
**E-ISSN: 2347-5129**
**P-ISSN: 2394-0506**
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2019; 7(2): 122-128

www.fisheriesjournal.com
Received: 26-01-2019
Accepted: 28-02-2019

**Odjo IN**
Laboratory of Research on Wet Lands, LRZH/FAST/University of Abomey-Calavi, Benin

**Djihinto GA**
Laboratoire de Recherche en Biologie Appliquée, LRBA/EPAC/University of Abomey-Calavi, Benin

**Vodounnou DSJV**
Laboratory of Research on Wet Lands, LRZH/FAST/University of Abomey-Calavi, Benin

**Djissou ASM**
Laboratory of Research on Wet Lands, LRZH/FAST/University of Abomey-Calavi, Benin

**Clément Bonou**
Institut National des Recherches Agricoles du Bénin (INRAB)

**Mensah GA**
Laboratoire de Recherche en Traitement et Conservation des Produits Halieutiques

**Fiogbe ED**
Laboratory of Research on Wet Lands, LRZH/FAST/University of Abomey-Calavi, Benin

**Correspondence**
**Odjo IN**
Laboratory of Research on Wet Lands, LRZH/FAST/University of Abomey-Calavi, Benin

# Organic waste management for the maggots production used as source of protein in animal feed: A review

**Odjo IN, Djihinto GA, Vodounnou DSJV, Djissou ASM, Clément Bonou, Mensah GA and Fiogbe ED**

**Abstract**
Fishmeal is the main component of feed in aquaculture and accounts for 40 to 60% of total protein in aquaculture and monogastric feeds. The alternative feed resources of insects and other edible invertebrates are a sustainable solution for animal feed but are classified in little known sources. They do not at the moment imply a feed competition with human nutrition. Among the most targeted invertebrates are the larvae of flies or maggots because of the ease of production, the duration of the production cycle and the importance of their biomass. The maggot meal has nutritional qualities comparable to fish meal, soy and contains many other conventional nitrogenous materials. The chemical composition of edible insects in generaly and maggots in particulary are similar or even better than those of conventional food ingredients and their use in fish feed induces good zootechnical performance. The consequences of this alternative mode of animal feeding are minimal and can be mitigated by the reasoned choice of the production substrates, the environment of their production and the processes of pre-processing into food ingredients comparable to fish. Its production makes it possible to recycle organic waste and consequently the management of the environment. Its insertion in fish feed is strongly recommended. The present work aims to summarize the studies on the biology and ecology of maggots, different production techniques maggots, their nutritional value and finally the various forms in which they are administered by fish.

**Keywords:** Aquaculture, maggot meal, organic waste, productivity

## Introduction

In Africa, the development of breeding in general, and fish farming in particular, has problems, among which the quality of food and particularly the lack of protein rations [1]. This protein deficiency is due to the high price of the various potential sources of protein often represented by fish meal and fish oil with high nutritional value (nutrient, digestibility, etc) on the one hand and the competition between man and animals with regard to these traditional food resources of animal and vegetable origin on the other hand [2] [3]. This situation is aggravated by a lack of foreign exchange for importing these food ingredients [3]. The fish meal, main component of aquaculture food, represents 40 to 60% of the total protein in the aquaculture diet [4]. Its interest in intensive aquaculture is closely linked to its nutritional richness and the bio-availability of these nutrients [5]. The high price of the fish meal has directed research towards new local alternative protein sources for feeding breeding including flour of maggots, termites, earthworms, cockroaches and others to maintain optimally the zootechnical performances of these animals and make the food of the breeding sector accessible in the developing countries [6] [2] [7]. The use of insects such as maggots, termites, earthworms and cockroaches in the human and animal diet is recommended by Van Huis *et al.* [8] for economic and sustainability reasons and can serve as substitutes for conventional sources of animal protein in the development of a balanced diet for animals in general and fish in particular [5]. Insects are often wrongly considered as a nuisance for humans and as real pests of crops but their breeding (insect farming) and their insertion in the food and feed are based on the strong recommendations of FAO because of their wealth in protein and other nutrients for fish [8]. Of all the insects used as sources of protein in animal feed, house flies and soldiers flies ideal larval [9] because they can be obtained freely from a wide range of household refuse original animal and vegetable. The whole world is subject to the daily production of organic waste which is an excellent medium for the production of maggots [2].

