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Life cycle assessment of Co-culture of Clarias gariepinus and Oreochromis niloticus in the whedos of Ouémé delta in Benin

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The development of the fish farming with regard to environmental sustainability is nowadays a serious alternative to satisfy the needs of the population in quality animal protein and to reduce imports in Benin. In this study we assessed the environmental impacts of co-culture of *Clarias gariepinus* and *Oreochromis niloticus* systems in the *whedos* of *Ouémé* delta in Benin. Life Cycle Analysis (LCA) which is a systemic method that assesses all potential environmental impacts of global and regional product, service, company or process has been used according to the CML baseline 2000 method. However, that method was adapted for fish farming system. The estimation of nitrogen (N) and phosphorus (P) wastes in production systems (T1: imported feed, T2: local feed and T3: mixed feed), was performed according to the nutritional balance method; and calculation of impact categories was conducted with environmental analysis software, SimaPro ® 8.0.5.13. For all the environmental impact category considered (non-renewable energy, climate change, eutrophication, freshwater ecotoxicity, terrestrial ecotoxicity and potential acidification), the T1 system recorded the lowest values of impacts compared to T2 and T3. Except the eutrophication dominated by the production process, the feed production process is the major contributor of other impact categories. To optimize fish productivity and sustainability of fish farming, the T1 system would be advisable.

Keywords: Life Cycle Assessment, happa, *Ouémé*, fish farming, *whedos*

INTRODUCTION

Fish is the most accessible animal protein for a large part of the world population. It contribute for about 20% to the protein supply for about 3 billion of people and about 15% for 4.3 billion of people in the world. In some countries, fish is an important resource. FAO (2011) reported that the fish ensures at least 50% of animal protein in some Asian countries (such as Cambodia, Indonesia, Sri Lanka) and some African countries (such as Sierra Leone, Gambia and Ghana). In Sub-Saharan Africa (SSA), the fish ensures about 22% of animal protein consumption. In some SSA countries, the fish contribution to animal protein consumption would be about 50% (Brummet et al., 2008; FAO, 2008, 2020). In Benin, the fish is the most important animal protein source (Agbohessi et al., 2018). It ensures about 31.9% of animal protein and about 5.5% of all proteins (FAO, 2020). The continental fishing (in streams, lakes, lagoons, plain liable to flooding) contributes for about 75% to the national halieutic production (Lalèyè et al., 2003). Unfortunately, the halieutic production is increasingly decreasing these last year because of the overexploitation of the natural streams, especially with the using of forbidden fishing engines and technics (Imorou Toko, 2007). Since 2005, the fish import in Benin is higher than the domestic halieutic production. Then it is necessary to promote the development of fish farming in order to ensure a large availability of halieutic products and to decrease the overexploitation of natural halieutic resources and the fish import (Elègbè et al., 2015a; Agbohessi et al., 2019). Despite the classical fish farming in Benin, the traditional fish farming, especially in whedos is the most developed form in the country. The existence of whedos in Benin (in the regions such as Sô-ava and Ouémé valley) go back to more than a century (Chikou, 2006). The whedos are traditional fish farming form developed by fishers to profit from the succession of flood and fall in plains liable to flooding (Imorou Toko, 2007). The development of that fish farming system faces today several constraints. The feeding which represents about 50% of the fish farming expenses is the principal constraints (Gourène et al., 2002; Agbohessi et al., 2018). Then it is important today to develop technics optimizing the fish feeding in this system. Researches on the co-culture of Clarias gariepinus and Oreochromis niloticus in the Ouémé delta in Benin allowed reducing the breeding expenses and to breed several species together, better profiting from the symbiosis of these species (Elègbè et al., 2015a and b; Agbohessi et al., 2018). However, the environmental and ecological sustainability of these fish farming systems is still to prove. In fact, the fish farming systems produce gases which require attention because of their effects on environment. The level of these emissions is an indicator of the efficiency of systems, their capacity to produce fish using the mobilized inputs (Effolé, 2011). The assessment of these effects on environment require the using of multi-criteria tools. The Life Cycle Analysis (LCA) is a global method which assesses the whole potential environmental impacts related to a product from its source to its recycling or its final waste (Guinée et al., 2002). This method was identified as pertinent for the environmental assessment of the agricultural production systems (van der Werf and Petit, 2002) with some references in fish farming (Casaca, 2008; Effolé et al., 2012; Aubin, 2014 and 2015; Abdou, 2017). The present paper uses the LCA to assess the environmental impacts of the co-culture of C. gariepinus and O. niloticus in Ouémé delta in Benin.

