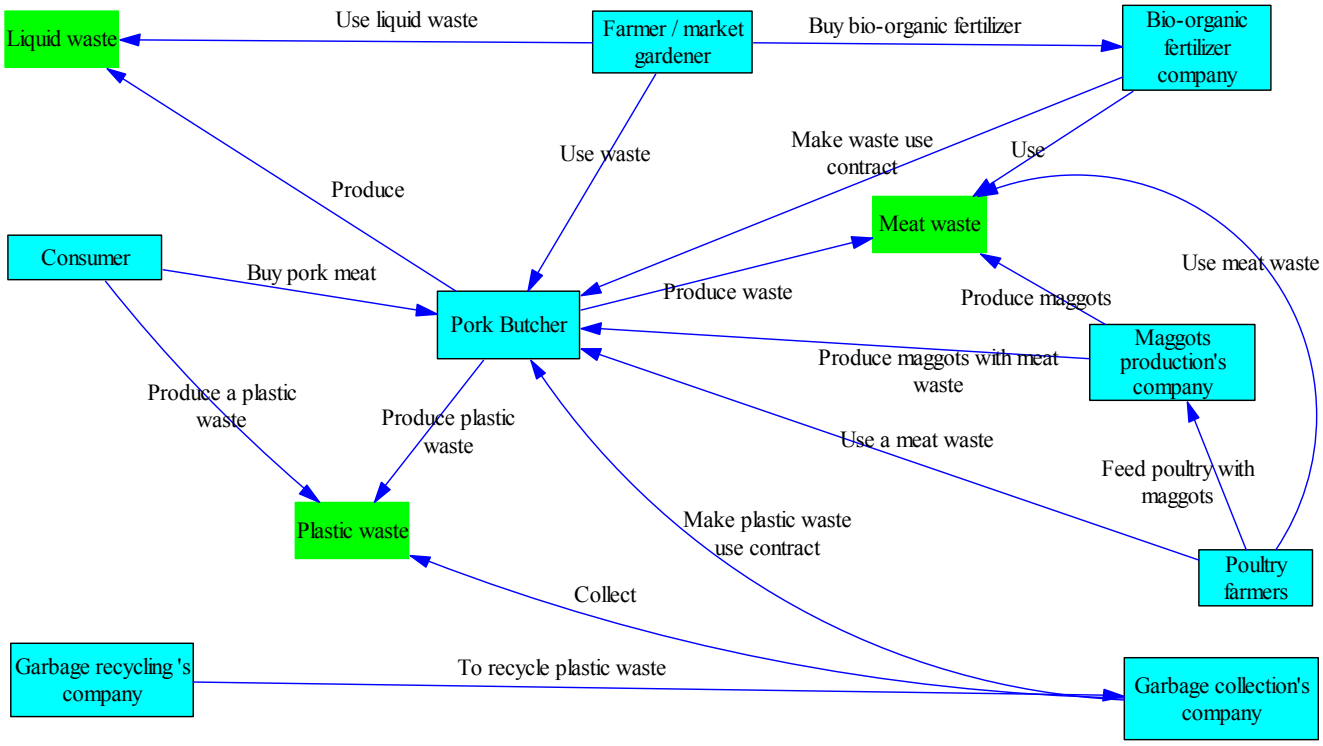

Figure 3. *Conceptual model of the pork-butcheries waste management in Ouémé-Plateau (South Benin).*

4. Discussion

This study reveals the working and practices of the different types of pork-butcheries in south Benin as well as the waste management mode that these pork-butcheries adopted. We focused on variations of socioeconomic, hygienic and environmental characteristics of the butcheries. The results provide a substantive database that would help involve both the authorities in charge of waste management and the butcheries actors in the sustainable environmental protection.