The present article summarizes the results of the various studies carried out on the production and use of maggots in the feeding of farmed animals in general and aquaculture in particular.

**Biology and physiology of maggots**

Maggots are the stage of metamorphosis of the fly corresponding to a product accumulation that normally gives rise to a pupa before evolving into the adult fly **[10] [11]**. They go in the same direction to say that maggots are derived from eggs laid on the surface of organic materials after a spontaneous incubation of varying duration depending on the conditions of the environment. The maggots live in a tropical or wetland environment. They can be typically found in soil, plant or animal tissues, as well as the carcass or any organic material, almost always in the places where the danger of drying is minimized [10]. The house fly goes through four stages of development during its life (The egg, larvae called maggots, pupae and winged adults) [10, 11]. The eggs take 8 to 12 hours before hatching under normal conditions. The larval stage lasts about 5 days while the pupal stage, 4 to 5 days [10]. The same authors add that adult female flies have the ability to lay more than two thousand eggs for the female lays every three to four days with rosaries of eggs. The development cycle of flies visiting garbage includes four stages (egg, larva or maggot, nymph or pupa and imago or adult) whose duration varies with temperature, humidity but also with food Bouafou *et al.* [12]. According to the same author, the development cycle of some families like the *Calliphoridae and Muscidae* lasts eight to ten days at 35.5-37°C, from oviposition to hatching of the fly. Under natural conditions, flies lay in the wet or decaying material such as manure, grains, and scattered food on the floor, soybean meal, corn, viscera and others [13]. The size of the adult will depend on the growth that the larva has developed during its feeding period and at the end of its feeding period. The maggot (third instar) moves away crawling from wet feed zones to a dry place to pupate [11]. This migratory stage before pupation often lasts 3 to 4 days and the pupation will have a brownish colour which does not feed, all the vital activities are slowed down until the adult fly is ready to leave the integuments (envelope) of the pupa [10]. The adult fly opens and pushes the end of the pupa envelope with a blade-shaped member on the head that alternately deploys and contracts to open a fly passage through manure and organic debris to allow him to reach the surface. These same authors add that the adult male and female flies feed from decaying organics materials and meanwhile these mate and lay eggs on the food and the cycle resumes [10]. Maggots belong to the phylum Invertebrates in the class Insecta, order Diptera, the family *Muscidae*, Diptera Cycorraphs eyes apart in the female and usually close or contiguous in the male. This family includes houseflies and tsetse flies, and is the most cosmopolitan family of insects [10]. Maggots are vermiform characterized by the absence of legs and a separate cephalic capsule, the mouthparts are reduced with the presence of oral hooks to feed. They can be 1 cm long (0.4 to 1.5 cm depending on age in days) before becoming pupae [10] [11]. The interesting stage is that of the maggot (L3), the nearest potential for its transformation into a pupa so as to have all the nutrients (carbohydrates, lipids, proteins and minerals).

