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Valorization of bio-organic household waste by associating Aquaponie–Lombricomposter

Valorisation des déchets ménagers bio - organiques en associant Aquaponie-Lombricompostage

André Talla[1,2,*] and Marima Ida Jantou Nankem[2]

[1] Energy, Water and Environment Laboratory, National Advanced School of Engineering, University of Yaounde I, P.O.Box 8390, Yaounde, Cameroon.
[2] Research Center, National Advanced School of Public Work, P.O.Box 510, Yaounde, Cameroon
***** Corresponding Author: andre_talla@yahoo.fr

ABSTRACT:

The management of household organic bio-waste in developing countries and more specifically in Cameroon is a great challenge. The situation is marked by poor management of household waste with a very low sanitation coverage rate and degradation of arable land, leading to food insecurity. The objective of this article was to set up a domestic aquaponics kit associated with a vermicomposter for 100 % organic production. The value-analysis method was used to design the home kit perfectly adapted to the needs of its user. As such, three main functions have been retained: degradation of household organic bio-waste, fish farming and plant cultivation. This innovative kit would allow each household with an average of five people with limited space to obtain 213.2 kg of authorized household organic bio-waste in the vermicomposter after 3 months. This waste would make it possible to obtain two types of natural organic fertilizers (vermicompost and vermicompost). A household of five people will have 167 tilapia fish in their procession every 3 months and 109 good quality plants after 30-60 days. It also follows that after 3 months, 180,000 earthworms from the vermicomposter will be used to degrade household organic bio-waste and 60,000 earthworms will be used to feed the fish until they mature. A prototype of the domestic aquaponics kit associated with a vermicomposter has been developed to demonstrate its feasibility and effectiveness.

Keywords: Home kit, Aquaponics, Vermicomposter, Household bio-waste, Value analysis.

RÉSUMÉ :

La gestion des biodéchets organiques ménagers dans les pays en développement et plus particulièrement au Cameroun est un grand défi. La situation est marquée par une mauvaise gestion des déchets ménagers avec un taux de couverture sanitaire très faible et une dégradation des terres arables, conduisant à l'insécurité alimentaire. L'objectif de cet article était de mettre en place un kit d'aquaponie domestique associé à un lombricomposteur pour une production 100 % biologique. La méthode d'analyse de la valeur a permis de concevoir le kit maison parfaitement adapté aux besoins de son utilisateur. A ce titre, trois fonctions principales ont été retenues : la dégradation des biodéchets organiques ménagers, la pisciculture et la culture des plantes. Ce kit innovant permettrait à chaque ménage de 5 personnes en moyenne disposant d'un espace limité d'obtenir 213,2 kg de biodéchets organiques ménagers autorisés dans le lombricomposteur après 3 mois. Ces déchets permettraient d'obtenir deux types d'engrais organiques naturels (le lombricompost et le lombricompost). Un ménage de cinq personnes aura 167 poissons tilapia dans leur procession tous les 3 mois et 109 plantes de bonne qualité après 30 à 60 jours. Il s'ensuit également qu'après 3 mois, 180 000 vers de terre du lombricomposteur seront utilisés pour dégrader les biodéchets organiques ménagers et 60 000 vers de terre seront utilisés pour nourrir les poissons jusqu'à leur maturité. Un prototype du kit aquaponique domestique associé à un lombricomposteur a été développé pour démontrer sa faisabilité et son efficacité.

Mots clés : Kit maison, Aquaponie, Lombricomposteur, Biodéchets ménagers, Analyse de valeur.

1. INTRODUCTION

Aquaponics and vermicomposting are two little-known concepts in several developing countries, notably Cameroon, while they are practised at different scales, more or less empirically or scientifically, in many other regions of the world. Most of the waste bins in these countries are made up of easily biodegradable organic waste that is collected, transported and sometimes incinerated throughout the country, whereas it could easily be recovered on the site, in the home.

The practice of composting therefore makes it possible to considerably reduce the quantity of waste produced daily, as well as the related transport and treatment costs. Composting requires the presence of a garden or, for the inhabitants of buildings wishing to practise collective composting, a sufficient and nearby green space (Ademe, 2002). There is also a technique, less known but just as effective, that allows households without a garden (apartments, town houses) to recycle their organic waste: **vermicomposting,** also known as **vermicomposting.** Thus, according to St-Pierre (1998), vermicomposting is a process of bio-oxidation and stabilisation of organic matter thanks to the combined action of microorganisms and vermicomposters giving a compost that does not require a thermophilic phase **(**hottest phase of the compost) characteristic of composting. This compost, called vermicompost, is of high quality, in particular because of its excellent granular structure. As a result, this compost is used in agriculture, one of the most important areas for the advancement of a country. Several authors have worked on this concept of vermicomposting (Byambas et al., 2017; Edwards, 1995**;** Mustin, 2015; Naigon, 2005; Ndegwa et al., 1999; Sierra et al., 2011; Azizi., 2017). Some of these authors based their work on the comparative study between vermicompost and compost, the roles and morphological characteristics of earthworms; while others experimented with earthworms to purify wastewater called lombrifilter.

Many techniques exist nowadays for the increase of innovative agricultural products such as aquaponics. Biton (2017) defines aquaponics as the cultivation of plants in symbiosis with fish farming for 100 % organic production. Some studies on aquaponics have already been published (Foucard et al., 2010; Harlaut, 2015; Nichols and Lennard 2010; Rakoczy, 2006; Savidov, 2007; Darfeuille, 2015). These authors all had the same objective of being able to provide the population with healthy foods (fish, vegetables and fruits) of good quality, all of which are in a biological state.