MATERIAL AND METHODS

Study area

The study was carried out in the village of Ayizè in the upper Ouémé delta, municipality of Ouinhi, department of Zou in southern Benin. This village is located between the 6°57 and 7°11 of North latitude and 2°23 and 2°33 of East longitude (Figure 1). Data were collected during 56 days (from 30 July to 24 September 2014). According to Adam and Boko (1993), the climate of the area is of sub-equatorial type characterized by 4 seasons: one big rainy season (March to July), one small dry season (July to August), one small rainy season (September to November) and one big dry season (December to March). In the Ouémé delta, there is one upper water season (with high amplitude from end of July to beginning of November) and one low water season (December to June) is noted in the year. In flood season, there is flooding in the delta. However in the fall season (low water season) the water level considerably decreases in the river bed, all plains liable to flooding dry allowing crops production (Welcomme, 2002; Imorou Toko et al., 2007; Lalèyè et al., 2007).

Animal material

The fry of C. gariepinus (initial average weight: 6.74 ± 0.27g) and O. niloticus (initial average weight: 8.11 ± 0.14g) used for the experiment were bought at the Center of Fish Farming Research and Incubation in Benin (CRIAD) in Cotonou. The density was 30 C. gariepinus per m² and 5 O. niloticus per m².

Description of the studied production systems

Based on food breeding three systems of C. gariepinus and O. niloticus installed in whedos were analyzed (Figure 2). These feed were included in arrangements of double happas (2.5*2.5m for O. niloticus and 1*1m for C. gariepinus). System 1 used imported food; system 2 used local food and system 3 used mixture of both imported and local food.

At total 3 rectangular whedos were used. The surface of each whedos was 127 m². These whedos were provided in water by the ground water with average water height which varied from 0.47 to 0.59 m. The lost water in the whedos was replaced each 2 weeks by pumping the river water.

Experiment conduct

Three categories of food were used in triplicat. 3 happas were introduced in each experiment whedos. Each happa contained O. niloticus and C. gariepinus. The fishes of each whedos received one category of food as follow:

• Treatment 1 (T1) for system 1: imported food containing 45% of protein (the commercial name is Skretting) ;

• Treatment 2 (T2) for system 2: local food (produced in Benin) containing 37% of protein;

• Treatment 3 (T3) for system 3: mixed food containing 50% of imported food and 50% of local food 41% of protein.

Only fry of C. gariepinus were fed ad libitum 3 times per day (at 8’, 13’ and 18’) during 2 months. The O. niloticus profited from the rests and throwing out from happas with C. gariepinus and/or primary production from the mineralization of excrements and non-apprehended feed. The final average weights of C. gariepinus varied from 30.7 ± 3.04 g to 42.6 ± 2.26 g. The average weights of O. niloticus varied from 18.4 ± 4.99 g to 19.6 ± 0.83 g.

The food quantity used during the experiment is mentioned in table 1. The data in the farm were obtained by direct measures (characteristics of equipment; water quality) and quantify (food quantity; water bulk) during the experiment (Table 1).