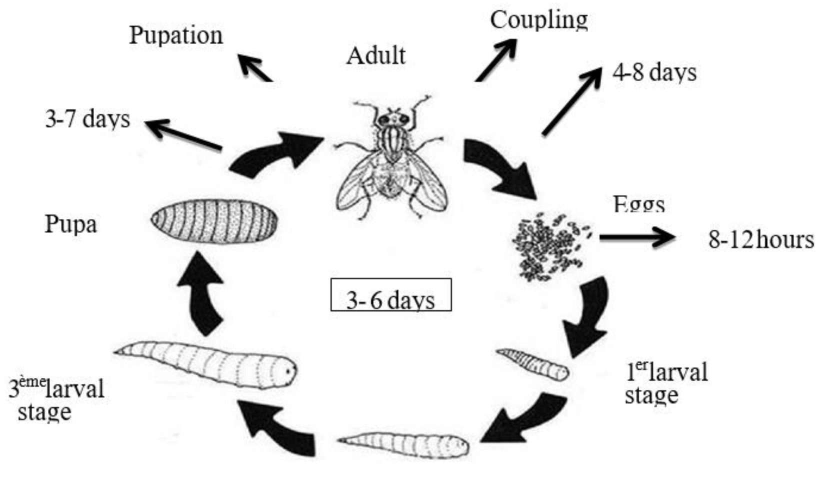


**Fig 1:** Development cycle of a fly [2]

**Production techniques of maggots and factors influencing this production**

**Production techniques of maggots**

The maggot production technique undertaken by Nzamujo [14] is an aerobic fermentation process consisting of putting a mixture of fresh excrement of animals and fresh greens into a large container. According to Ekoue *et al.* [7], large cans are filled with cow rumen content at eight o'clock and then allowed to flies in the open air for ten hours. They are then covered by mosquito nets. The maggots are harvested four days later. The maggot production technique implemented by Bouafou *et al.* [12] is described as follows: Peelings of yams and remains of fresh fish arranged in layers in a half-barrel, are exposed to flies. After 24 hours of seeding substrates by the latter, the half-barrel is covered. Four days later, the maggots are harvested in boiling water. Djissou *et al.* [6] have produced maggots using animal dung, food waste and their respective mixtures all triplicate tested in containers deposited in the shade sheltered from sunlight and rain. The harvest of the maggots starts from the 5th day after the beginning of the experiment using a sieve on which he pours and under which is a basin to collect the maggots.

**Factors influencing the production of maggots (Humidity, temperature and season)**

The eggs of house flies and meat flies need a lot of moisture. Larval development requires a relative humidity of over 97% [15, 14]. At 35.5-37°C, the development cycle of *Calliphora* or meat flies and *Musca* (houseflies) lasts eight to ten days (from oviposition to the fly or imago stage) with five days (on average) of larval phase or maggot [12]. According to Ekoue *et al*. [7] The duration of housefly's development cycle (oviposition to hatching) is a function of ambient temperature and is between 32 C and 35 C. The percentage of eggs hatched is maximum between 15-40 C and below 8 C and above 42 C, all eggs die before hatching and all ceases to copulate and lay between 10 and 15 C [16]. The most favourable temperature for larval development is 35°C [15]. Productivity drops in the dry season and during the harmattan [14, 12]. A warm atmosphere accelerates the development of maggots by shortening the cycle and a weak environment delays the evolution of the larvae by extending the development cycle [12].

## Nutrition of flies

The flies only settle in an environment if this environment fulfils some conditions favourable to the life of the insect and the first of these conditions is the presence of food. They have a sense of smell highly developed that allows them to feel the presence of food in kilometers distance. It is therefore the smell of substrates that attracts them (Anonymous). Male or female flies and soldier flies survive by feeding on water supplemented with sugar and other available carbohydrates. In order for female eggs to form, they need more protein or amino acids but no fat [17]. During the ingestion of food followed by digestion, maggots produce enzymes that attack proteins and fats. However, they have virtually no enzymes acting on carbohydrates [18].

## Other factors

The studies of Yamamoto *et al*. [19] have shown that odors of materials in fermentation and putrefaction, alcohols, aliphatic acids, short chain (acetic acid), aldehydes and esters attract flies [20]. But they are also attracted by toxic substances such as chloroform, formalin, some organophosphorus insecticides and jatropha seed cake mixed with earthworms [21, 2]. Flies' responses to light are complex and correlate with other physical, chemical and physiological factors [15]. Young flies have a preference for dark places, which is not the case in older flies, some of which show preference for light and others for darkness [22]. According to Keiding [15], ventilation, heat, cold, color and texture of surfaces exercise an influence over an attraction on the housefly but avoid wind and drafts. Inside a building, the house fly prefers yellow, white and red and avoids black. It prefers rough surfaces and particularly edges [16]. Predators of maggots are lizards, agamids, birds and other insectivorous vertebrates [14].

## Inventory of the different types of substrates used for the production of maggots

Cassava semolina, cassava, banana and yam peelings, have low productivity in maggots. On the other hand, garbage of animal origin and their mixture with garbage of vegetable origin have good productivity in maggots [6]. Maggots can be produced on various types of substrates that influence not only maggot biomass but also larval quality [23]. The productivity of maggots obtained Djissou *et al*. [6] from themixture chicken meal viscera were confirmed B ouafou [24] who says that the mixture of animal and vegetable waste has an important attractive potential for flies by their color, texture and smells. The substrates on which flies lay in the wild are very varied, but they are almost always more or less decomposed organic matter. The choices seem so wide and the logic recommends using substrates available throughout the year, preferably free. It is about wheat bran, maize bran, millet, sorghum, palm kernel cake, palm wine, animal carcass, palm nut waste, wax, soy bean, ot her animals, fresh leaves, vegetables rotten, residues processin g, remains of fermented cassava, butchers' remaig meat, rotten oranges, mango peels, ripe mangoes, prepared palm seeds, fresh ripe banana peelings. Some researchers using the substrates for the production of maggots take some parameters to ensure the productivity of the latter; this is the case of Table 1 which presents the inventory of some substrates.