However, these authors are not concerned with the association aquapony-worm composting. The Vermicomposter is a device that can be kept inside the house, in which earthworms live and transform our organic waste into a resource that makes a solid compost (the vermicompost) and a liquid compost (the vermicompost) that can be used for plants, flower boxes, vegetable gardens and many others. Both types of compost are 100 % natural fertiliser. The aquapony-worm composter combination pools earthworms (vermicomposters) that will degrade organic waste and also serve as food for fish. The objective of this study is to set up a domestic kit of aquapony associated with a vermicomposter for a 100 % organic production.

2. MATERIALS AND METHODS

2.1. Hardware

The material used for the domestic kit of aquaponics associated with a vermicomposter consists of :

- From a **fish tank**;

- From a **culture tank**;
- **Compost bins**;
- An **air filter pump**. It will play several functions:
  - Replace the water in the fish tank to prevent the ammonia they excrete from becoming concentrated;
  - Distributing nutrient-laden water to plants;
  - Distribute oxygen from the air throughout the system;
  - Give the fish some exercise.

2.2 Methods

The design method associated with the dimensioning has been developed.

2.2.1. Design method

A comparative analysis was carried out in order to choose the best approach to set up the aquaponics kit associated with a vermicomposter. The choice of method for the design considered Value Engineering (VA), also known as Value Engineering. Indeed, it is a method of investigation that involves a crossroads of multiple views on the product, on the user's needs, on the costs, on the environmental constraints, on the market and therefore on the value of this product.

Application of Value Analysis to Design

a) Information phase

In order to apprehend the different aspects of the design, it will be necessary to use a quality management tool that will allow structuring the information in order to analyse the situation: It is the **QQOQCP** method **(**What? Who? Where? When? **How?** Why?**)**. It is a question of asking the questions in a systematic way so as not to forget any known information. The search for information for a domestic aquaponics kit associated with a vermicomposter was collected in Table 1.

Table 1: Collection of information for the home aquaponics kit associated with a vermicomposter

QUESTIONS	ANSWERS
What? (problem)	➢ The amount of household bio-waste contained in a bin; ➢ Proliferation of foodstuffs from chemical fertilisers ; ➢ Diseases caused by chemical waste on humans (typhoid, malaria, cholera); ➢ Diseases caused by chemical fertilisers (heart and lung diseases, nervous system disorders, gastrointestinal disorders, musculoskeletal disorders, anaemia, behavioural and mental disorders).
Where? (place of applications)	Within Each Household
When? (time of application)	At Any Time
How? (problem development)	➢ Increased production of households bio-waste ; ➢ Increase in diseases from waste and chemical fertilisers.
Why? (reason for the kit design)	➢ Reducing the amount of household bio-waste ; ➢ Reduce the proliferation of harmful organisms (rats, mosquitoes, cockroaches) ; ➢ Preserving the population and the environment ; ➢ Reduce the use of chemical fertilisers.

b) Functional analysis

Functional analysis is an approach that consists of analysing a product in a systemic way by examining it from both inside and outside in order to pay particular attention to the interactions between its various components and the environment. Thus the expression of need has been materialised through the "**beast with horns"** method shown in figure 2.