4.1. Type of Pork-Butcheries and Management Modes of Waste Adopted

There were three types of pork-butcheries with the significant positive correlation between the number of pigs slaughtered and the quantity of waste produced. Reference [1]reported the environmental impacts connected with the processes in the meat chain that occur on site during meat production/processing. Compared with the livestock

production phase, impacts of meat production phases (slaughtering and meat processing) although lower, are still of importance [24]. Similar conclusion was shown in another research highlighting that vast differences in the levels of implementation of environmental practice in relation to the quantity of waste produced exits in the meat sector, both in slaughterhouses and in meat processing plants [25]. The study also revealed that the pork-butcheries which are potential income sources, have a system and disposal to manage waste when the pork-butcheries with low porks slaughtered per day dumped the meat waste in nature and use traditional open pits as wastewater collectors. Several authors confirm a relationship between environmental and economic performance [26, 27]. Regarding financial performance, companies can harbor the belief that environmental management increases costs and reduces profit [28]. This is specifically present in small and medium sized companies that perceive adoption of environmental practices as costly [29]. However, several authors have confirmed that environmental practices may lead to innovations and contribute to reducing costs [30, 31]. According to Djekic *et al* [25], the scientific value of this approach is the identification of areas of improvement in the meat chain in respect to managing energy usage, water usage, waste handling and wastewater discharge. Also, affirmation of two dimensions, the environmental and the economic, in this case, contributes to the analysis of the meat chain's sustainability. The high good hygienic practices are also evidenced by the formal education, a professional experience or seniority in the pork-butcher's activity. Since the purpose wearing overalls is to protect both the foods products and the meat handler from cross contamination, overall should be suitable to wear over other clothing [32]. However this study showed that the most of butchers of type 1 don't use protective clothes, handle money while manipulate meat as well have any disposal for waste management. Hygiene problems are not limited to slaughtering house but also associate with incorrect processing practices [33]. A study on Meat production and consumption in the Wa Municipality of Ghana, conducted by Mahaboubil-Haq [34] confirm that majority (55%) of meat consumers rated that meat locally produceas unhygienic with great environmental impact.

4.2. Model of Pork-Butcheries Waste Management

The main environmental aspects associated with meat slaughtering and processing are, on one hand, water and energy consumption, and on the other, discharge of waste water and solid waste. Water is consumed in all stages of meat processing, starting from the first step when the live animal enters the facility, until the last step, when meat products are dispatched from the meat processing plant [35]. Spanish slaughterhouses recognize water consumption, generation of waste water with a high organic load and the energy input needed to refrigerate and to heat water as main environmental aspects [36]. Results also indicated the high level of plastic waste produced by pork-butcheries. The issue of biofilms in the food industry has been reviewed by numerous authors [37, 38]. As discussed by Sofos [39], biofilms may form in all areas of food processing environments, including floors, walls, pipes and drains. Materials commonly used in food processing, such as stainless steel, aluminum, nylon, teflon, rubber, plastic, Buna-N, glass, etc., may be subject to biofilm formation. Hard to clean and sanitize crevices, in conveyor belts, pasteurizers, gaskets and dead spaces, become hosts of biofilms. Strong attachment of cells on food surfaces and potential biofilm formation may also affect the efficacy of antimicrobial interventions applied to carcasses, meat, produce or other foods to reduce contamination [39, 40]. Waste water management was significantly different between big companies and the other two groups (medium and small) for all five topics. Big companies (Type 3 of pork-butcheries) had objectives related to waste water, had high levels of 'Performance Management' in monitoring waste water discharge, employed staff that was aware of how waste water from the meat sector affects the environment, communicated this environmental aspect and analyzed the effects of this aspect on the environment. On the other hand, all scores for smaller companies were below, meaning that this environmental impact was not managed by these companies. Boiral and Henri [41] confirmed a positive correlation with reduction of environmental impacts, associated with the volume of waste generated, and water and energy consumption in several case studies of implemented environmental management.

5. Conclusion

This study evidenced that pork-butcheries operate differently according to their hygienic practices, waste management and net income per day. Three types of pork-butcheries were distinguished. Results support the hypothesis that professional experience or seniority in the pork-butchery's activity, formal education and membership to a professional butcher's association are determinant variables of waste management produced by pork-butcheries. It also clearly evidenced a high link between the respect of hygienic standards and waste management model adopted. These findings encourage actions that will contribute to better management of pork-butcheries waste while sustaining environment. Actions should involve pork-butchers according to theirs hygienic and environmental knowledge and waste management models, as described above. These actions must focus on the group (type 1) of pork-butcheries who have a low knowledge about both hygienic practices and waste management, but should not neglect a two others groups (type 2 and types 3) of pork-butchers. Actions must also look at the promotion of waste recycling and training of all actors implicate in pork-butcheries waste management.

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