**Table 1:** Inventory of some of the most used substrates in Africa for the production of maggots.

| Substrates | Proportions | Productivity in g / kg | Ecological conditions | References |
|---|---|---|---|---|
| Ruminal + Blood Content (RBC) | 90% CR + 10% S | 66.1 | T: 25 and 30°C H : 60 | [25] |
| Pig + Blood Slurry (PBS) | 90 % LP + 10% S | 189 g / Kg | T: 28 °C H 70 | [25] |
| Pork Slurry + Ruminal + Blood Content (PSRBC) | 45 % LP + 45 % CR + 10% S | 128 g / Kg | T:25 and 30°C H : 60 | [25] |
| Ruminal Content (RC) | 100% CR | 31.3 g / Kg | T: 28°C H 70 | [25] |
| Pig Slurry + Ruminal Content (PSRC) | 50 % CR + 50% PL | 58.5 g / Kg | T: 25 and 30°C H : 60 | [25] |
| Slurry of Pork | 100% | 33.2 g / Kg | T: 28°C H 60 | [26] |
| Soybean meal | 100 % | 218g / kg | T: 28.7°C H : 94 ± 2 | [6] |
| Cow dung | 100 % | 0.037g/ kg / d | T : 28°C H 94 | [3, 6] |
| Viscera of poultry | 100% | 3.20 g / Kg | T : 28°C H 70 | [6] |
| Human waste | 100% | 2.5 g / kg | T : 28°C H 60 | [26] |
| Pigs | 100% | 2.62 g / Kg | T : 28°C H 70 | [6] |
| Poultry droppings | 100 % | 0.12 g / kg / d | T : 29.7°C H : 68 | [3] |
| Household waste | 100 % | 10.7 g / kg | T : 28.7°C H : 78 | [26] |
| Cassava and yam peelings | 50% and 50% | 3.10 g / Kg | ND | [27] |
| Rotten fruit and Rotten vegetables | ND | 10,22g / kg | ND | [27] |
| Jatropha seed meal + earthworms | ND | 44.5 g / Kg | ND | [2] |
| fresh brewery | 100 % | 63,3g / kg | T : 28.7°C H : 94 ± 2 | [28] |
| Content of cattle belly And pigs | 100 % | 10 to 14g / kg | T : 28°C H : 60 | [26, 20] |

ND: Means No Determined; H: Humidity and T: Temperature

**Nutritional values of larvae of maggots used in animal feed**

The chemical composition of fly larvae varies according to the form in which they were presented (Table 2). The fresh and dried flies larvae have similar proteins contents (59.10 and 59.48% DM, respectively) **[29]** while those put into flour form has a content of 50.4% DM **[2]**. The same author continues that, however, the variations of amino acid contents are much more remarkable at the level of the floury form.

**Table 2:** Chemical composition of fresh, dried and floury fly larvae

| **Chemical composition** | **Maggots in form** | | |
|---|---|---|---|
| | **Fresh** | **dried** | **Flour** |
| EM ($Kcal.kg^{-1}$) | 3207.457 | 3 291.10 | 5803.95 |
| PB (%MS) | 59.10 | 59.48 | 50.4±5.3 (42.3, 60.4) |
| Lindenic acid (%MF) | ND | ND | 2.0 |
| NDF (%MS) | 4.05 | 6.66 | ND |
| ENA (%MS) | 11.49 | 8.08 | ND |
| CB (%MS) | 13.92 | 11.53 | 10.1±3.3 |
| $Ca^{++}$ ($g.Kg^{-1}$ MS) | 3.62 | 5.96 | 4.7±1.7 |
| P (g / Kg MS) | 1.95 | 1.05 | 5.7±3.5 |
| Ash (% MS) | 11.53 | 14.24 | 10.1±3.3 |
| Lysine (g/16gN) | 4.43 | 4.41 | 6.1±0.9 |
| Methionine (g/16gN) | 1.53 | 1.50 | 2.2±0.8 |
| Cystine (g/16gN) | 0.43 | 0.46 | 0.7±0.2 |
| Authors | [38] | [38] | [29-37] |