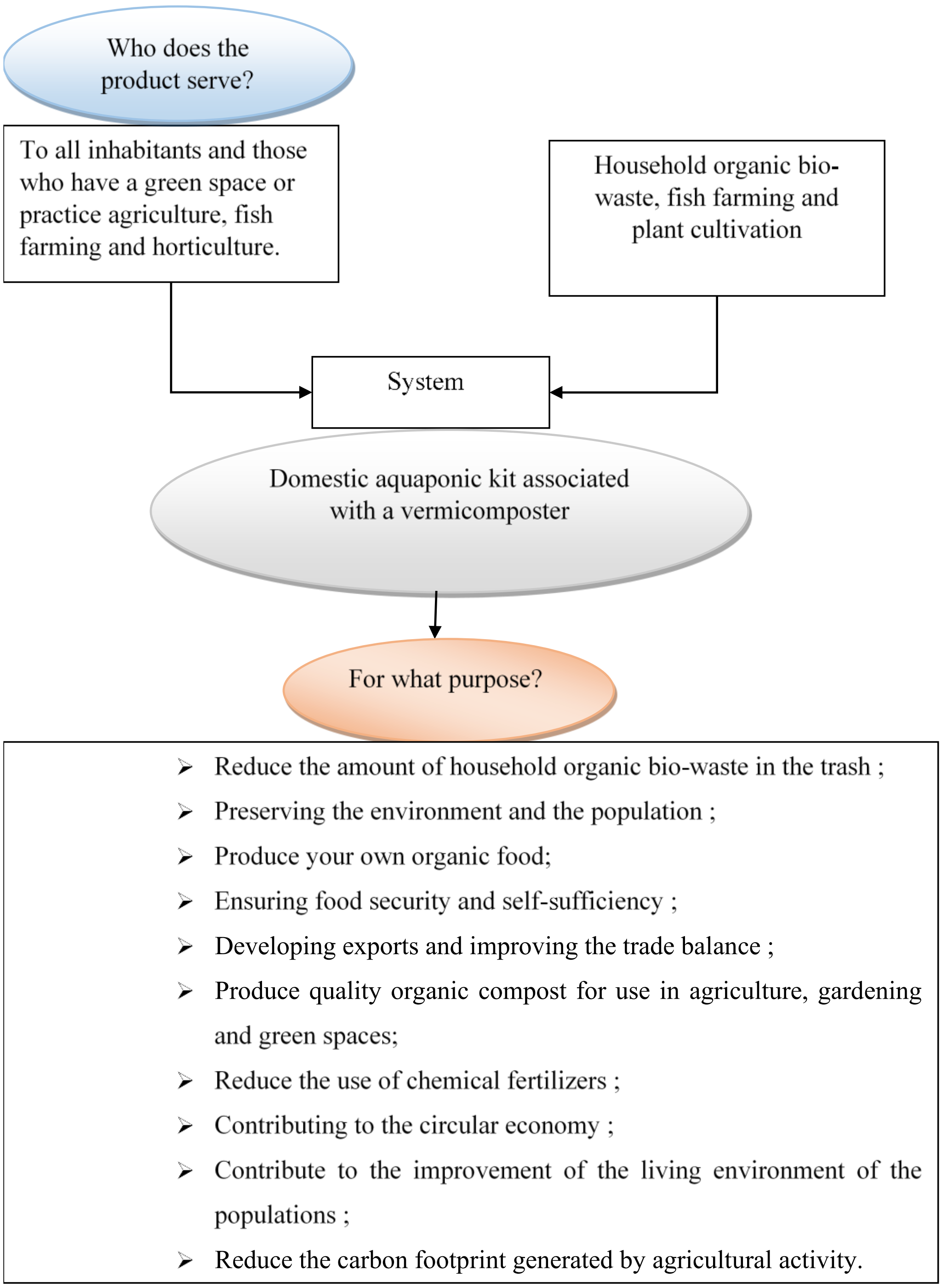

Figure 2: "Horned Beast" diagram for setting up a domestic aquaponics kit associated with a vermicomposter

However, there are two types of functions: the main function rated **FP** and the complementary or constraint function rated **FC.** The main function justifies the product's raison d'être while the constraint function completes, improves the service rendered, and adapts the product to the requirements of the environment. In the "Octopus" diagram, three main functions (**FP1**: Household organic bio-waste; **FP2**: Fish farming and **FP3**: Plant cultivation) then eleven constraint functions (**FC1:** Ideal conditions; **FC2** : Easy feeding of fish; **FC3:** Economy; **FC4:** Quality; **FC5:** Solidity; **FC6**: Easy maintenance; **FC7:** Durability; **FC8**: Easy assembly and disassembly; **FC9:** Easy harvesting; **FC10**: Small vegetable garden and **FC11**: Aesthetics) shown in figure 3.

Figure 3 shows the octopus diagram and Table 2 explains the role of the functions shown in the Octopus diagram in Figure 3.