Life Cycle Analysis

The limits of each fish farming system analyzes in this paper include the process of breeding equipment construction (happas), food production for the fishes, the fry and commercial fish production, the transport at all stages from the cradle to the farm door (Aubin et al., 2009) (Figure 3). The inventory data collection concerned one production cycle. The LCA was done following the CML2 baseline 2000 version 4.2. method (Guinée et al., 2002). However, that method was adapted to the fish farming considering its previews application in different fish farming systems (Aubin et al., 2006; Casaca, 2008; Roque d’Orbcastel et al., 2008; Aubin and van der Werf, 2009a; Effolé, 2011; Aubin, 2014 and 2015; Abdou, 2017) on production cycle using:

• The economical allocation based on the average market price of the study area during the year 2014;

• One ton of fresh fish produced at the exit of the farm as functional unit,

• The secondary data on the energy, the transport, the minerals, … from the Ecoinvent LCA inventory database (Eoinvent, 2007).

The calculation of nitrogen (N) and phosphorus (P) quantity in the food was made using chemical analysis of the dry matter of the food (total N and P). The level of N and P loss was calculated using the nutritional balance method (Cho and Kaushik, 1990). The impacts were calculated using the environmental analysis software SimaPro ® 8.0.5.13 (Pre Consultants, Netherlands). The impact categories retained for this study were: the non-renewable energy (EU expressed in MJ); the climate change potential (CC expressed in kg CO_2); the toxicity of fresh waters (TED) and the earth eco-toxicity (ET expressed in kg 1.4 DB); the potential acidification (AP expressed in kg SO_2) and the eutrophication (E expressed in kg PO_4). To put the studied systems in a global context, their environmental impacts were compared to those of other previews studies using the same method in Brazil (Casaca, 2008), in France (Aubin et al., 2009a), in Canada (Nathan et al., 2008), in Cameroon (Effolé et al., 2012) and Ivory Coast (Ngongang Nganso, 2015) (Tables 2 and 3).

The effect of the different treatments (T1, T2 and T3) on the environment was tested comparing the impacts (EU, CC, TED, ET, AP and E) using one-way Analysis of Variance (ANOVA1). The HSD test of Turkey was used to compare the means of the impacts of the different treatments at the threshold of 5%. The statistical analysis was done using the STATISTICA 6.0 (Statsoft, Inc.) software.

RESULTS

The table 4 presents the results of the potential environmental impacts per ton of fish in the co-culture system of C. gariepinus and O. niloticus. This table showed that lowest impacts values of different impacts category considered (EU, CC, TED, ET, AP and E), was obtained with T1 system. The highest level value recorded in T2 system. The ANOVA1 analysis showed that there is significant difference ($p < 0.05$) at the threshold of 5% among the different impact category values (EU, CC, E, TED, ET and AP) following the treatment. Moreover, the HSD test of Turkey showed that the values of EU, CC, E, TED, ET and AP were significantly ($p < 0.05$) different from each other at the threshold of 5%.

The average relative contribution of the system processes to the different impact categories showed that apart from the eutrophication impact dominated by the production process, the food processing is the major contributor of the other impact categories (Figure 4).

DISCUSSION

The high values of potential environmental impacts for the eutrophication category of the system 2 (related to the treatment T2: local food) in comparison with the system 3 (related to the treatment T3: mixture of local and imported food) and the system 1 (related the treatment T1: imported food) could be explained by the low assimilation of the local food due to its physical characteristics in comparison with the imported food. In fact, the resistance of the local food to the water is relatively low. Accordingly, if the food is not caught by the fish, few minutes after it leaks in the water, disintegrates and becomes inaccessible to the fishes. Therefore, the environment gets richer in biogenic nutrients than their assimilation by the fishes (Yakupitiyage et al., 2007; Aubin, 2014). These results are in accordance with the process of nutrient repartition in a pond ecosystem (Nathan et al., 2006 and 2007; Abdou, 2017).