***Source*:** Makkar *et al.* [29]

**ND: Not defined; NDF: Neutral Detergent Fiber, ENA: Non-Nitrogen Extractive; PB: Raw Protein; CB: Brut Cellulose; EM: Metabolizable Energy; MG: Fat; MS: Dry matter.**

The analyses carried out by Hardouin *et al.* [11] and Inaoka *et al.* [39] on dried and crushed pupa flour and dried and ground larvae of house flies (*Musca domestica*) yielded the chemical composition and amino acid composition of both types of larvae. According to Ekoue *et al.* [7] and Meneguz *et al.* [27] the chemical composition of maggots would depend on their stage of larval development (Table 3a and 3b).

**Table 3 a:** Chemical composition of domestic fly larva *Musca domestica*

| **Nutrients** | **Dried and crushed pupae** | **Dried and crushed larvae** |
|---|---|---|
| Metabolizable energy kcal / kg | 3790 | 4349 |
| Raw protein% | 63.1 | 59.65 |
| Lipids% | 16.5 | 19,00 |
| Minerals | 5.3 | 7.26 |
| % Water | 3.9 | - |
| Non-nitrogenous extractant | 12.1 | 14.09 |

**Source**: Hardouin *et al.* [11] and Inaoka *et al.* [39]

**Table 3b:** Amino acid composition of *Musca* larvae *domestica*

| **Nutrients** | **Dried and crushed pupae** | **Dried and crushed larvae** |
|---|---|---|
| Arginine | 4.2 | 2.22 |
| Wisteria | 3.9 | 2.23 |
| Histidine | 2.6 | 1.41 |
| Isoleucine | 3.5 | 1.86 |
| Leucine | 5.3 | 3.10 |
| Lysine | 5.2 | 3.60 |
| Methionine | 2.6 | 1.40 |
| Phenylalanine | 4.2 | 3.51 |
| Threonine | 3.2 | 2.09 |
| Valine | 3.4 | 2.29 |
| Glutamic acid | 10.8 | 6.43 |
| Alanine | 4.2 | 3.00 |
| Cysteine | 0.4 | 0.58 |
| Tyrosine | 4.8 | 5.35 |
| Proline | 3.1 | 2.37 |
| Serine | 3.2 | 2.08 |
| Aspartic acid | 8.5 | 4.84 |
| Ammonia | 2.5 | - |

***Source*:** Hardouin *et al.* [11] and Djissou *et al.* [5]

The data reported by Nzamujo [14] indicate that the rate of determined mineral is 9.10% of dry matter. It seems, therefore, that maggot meal is a food source relatively poor in minerals. This information is contrary to the general observation made about flours of animal origin. Indeed, these animal meals have a good ash content (thus in mineral) greater than or equal to 20%. Because of its chemical composition (Table 4), the dried maggots flour is a abundant source of animal protein (47.50 to 52.23%) [27, 40], comparable to the cake of oleaginous, commonly used in animal feed.

**Table 4:** Chemical Compositions of dried maggots' flour in % on dry matters

| | Protein | Fat | Dry matter | Ashes | $K^+$ | $Ca^{++}$ |
|---|---|---|---|---|---|---|
| Maggot meal [14] | 47.50 to 50.10 | 19.30 | ND | 9.10 | 1.30 | 1.50 |
| Maggot meal [41] | 47.50 to 54.00 | 19.30 | ND | 9.10 | 1.30 | 1.50 |
| Flour of dried maggots [31] | 52.23 | 24.43 | 92.51 | 7.33 | 0.10 | 0.60 |
| Dried maggot meal [35] | 50.17 | 35.41 | 93 | 6.57 | 0.58 | 0.70 |

ND: Not determined

**Table 4b:** Comparison of chemical compositions of dried maggot meal and other conventional sources of dietary protein

| | Protein | Fat | Dry matter | Ash |
|---|---|---|---|---|
| Dried maggot flour * | 52.23 * | 24.43 * | 92.51 * | 7.33 * |
| Fat fish meal | 59.3 | 9.2 | 92 | 20 |
| Fat meat meal | 50.5 | 10 | 93 | 30.3 |
| Soybean meal | 45.8 | 2 | 88 | 6.3 |
| Peanut cake | 49.2 | 1.4 | 91 | - |
| Cotton cake | 41 | 1.4 | 91 | 6.46 |

***Source*:** Inra [42]* Meneguz *et al.* [27]

## 5- Utilities of fly larvae in the diet of monogastric and piscicultural animals

Larvae of maggots are very low in protein (40%), and are generally foods that can replace some or all of the fishmeal in feed. The larva of the black soldier fly is also very rich in fats (30%) which are of good quality because balanced in omega 3 **[27]**. They also recorded good palatability and significant weight gain when introducing maggot meal into the diet of growing rats. Table 5.a and 5.b show the values of some evaluation parameters in the nutritional value of the dried maggots meal.