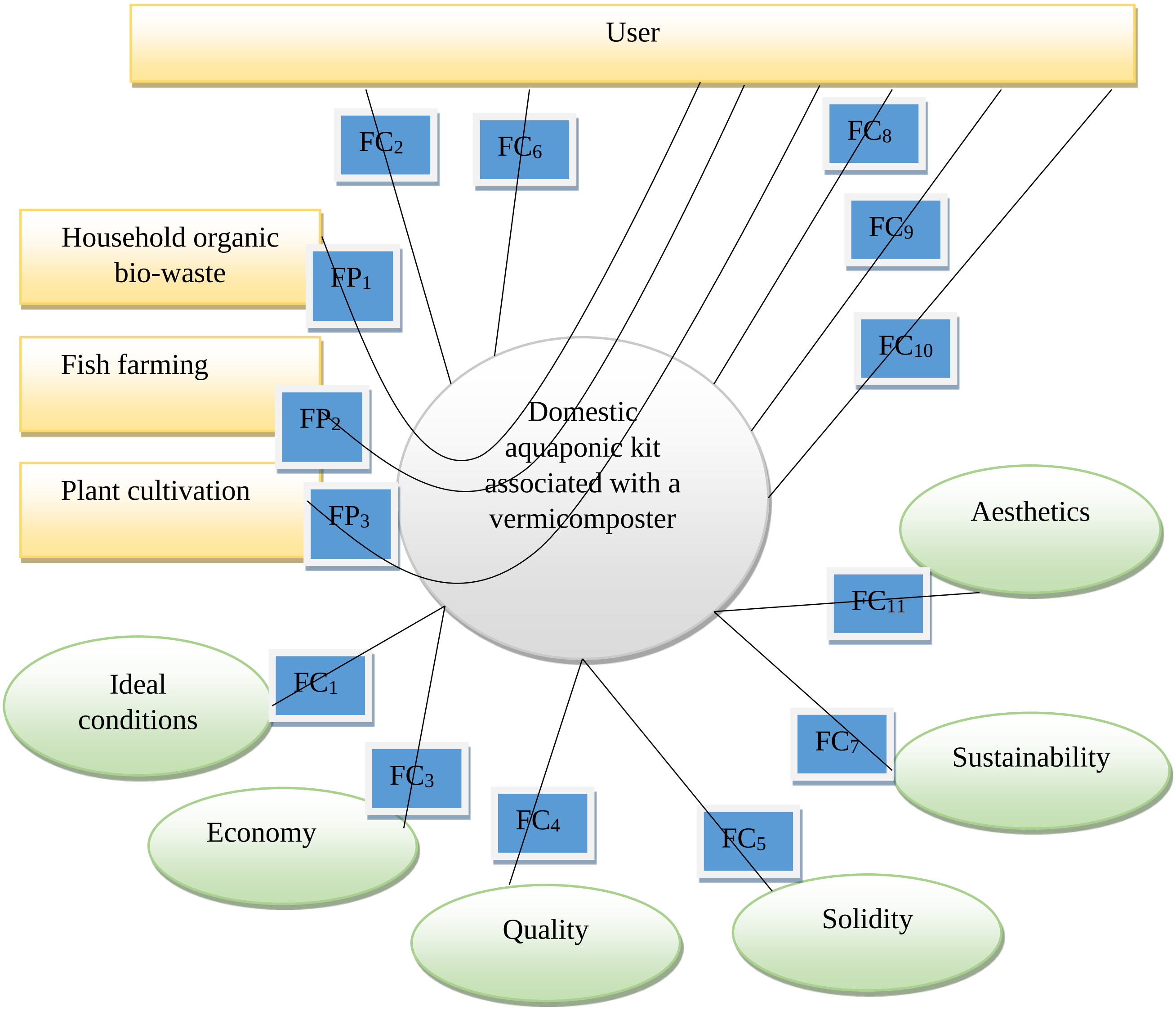

Figure 3: "Octopus" diagram for an aquaponics kit associated with a vermicomposter.

Table 2: Role of the functions of a vermicomposter-associated aquaponics kit

Functions	Expression of each function
FP1	To allow the user to obtain a natural and good quality organic fertiliser.
FP2	Allowing the user to obtain fresh, organic fish.
FP3	To allow the user to obtain natural, organic and good quality plants.
FC 1	Respecting the right conditions (temperature, pH, humidity, ventilation, darkness, light and absence of noise)
FC2	The user must be able to easily feed the fish
FC3	Adapting to the economic context of Cameroon
FC4	Meet quality requirements (hygiene and cleanliness)
FC5	Be strong by being resistant to the environment
FC6	The user will not make any effort during maintenance
FC7	The kit must be durable
FC8	Be easy to assemble and disassemble
FC9	Allowing the user to harvest the products easily
FC10	The user must have a small vegetable garden at his disposal which will serve as a germinator for new plants to be introduced into the growing tray. This vegetable garden will be enriched with natural organic fertiliser extracted from the vermicomposter.
FC11	The kit must be attractive and attractive.

2.2.2. Sizing method

The domestic kit of aquaponics associated with a vermicomposter is dimensioned according to the quantity of bio-waste to be composted, the quantity of fish, food and plants to be introduced, the number of people in a household and the type of meal essentially. It is also sized for a maturation period. The dimensioning will start from the potential of the household organic bio-waste produced in a household up to the culture bin.

Quantity of household organic bio-waste authorised after 3 months

The study was based in the city of Yaoundé, the capital of Cameroon. According to Talom (2007), the average person living in a household in the city of Yaoundé is 5 people per household. It also shows that the average amount of solid waste produced per day by an inhabitant is 0.6 kg. hab-1 .day-1 in the dry season and 0.98 kg. hab-1 .day-1 in the rainy season. For the 2011 campaign, biodegradable organic matter is preponderant at 58.9 % in the dry season and 76.0 % in the rainy season (Ngnikam et al., 2017).

Vermicompost takes place from three months onwards (Chaoui, 2010). The equivalence of 3 months will be equal to 90 days for the sizing of the kit, i.e. 360 days a year. Based on this, the quantity of household organic bio-waste available during this period will be determined. In order to do this, several steps have been carried out, namely the calculation :

a) The potential of household organic bio-waste after one year

It is given by formula (1):

$$\mathbf{P_{boma} = P_{bomss} + P_{bomsp}} \quad \textbf{(1)}$$

With

- **Pboma**: potential of households organic bio-waste after one year (in kg.yr-1) ;
- **Pbomsp**: potential of households organic bio-waste in the rainy season (in kg) ;
- **Pbomss**: potential of households organic bio-waste in the dry season (in kg).

In the course of our work, we estimated that 15 % of the unauthorised household organic bio-waste and 85 % of the authorised organic bio-waste was destined for the vermicomposter.

b) The amount of household organic bio-waste allowed after one year

Evaluated by formula (2) :

$$\mathbf{M_{boma} = F_{boma} \cdot P_{boma}} \quad \textbf{(2)}$$

With:

- **Fboma:** fraction of authorised household organic bio-waste (in %) ;
- **Mboma**: quantity of households organic bio-waste authorised after one year (in kg.).

Hence the amount of household organic bio-waste allowed after 3 months is obtained from formula (3):

$$\mathbf{M'_{boma} = \frac{N_{j90} \cdot M_{boma}}{N_{j360}}} \quad \textbf{(3)}$$

With:

- **M'_{boma}**: quantity of households organic bio-waste authorised after 90 days (in kg) ;
- **Nj90** : number of days equivalent to 90 days ;
- **Nj360**: number of days equivalent to 360 days (in days).