Moreover, the low value of the eutrophication impact of the system 1 (imported food) can be due to the form of the diet (pellet). In fact, these pellet are more floating than T2 and available for the fishes. In addition, their quality in relation with their high digestibility and the protein rate (45%) (Aubin et al., 2009b; Effolé et al., 2012). Nevertheless, the values of eutrophication obtained with T3 system were lower than those obtained by Ngongang Nganso (2015) in extensive O. niloticus fish farming in Ivory Coast and those obtained by Efolé et al. (2012) in semi-intensive pond system integrating both fish and pig in Cameroon (Tables 2, 3 and 4). These differences can be justified by the relatively low yield of these systems (1 to 7t/ha/year) in comparison with the production systems of whedos analyzed in this study (14.9 t/ha/year; 10.2 t/ha/year and 15.6 t/ha/year).

Furthermore, the high values of the eutrophication in the systems 2 and 3 in comparison with those obtained by Casaca (2008) and Nathan et al. (2008) in pond semi-intensive system could be explained by the low number of species in the co-production system (Table 2). In fact, the poly-culture systems developed in Brazil uses a large number of species even with low growing capacity but with important ecological roles which enable optimizing the nutrients.

The values of impact categories such as the non-renewable energy (EU) (976942 ± 33744 MJ; 480636 ± 18645 MJ), the climate change (CC) (100124.25 ± 3480.07 Kg CO2; 48838 ± 1928 Kg CO2) and the potential acidification (AP) (respectively obtained for systems 2 and 3) were high relatively to system 1 (Table 4). This fact could be explained by the source and the origin of the inputs (Aubin and van der Werf, 2009a; Aubin et al., 2009b; Effolé, 2011). Aubin et al. (2009b) reveal that the agricultural input production and transportation would contribute to the acidifying substances emission for about 10 to 17%. Therefore, the usage of imported products from Europe in the local food production combined with their weak optimization justifies the high level of these impacts. The exclusive usage of local by-products can contributes to reduce these impacts (Effolé et al., 2012). The values of EU, CC and AP obtained in the frame of this study are higher than those obtained in other fish farming systems (Casaca, 2008; Nathan et al., 2008; Aubin and van der Werf 2009a; Effolé et al., 2012; Ngongang Nganso, 2015) (Tables 3 and 4). These differences could menly be justified by the origin of the ingredients used in local food processing and the low yield of the local crop production systems. The same raisons explain the high values of TED and in the studied systems.

CONCLUSION

The semi-intensive whedo T2 system recorded the highest environmental impact level. Food processing, origin and source of ingredients where determinant. Life Cycle Analysis is adapted to the fish farming system with low level of inputs. The less impact level recorded with the T1 system are link to the digesbility of the imported food

The improvement of local food processing and diversification of species can lead to less environmental impact level and a better optimization of studied systems.

REFERENCES

Abdou K. (2017). Evaluation des impacts environnementaux du chalutage de fond et de l’aquaculture en Tunisie: approche comparative par les Analyses de Cycle Vie (ACV). Ecologie, Environnement. Université de Bretagne occidentale - Brest; Institut national agronomique de Tunisie, Français.

Adam K.S., Boko, M. (1993). Le Bénin. Les Editions du Flamboyant / EDICEF. Vanves, Cedex, 96.

Agbohessi P.T., Houndji A.M.B., Dégila B.D.D.,Elègbè H.A., Adouwekonou V.M.S., Pèlèbè R.O.E., Imorou Toko I. (2019). Utilisation des farines d’asticots, de poisson et des feuilles de Moringa oleifera comme sources de proteins alimentaires chez les larves de Clarias gariepinus (Burchell, 1822). Cahiers du CBRSI Agriculture, Environnement et Sciences de l’Ingénieur, 15: 1-23.

Agbohessi T.P., Dégila B.D.D., Elègbè A.H., Pèlèbè E.O.R., Okéwolé J., Houndji A.M.B., Imorou Toko I. (2018). Optimisation de la productivité piscicole des étangs par l’association du jeûne et de la co-culture chez Clarias gariepinus et Oreochromis niloticus. J. Appli. Biosci., 130: 13138 – 13147.