**Table 5.a:** Evolution of the average weight of the young rats in growth and the dry matter ingested

| Lots of animals | Initial weight (g) | Final weight (g) | Daily weight gain ($g.d^{-1}$) | Dry matter Ingested ($g.d^{-1}$) |
|---|---|---|---|---|
| Proteiprive (diet without protein) | 56.47±8.83$^a$ | 40.23±6.67$^b$ | -1.10±0.21$^e$ | 3.06± 0.45 |
| Dried maggot flour | 62.07± 10.96 $^a$ | 113.82 ± 10.70 $^c$ | 3.45 ± 0.44 $^d$ | 8.08± 0.61 |

***Source*:** Meneguz *et al*. [27]

**Table 5.b:** Values of some parameters for assessing the nutritional value of dried maggot meal**.**

| Settings | Protein efficiency coefficient | Coefficient of food efficiency | Actual digestibility | Biological value |
|---|---|---|---|---|
| Dried maggot flour | 2.65 | 0.41 | 0.92 | 84.72 |

Teotia *et al*. [43] in their experimental approaches, report that there is no significant difference in carcasses, weight gain, food intake and food conversion between chicks fed with dried flies and those fed from a standard food. Based on these parameters, Teotia *et al*. [43] concluded that maggot meal is a good source of protein that can replace any protein source, animal or vegetable in the chicken diet, and that pupa flour flies is a good source of vitamins B. Wigglesworth [18] reports that in India, to attract fish to a given area, fishermen threw in maggots produced from putrefying or fermented fish. Dashefsky *et al*. [44] showed that the house fly is not only high in protein (53.4%) but has high phosphorus bioavailability (92 to 100%) for chickens when used as a supplementation feed. Myers [45] recommended the house fly nymph for human consumption because it is richer in protein (64%) than chicken (23%), beef (21%), sheep (20%) and pork (17%) which are human foods. Atteh [46] shows that fowl fed on maggots have growth comparable to that of a commercial reference diet. In Benin, maggots produced from pig manure are used to feed pigs and fish [14]. Table 5-c present some nutritional parameters compared flour of dried maggots and other sources of dietary protein.

**Table 6:** Some comparative nutritional parameters.

| Food | Protein efficiency coefficient | Actual digestibility | Net protein used | Biological value |
|---|---|---|---|---|
| Dried maggot flour | 2.65 * | 0.92 * | 0.78 * | 84.72 * |
| Herring fish * | 3.02 * | 0.89 * | 0.78 * | 87.40 * |
| Fish | 3.55 | 0.95 | - | 76 |
| Beef | 2.30 | 0.95 | 0.67 | 74 |
| Soy | 2.32 | 0.86 | 0.61 | 73 |

**Source**: Inra [42]* Meneguz *et al.* [27]

**Table 7:** Breeding monogastric animals and fish fed with maggot meal

| Authors | Feeding species | Country |
|---|---|---|
| [2] | Local chickens | Benin |
| [5] | Poissons | Benin |
| [47] | Duck | Benin |
| [48] | Pork | Russia |
| [49] | Local chickens | Ghana |

| | | |
|---|---|---|
| [29] | Chicken | Nigeria |
| [7] | Local chickens | Togo |
| [50, 51] | Flesh chicken | Nigeria |
| [52] | Laying hens | Nigeria |
| [2] | Poult | Benin |
| [53] | Catfish | Nigeria |
| [54] | Rats | Ivory Coast |

**Conclusion**

Maggots are one of the sources of animal protein of high nutritional value that can be well incorporated into the diet of fish and monogastrics. The development of maggot production techniques is one of the solutions to the many problems that limit many breeders to the use of maggots. Organic substrates give peasants free choice which allows them to have easy access to them. Maggots are often used in various forms. We therefore hope that studies will diversify further for the development of maggots in fish feeding at all ontogenetic stages.

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