Quantity of worms available for the kit

Earthworms develop very quickly and are very fertile. A worm can produce one to four cocoons (the envelope that the larvae spin.) per week. After three weeks, each cocoon produces one to four babies that will become adults and breed in turn at 8 to 10 weeks (Harlaut, 2015). Manure worms are hermaphroditic (animal that processes both male and female organs) and have a lifespan of about 5 to 6 years. Part of the manure worms from the vermicomposter will be used as fish food and the other part will be destined for the vermicomposter to be used for the degradation of household organic bio-waste. Assuming that an adult worm produces 1000 to 1500 worms per year (Byambas et al., 2017), and that manure worms consume half their body weight per day (Chaoui, 2010). Assume 25 % of the worm fraction to be eaten by fish and 75 % of the fraction to degrade household organic bio-waste.

a) Number of earthworms available for fish

For the maturity of the fish. Ndombour (2008) states that it takes place from 3 months onwards. The number of worms available to the fish during this period will be determined by formula (4):

$$\mathbf{N_{vdp} = F_{vmp} \cdot N_{vo}} \quad \textbf{(4)}$$

With:

- **Fvmp**: fraction of worms eaten by fish (in %) ;
- **Nvo** : number of worms to be obtained after 3 months;
- **Nvdp**: number of worms available for fish after 3 months.

b) Number of worms available for household bio-waste

This number of worms is determined from the formula (5) :

$$\mathbf{N_{vdb} = F_{vdb} \cdot N_{vo}} \quad \textbf{(5)}$$

With:

- $\mathbf{F_{vdb}}$: fraction of worms that degrade household organic bio-waste (in %) ;
- $\mathbf{N_{vdb}}$: number of worms available for households bio-waste after 3 months.

Volume of the compost bin

The vermicomposter will be separated into three compartments of equal volume. Therefore, the volume of a compost bin will be determined by formula (6):

$$\mathbf{V_C = \frac{V_{tc}}{N_C}} \quad \textbf{(6)}$$

With:

- **Vtc**: Total volume of the vermicomposter (in L);
- **Nc** : number of composters equivalent to 3 ;
- **Vc**: volume of a compost bin (in L).

Number of fish available for the tank

An adult fish eats four worms a day (Pauly, 1986). To find the number of fish available for a household of five people, it is determined through equation (7):

$$\mathbf{N_{pd} = \frac{N_{vdp}}{N_{vcp}}} \quad \textbf{(7)}$$

With:

- $\mathbf{N_{vcp}}$: number of worms consumed by an adult fish after 90 days ;
- $\mathbf{N_{pd}}$: number of fish available.

Actual water volume for fish

The mature size of Tilapia fish (Oreochromis Niloticus) is between 12 and 20 cm (Lowe, 1958). For the rest of the calculations, the average size would be taken into account, resulting in a size of 16 cm for a mature fish. The actual water volume will therefore be calculated using the formula (8):

The classic rules of aquarium keeping advise 1 cm of fish for 1 L of real water.

$$\mathbf{V_{er}} = \frac{\mathbf{L_{tp}} \cdot \mathbf{V'_{er}}}{\mathbf{L_{P}}} \quad \mathbf{(8)}$$

With:

- **Worm**: actual volume of water (in L);
- $\mathbf{L_{tp}}$: total length of fish (in cm);
- $\mathbf{L_{p}}$: length of the fish equivalent to 1 cm;
- $\mathbf{V'_{er}}$: real volume of water equivalent to 1 L (in L).

Volume of the fish tank (gross volume)

The actual volume of water where fish will live is equal to 80 % of the gross volume (Harlaut, 2015). This volume will be evaluated by the formula (9):

$$\mathbf{V_{bp}} = \frac{\mathbf{V_{er}} \cdot \mathbf{100}}{\mathbf{80}} \quad \mathbf{(9)}$$

With:

- **Vbp**: volume of the fish tank (in L).

Theoretical pumping rate

According to Harlaut (2015), the pump must have a theoretical flow rate of **3 times the** actual volume of water in the fish tank. It will be calculated from the formula (10):

$$\mathbf{Q_{tp}} = \mathbf{3} \cdot \mathbf{V_{er}} \quad \mathbf{(10)}$$

With:

- **Qtp**: theoretical pumping rate (L/h).

Flow rate of water circulation

It is said that the water in the system must be completely renewed every hour using a pump (Harlaut, 2015). The circulation rate will be determined by formula (11):

$$\mathbf{Q_{ce}} = \frac{\mathbf{V_{er}}}{\mathbf{T_{ce}}} \quad \mathbf{(11)}$$

With:

- $\mathbf{T_{ce}}$: water circulation time equivalent to one hour (in h) ;
- $\mathbf{Q_{ce}}$: flow rate of water circulation (L/h).

Surface area of the growing tray

The depth of an aquaponics culture tank should be between 25 cm and 30 cm deep and the substrate introduced into the tank should be between 15 cm and 20 cm deep (Foucard et al., 2010**). The** dimensions of the lengths and widths should be fixed to approximate the golden section. The culture trough has the shape of a rectangular parallelepiped, hence the calculation of the surface area using formula 12:

$$\mathbf{S_{bc} = 2\,.\,\left((L_{bc}\,.\,l_{bc}) + (L_{bc}\,.\,h_{bc}) + (l_{bc}\,.\,h_{bc})\right)} \qquad \textbf{(12)}$$

With:

- $\mathbf{L_{bc}}$: length of the culture tank (in cm;
- $\mathbf{l_{bc}}$: width of the grow tank (in cm);
- $\mathbf{h_{bc}}$: height of the growing tray (in cm);
- $\mathbf{S_{bc}}$: surface area of the culture tank (in cm 2).