Aubin J. (2015). Comprendre les interactions entre la pisciculture et l'environnement. Sciences du Vivant [q-bio]. Université de Rennes 1. 89p.

Aubin J. (2014). Contribution de l'analyse du cycle de vie à l'analyse environnementale des systèmes de pisciculture. Sciences du Vivant [q-bio]. AGROCAMPUS OUEST. 174p. Français.

Aubin J., Papatryphon E., van der Werf H.M.G., Chatzifotis S., (2009b). Assessment of the environmental impact of carnivorous finfish production systems using life cycle assessment J. Cleaner Prod., 17: 354-361.

Aubin J., Papatryphon E., Van der Werf H.M.G., Petit J., Morvan Y.M. (2006). Characterisation of the environmental impact of a turbot (Scophthalmus maximus) recirculating production system using Life Cycle Assessment. Aquaculture, 261: 1259- 1268.

Aubin J., van der Werf H.M.G. (2009a). Pisciculture et environnement: apports de l'analyse du cycle de vie. Cah. Agric., 18: 220-226.

Brummet R., Lazard J., Moehl J. (2008). African aquaculture: Realizing the potential. Food policy, 33: 371-385.

Casaca J.M. (2008). Policultivos de peixes integrados à produção vegetal: avaliação econômica e sócio ambiental (peixe-verde). Doctorat : Universidade Estadual Paulista Júlio de Mesquita Filho (UNESP), São Paulo (Brésil).

Chikou A. (2006). Etude de la démographie et de l'exploitation halieutique de six espèces de poissons-chats (Teleostei, Siluriformes) dans le Delta de l'Ouémé au Bénin. Doctorat, Université de Liège (Belgique).

Cho C.Y., Kaushik S.J. (1990). Nutritional energetic in fish: energy and protein utilization in rainbow trout (Salmo gairdneri). World Rev. Nut. Diet, 61: 132-171.

Ecoinvent (2007). Online: http://www.ecoinvent.ch/ (consulté en janvier 2022).

Efole E. T. (2011). Optimisation biotechnique de la pisciculture en étang dans le cadre du développement durable des Exploitations Familiales Agricoles au Cameroun. Thèse de Doctorat, Institut supérieur des sciences agronomiques, agroalimentaires, horticoles et du paysage de l'Université Européenne de Bretagne, 215p.

Efole E. T., Aubin J., Mikolasek O., Corson M.S., Tomedi E.M., Tchoumboue J., van der Werf H.M.G., Ombredane, D. (2012). Environmental impacts of farms integrating aquaculture and agriculture in Cameroon. J. Cleaner Prod., 28: 208-214.

Elegbe A.H., Agbohessi P.T., Békima Nkoue P., Imorou Toko I., Chikou A., Blé C., Laleye P. Tomedi Eyango, M. (2015a). Co-culture Clarias gariepinus-Oreochromis niloticus: quels avantages pour l'amélioration des performances zootechniques et économiques des poissons élevés dans les «whedos» du delta de l'Ouémé au Bénin? Int. J. Biol. Chem. Sci., 9: 1937-1949.

Elègbè A. H., Agbohessi P.T., Nkoué Békima P., Imorou Toko I., Chikou A., Blé C., Laleye P., Eyango Tomedi, M. (2015b). Effet du jeûn chez les juveniles d'Oreochromis niloticus et de Clarias gariepinus sur la productivité des "whedos" du delta de l'Ouémé, Bénin, Afrique de l'Ouest. Afrique Sciences, 1: 125-138.

FAO (Food and Agriculture Organization) (2020). La situation mondiale des pêches et de l'aquaculture 2018: La durabilité en action. Manuel technique sur les pêches, 425.

FAO (Food and Agriculture Organization) (2011). La situation mondiale des pêches et de l'aquaculture 2010. Des défis à relever, un potentiel à réaliser. Janvier 2011.