Number of plants available for the growing tray

The spacing between two plants is 25 cm on either side in a growing tray (. Foucard et al., 2015). The number of plants available will be taken from the formula (13):

$$\mathbf{N'_{Pd} = \frac{S_t}{S_e}} \qquad \textbf{(13)}$$

With:

- $\mathbf{N'_{pd}}$: number of plants to be introduced in our growing tray ;
- $\mathbf{S_t}$: total surface occupied by plants (in cm 2) ;
- $\mathbf{S_e}$: area of spacing between two plants (in cm 2).

3. RESULTS AND DISCUSSION

In this section, the results and discussion of the methodological analysis are presented.

3.1. Design output

3.1.1. Vermicomposter device assembly

The three composters will be stacked. First fill the first composter, then add the second one on top of the first one. The worms must arise spontaneously from the first to the second composter, which is rich in food. When the second composter is filled, a third composter is added using the same process. After 3 months, the compost will be harvested in the first composter. When you have the second composter, the vermicompost will be in the process of maturing and the third composter will have the fresh fractionated waste. After the vermicompost is collected in the first composter, it is reused, this time being so above the others and so on. These three bins are top composters with perforated bottoms and sides to allow the worms to move from one bin to another and have good aeration. Add to these bins, a lower bin with a tap whose bottom is not perforated, which will allow the juice from household organic waste (earthworm) to be collected as it comes out, using a tap. The vermicomposter can be installed anywhere because it does not give off any odours: either on a balcony, inside the house, in the kitchen, in a corner of the yard that does not reflect the sun's rays because worms do not like light. Figure 4 illustrates the assembly of the vermicomposter device.

Figure 4: picture of vermicomposter device assembly

3.1.2. Assembly of the aquaponics device

These culture tanks will be connected from the PVC pipes to the fish tank. A filter pump will be raised in the fish tank so that the fish droppings can be pumped out and assimilated into the culture tanks. Once the nutrient-rich fish water arrives in the fish tanks, it will be captured by pozzolana which will act as a bio-filter and assimilate the nutrient into the plant roots. The water will then return filtered in the form of automatic drainage to the fish tank via siphons in the culture tanks. Since fish are stressed by strong light contact, and plants need photosynthesis to develop better, it would be desirable to install the device in a place that does not reflect too much sunlight. Figure 5 illustrates the assembly of this aquaponics device.

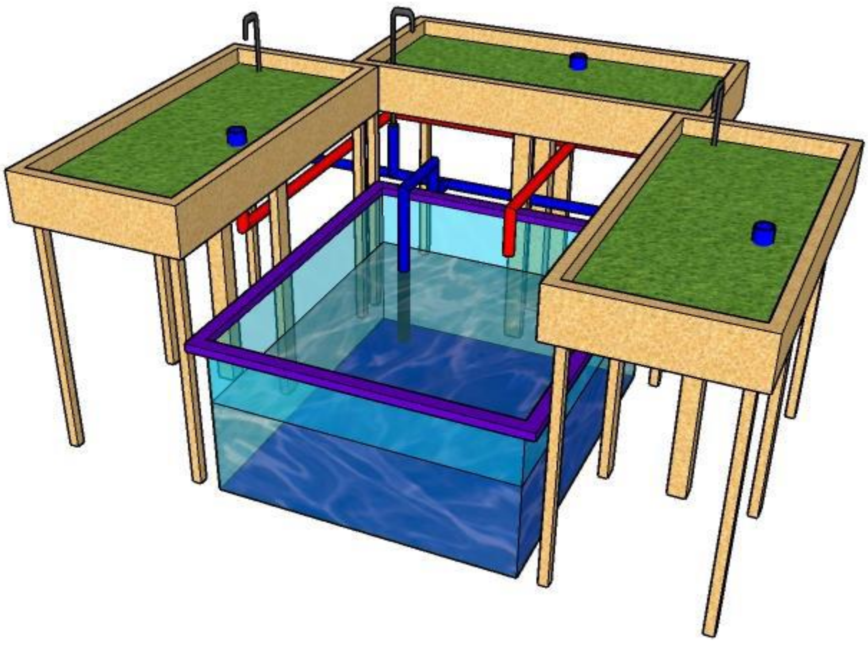

Figure 5: picture of assembly of the aquaponics device

3.1.3. Result of sizing

- **Potential of household bio-waste**

Relationship (1) leads to the results for the potential of household organic bio-waste, the results of which are shown in Table 3.

Table 3: Result of the calculation of the potential of household organic bio-waste

Designation	Settings	Results	Units
Average amount of solid waste produced in the dry season	Q_{dsss}	0,6	$kg.hab^{-1.}$ Day^{-1}
Fraction of bio-waste in the dry season	F_{bomss}	58,9	%
Average household size	N_{hab}	5	hab
Total number of days in the dry season	N_{tjss}	182	day
Potential of bio-waste in the dry season	P_{bomss}	321,6	kg
Average amount of solid waste produced during the rainy season	Q_{dssp}	0,98	$kg.hab^{-1.}$ Day^{-1}
Fraction of bio-waste in the rainy season	F_{bomsp}	76,0	%
Total number of days in the rainy season	N_{tjsp}	183	day
Potential of bio-waste in the rainy season	P_{bomsp}	681,5	kg
Potential of household bio-waste	P_{boma}	1003,1	$kg.yr^{-1}$

Table 3 shows that a household of five (5) people in the city of Yaounde produces 321.6 kg of household organic bio-waste in the dry season and 681.5 kg in the rainy season. This means that for the year, it produces 1003.1 kg of household organic bio-waste.

- **Amount of household organic bio-waste allowed**

Formulas (2) and (3) are used to find the amount of household organic bio-waste allowed in the vermicomposter, the results of which are presented in Table 4.

Table 4: Result of the calculation of the amount of permitted bio-waste

Designation	Settings	Results	Units
Potential of household bio-waste	P_{boma}	1003,1	$kg.yr^{-1}$
Fraction of bio-waste allowed	F_{boma}	85	%
Amount of bio-waste permitted after one year	M_{boma}	852,6	$kg.yr^{-1}$
Number of days (90 days)	N_{j90}	90	day
Number of days (360 days)	N_{j360}	360	day
Amount of bio-waste authorised after 3 months	M'_{boma}	213,2	kg

The results in Table 4 show that 852.6 kg of household organic bio-waste is allowed to be placed in the vermicomposter after one year. Similarly, the table shows that the amount of household organic bio-waste generated by a five-person household after three months is 213.2 kg.

- **Quantity of worms available for the kit**

Equations (4) and (5) show the different steps in distributing the quantities of earthworms to feed the fish in the bin; and those to degrade household organic waste in the vermicomposter. The results are presented in Table 5.

Table 5: Result of the calculation of the quantity of worms available for the home kit

Designation	Settings	Results	Units
Number of worms to be obtained after 3 months	Nvo	240 000	-
Fraction of worms eaten by fish	Fvmp	25	%
number of fish worms after 3 months	Nvdp	60 000	-
Fraction of worms that degrade household organic bio-wastes	Fvdb	75	%
Number of bio-waste worms after 3 months	Nvdb	180 000	-

It follows from the table (5) that after three months (maturity of fish and vermicompost), earthworms will be estimated at 240,000. From this, 60,000 earthworms will be available to feed the fish until maturity and 180,000 worms are set aside in the vermicomposter for the degradation of household organic bio-waste.

- **Volume of a compost bin**

The result of the volume of a compost bin will be determined in the table (6) from formula (6).

Table 6: Result of vermicomposter weight and volume calculation

Designation	Settings	Results	Units
Total vermicomposter volume	Vtc	520	L
number of composters (3)	Nc	3	-
compost bin volume	Vc	173	L

To install a vermicomposter in a five-person household in the city of Yaoundé, Table (6) shows that three composters of the same volume with a capacity of 173 L each is required, for a total volume of 520 L.

- **Tank volume and number of fish available**

The results of the tank volume and the number of fish available are grouped in the table (7) from formulas (7) to (9).

Table 7: Result of the calculation of the tank volume and number of fish available

Designation	Settings	Results	Units
Number of worms consumed by an adult fish after 90 days	N_{vcp}	360	-
Number of fish worms after 3 months	N_{vdp}	60 000	-
Number of fish available.	N_{pd}	167	-
Total length of fish	L_{tp}	2 672	cm
Length of the fish (1 cm)	L_p	1	cm
actual water volume (1 L)	V'_{er}	1	L
Actual water volume	Ver	2 672	L
fish tank volume	V_{bp}	3 340	L

Table (7) shows that a fish tank volume of 3340 L would be required for an actual water volume of 2672 L or 167 fish would live. A household of five people will therefore have 167 fresh fish in its procession every three months (90 days).

- **Theoretical pumping and circulating water flow rate**

Relationships (10) and (11) are used to obtain the theoretical pumping rate and the flow rate of the water circulation. The results are given in the table (8).

Table 8: Result of the calculation of the pumping and water circulation flow rate of water

Designation	Settings	Results	Units
Actual water volume	Ver	3 340	L
theoretical pumping rate	Q_{tp}	8016	L/h
Water circulation time (1 hour)	T_{ce}	1	h
Flow rate of water circulation	Q_{ce}	2672	L/h

Table (8) shows that the actual water in the fish tank must be completely changed after everyone hours through a filter pump. Therefore the water circulation rate is 2672 L/h. For good water circulation, the pumping rate must be three times or more the actual water volume in the fish tank. It would therefore be preferable to have a filter pump with a flow rate greater than or equal to 8016 L/h in order to effectively filter the tank and ensure safe water for the fish.

- **Area of the cultivation tray and number of plants to be introduced**

Formulas (12) to (13) will be used to calculate the surface area of the growing tray and to determine the number of plants to be introduced into the tray. The results are grouped in the table (9).

Table 9: Result of the calculation of the area of the growing tray and the number of plants

Designation	Settings	Results	Units
Length of the culture tank	L_{bc}	400	cm
Width of the culture tank	lbc	170	cm
Height of the cultivation tray	h_{bc}	30	cm
Surface area of the growing tray	S_{bc}	15, 3	m^2
Spacing surface between two plants	Se	625	cm^2
total plant area	St	68 000	cm^2
Number of plants	N'_{pd}	109	-

From table (9), it can be seen that a household of five people will have a 15.3 m^2 cultivation tank that can accommodate 109 plants of various varieties (aromatic, medicinal, vegetables and fruits). But to save space, the idea was to divide the surface area of the bin into three to make small bins of 5.1 m^2 each.

- **Realisation of the prototype**

After sizing the home kit for a household of five people, it was wise to be able to go through a practice test to be able to show the feasibility of the project. Therefore a prototype was designed, tested and then followed up until the maturity of its products namely.

- The monitoring of plants (mint, lemongrass, lettuce, sage, chives, basil) to maturity is shown in figures 6 to 8.