FAO (Food and Agriculture Organization) (2008). Aperçu général du secteur national d'aquaculture ; Département de Pêches et Aquaculture, Organisation des Nations Unies pour l'Alimentation et l'Agriculture Rome. http://www.fao.org/fishery/countrysector/naso_cameroun (consulté en Janvier 2022).

Gourène G., Kobena K. B., Vanga A. F. (2002). Etude de la rentabilité des fermes piscicoles dans la région du moyen Comoé. Abidjan, Côte d'Ivoire, Université Abobo-Adjamé: Rapport Technique.

Guinée J.B., Gorree M., Heijungs R., Huppes G., Kleijn R., de Koning A., van Oers L., Wegener Sleeswijk A., Suh S., Udo de Haes H.A., de Bruijn H., van Duin R., Huijbregts M.A.J. (2002). Handbook on Life cycle assessment. An operational guide to the ISO standards (Ed) Guinée J.B., Kluwer Academic Publishers, Université de Leiden (Pays-Bas).

Imorou Toko I. (2007). Amélioration de la production halieutique des trous traditionnels à poissons (Whedos) du delta de l'Ouémé (sud Bénin) par la promotion de l'élevage des poissons-chats Clarias gariepinus et Heterobranchus longifilis. Doctorat : Facultés Universitaires Notre-Dame de la Paix de Namur (Belgique).

Imorou Toko I., Fiogbe E.D., Koukpodé B., Kestemont P. (2007). Rearing of African catfish (Clarias gariepinus) and vundu catfish (Heterobranchus longifilis) in traditional fish ponds (whedos): Effet of stocking density on growth, production and body composition. Aquaculture, 262: 65-72.

Lalèyè P., Akélé, D., Philippart, J.C. (2007). La pêche traditionnelle dans les plaines inondables du fleuve Ouémé au Bénin. Cah. Ethol ., 22: 25-38.

Lalèyè P., Chikou A., Ezin A., Philippart J.C., Welcome R. L. (2003). Fish and fisheries of the Oueme Delta, Benin (West Africa). Paper presented at the Second International Symposium on the Management of large Rivers for Fisheries, Phnom Penh.

Nathan W.A., Peter H., Tyedmers (2009). Assessing alternative aquaculture technologies: Life cycle assessement of Salmonid culture systems in Canada. Journal of Cleaner Production,17:362-373.

Nhan D.K., Phong Le T., Verdegem M.C.J., Duong Le T., Bosma R.H., Little D.C. (2007). Integrated freshwater aquaculture, crop and livestock production in the Mekong delta, Vietnam: Determinants and role of pond. Agric. Syst., 94: 445.

Ngongang Nganso F.R. (2015). Evaluation environnementale des fermes piscicoles extensives dans le centre Ouest de la Côte d'Ivoire. Mémoire pour l'obtention du diplôme d'ingénieur de conception des eaux, forêts et chasses. Faculté d'Agronomie des Sciences Agricoles, Département de Foresterie, Université de Dschang (Cameroun).

Roque d'Orbcastel E., Blancheton J.P., Boujard T., Aubin J., Moutounet Y., Przybyla C. Belaud A. (2008). Comparison of two methods for evaluating waste of flow through trout farm. Aquaculture, 274: 72-79.

Van der Werf H.M.G., Petit J. (2002). Evaluation of the environmental impact of agriculture at the farm level: a comparison and analysis of twelve indicator-based methods. Agric. Ecosyst. Environ., 93: 131-145.

Welcomme R.L. (2002). An evaluation of tropical brush and vegetation park fisheries. Fish Manag. Ecol., 9: 175- 188.

Yakupitiyage A., Ranamukhaarachchi S.L., Yi Y., Mizanur R. (2007). Nutrient accumulation in Tilapia pond sediment and its agricultural uses. In: van der Zijpp, A.J., Verreth, J.A.J., Le Quang Tri, Van Mensvoort M.E.F., Bosma R.H., Beveridge M.C.M. (Eds.), Fishponds in Farming Systems. Wageningen Academic Publishers (Netherlands).

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References