Figure 6: Picture of beginning of growth

Figure 6 shows the beginning of the evolution of the growth of aromatic and medicinal plants (mint, sage, lemongrass, basil, chives and lettuce). The roots of these plants grow in a substrate composed of the cheapest and most readily available pozzolan and charcoal. Its only disadvantage is its weight.

Figure 7: Picture of growth after 45 days

Figure 8: Picture of growth more than 45 days

Figures 7 and 8 show these different varieties of plants that are ready to be harvested since they mature in 30 to 60 days (Biton, 2017). It is noted here that the plants can be harvested in two ways, namely: harvesting by foliage (in this case, the leaves of the plants must be cut off after every two weeks) or harvesting the mature plants from the growing tray completely (in this case, it is necessary to think about replanting the new plants).

- Figures 9 and 10 show the monitoring of Tilapia (oreochromis Niloticus) fish until maturity (Figure).

Figure 9: Picture of growing juvenile fish

Figure 10: Picture of mature fish

The choice of fish for the aquaponic system was Nile tilapia (Orechromis Niloticus) for several reasons: they are freshwater fish of the exotic carp species, abundantly bred and consumed worldwide, especially in Cameroon, they are growing fast, and can withstand very poor water conditions. Figure 9 shows the juvenile fish in growth evolution and Figure 10 shows the fish that have already been 3 months old (mature fish). These were grown in a tank filled with borehole water after analysis with PH strips (PH= 7).

- Monitoring the decomposition of household organic bio-waste using earthworms until the maturity of two types of natural compost (vermicompost and vermicompost) is shown in figures 11, 12 and 13 (a, b and c).

Figure 11: Picture of decaying bio-waste

Figure 12: Picture of mature vermicompost

(a) b) (c)

Figure 13: (a) picture of nearly mature vermicompost; (b) picture of collection of vermicombs: (c) picture of wormhole obtained after 2 weeks

In the first compost bin, 1 kg of worm-friendly household organic bio-waste was introduced with a handful of worm manure that was left for two weeks (14 days) without introducing any new waste. This allowed the worms to better acclimatize and decompose the bio-waste (Figure 11).

Once the two weeks have passed, the household organic bio-waste will be constantly introduced into the composters in small pieces to speed up decomposition until vermicompost (Figures 12 and 13(a)) and lombrithe (Figures 13 (a) anb (b)) are obtained. However, since vermicompost and lombrithe are very rich and should not be used alone, they will need to be diluted.

Figure 14 shows the earthworms harvested from the vermicomposter

Figure 14: Picture of earthworms harvested from the vermicomposter

Figure 15 shows the overall prototype produced

The benefits of lombrithe according to Dominguez et al. (1997) are listed below:

- The compost juice diluted 1/10 (earthworm) will be used as a spray treatment for plant leaves;
- Vermithe is a degreasing product (removes paint from walls, grease oil on containers);
- It is an anti-parasite that eliminates odours (drains, washbasins, horse and dog soap, bathtub, sinks, shower tray, etc.);
- Best drink for dogs and chicken.

The vermicompost should be stored in a cool, dark place and used quickly (ten days) afterwards. It is advisable to put it back in the vermicomposter to reintroduce microorganisms (Dominguez et al., 1997).

The benefits of vermicompost according to Dominguez et al. (1997) include:

- Mixing one quarter vermicompost with three quarters ordinary garden soil or old soil;
- The use of vermicompost on organic farming, on gardens, vegetable gardens, lawns, flower pots and plants.

Figure 15: Picture of prototype of the home kit

4. CONCLUSION

Following the observation of the proliferation of household organic bio-waste and the problem of food security among households in the streets of developing countries, particularly Cameroon, this study aimed to set up a domestic aquaponics kit associated with a vermicomposter for 100 % organic production. To achieve this, the material used for the home kit and the design method (value analysis) associated with the dimensioning were presented in the first part. The second part focused on the results of the design (assembly of the vermicomposter device and the aquaponics) and sizing (obtaining 213.2 kg of authorised household organic bio-waste which allowed the vermicompost and vermicompost to be produced, the harvest of 167 tilapia fish after 3 months and 109 plants after 30-60 days). After having sized the household kit for a household of five people, it was wise to be able to go through a practice test to be able to show the feasibility of the project. Therefore a prototype was designed, tested and then followed through to maturity (natural fertiliser, fish and plants).

The amount of organic bio-waste produced in the locality is an important raw material for the establishment of a stand-alone vermicomposting facility. In addition, the problem of food security in households calls for an urgent need to adopt a self-contained aquaponics system to increase local production of good quality.

Such a domestic aquaponics kit combined with a vermicomposter in a household allows the individual to be a:

- Eco-citizens: Adopting the gesture of sorting household organic bio-waste as a matter of habit would be an alternative allowing the individual to reduce the volume of waste in his or her bin while eliminating infectious and parasitic diseases caused by an unhealthy environment.
- Self-producer: producing healthy fish, by providing organic fruits and vegetables will limit the chemical fertilisers that undermine our society.
- Self-employer: becoming an entrepreneur would be an opportunity to reduce the unemployment rate in the country.

The implementation of a domestic kit of aquaponics associated with a vermicomposter is one of the new methods of innovation, hoping that this new technique will take place in our country and that it can improve the productivity of our agriculture and the ecological state of our environment. In the same way, it can reduce the food bill and improve Cameroon's balance of trade by making it an exporter of its foodstuffs while ensuring its food self-sufficiency.

5. CONFLITS OF INTEREST

None to declare.

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