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Use of non-conventional protein resources in the diet to improve zootechnical performances in poultry

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Abstract

Traditional avian production in developing countries is experiencing low productivity, of which one of the major causes is the absence or insufficiency of protein in their diet. The conventional sources of such proteins are vegetable seeds and their cakes (peanut, soy, etc.), fish or meat meal, etc. This bibliographical synthesis focuses on the reproductive performance of traditional hens, followed in real life or in station then alternative food resources that represent insects, other edible invertebrates and other unconventional plant food resources and finally the improvements induced by these resources on the performance of poultry. Among the most targeted invertebrates today for this new protein approach are fly larvae or maggots. The maggots of house flies (*Musca domestica*) and black soldier flies (*Hermetia illucens*) are favored because of the ease of their production and the size of their biomass. These resources constitute a sustainable solution in animal feed but are classified in little-known and unknown sources of animal or vegetable proteins. Most of these protein resources are still inexpensive, can't compete with human food and their production or use has a negligible negative impact on the environment.

Keywords: Zootechnical performance; Traditional poultry farming; Poultry feeding; Alternative proteins

1. Introduction

The increase of the world population to nine (9) billion from now until 2050 [1] is of great concern for food security. The breeding of short-cycle species such as poultry, proposed as a solution to fill the deficit in animal protein is increasingly faced with a problem of adequate coverage of their dietary needs, dependent on specific food ingredients that provide protein but are generally very expensive and unsustainable [2]. These potential sources of protein frequently represented by fishmeal, meat meal, pulses and oilseed cakes used in animal feed are also facing food competition with humans (soybeans) and soaring prices on markets (fishmeal) [2]. In Africa, feed is a major constraint for poultry farming. The marginal supplementation provided by rural farmers to stray poultry does not optimize the productivity and profitability of poultry farms [3, 4, 5]. The use of local legume seeds and other non-conventional feed resources, where availability or cost are not limiting factors, could be a solution [3]. Better yet, due to the demand for animal proteins, the consumption of raw materials in animal feed and the evolution of their prices, which are constantly increasing, insect protein meal is proposed as the best alternative to the proteins currently used [6, 7, 8, 9, 10, 11, 12, 13]. All countries around the world are subject to the daily production of organic waste that constitutes excellent support for the production of insects used for animal feed [14, 2]. These insects are able to produce antimicrobial peptides [15] to protect themselves from infection and also reduce harmful bacteria in the manure [16]. Compared to conventional livestock, insects have higher feed conversion efficiency [17, 18]]. Insect production results in low

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greenhouse gas release, energy, and resource consumption (it takes 10 kg of grain for 1 kg of meat versus 7 kg of insects) [6]. Insects can be an attractive alternative protein source, especially for poultry, as they are part of the "natural" diet of chickens [7, 12, 19]. Indeed, the use of invertebrates (insects primarily) in both human and animal feed for economic and sustainability reasons [1]. Invertebrates such as maggots and termites, earthworms, and snails can be used as substitutes for conventional sources of animal protein in the development of a balanced diet for animals, especially farmed monogastric [20, 21]. The search for improved animal performance in terms of quality and cost has led many authors to test non-conventional feed resources in animal feeding. This article summarizes the results of various studies on the uses of maggots and other non-conventional feed resources in the diet of farmed monogastric animals. The synthesis review on insects specifically used in animal feed in West Africa was published by Kenis et al. [22]. More importantly, insects and other edible invertebrates used in monogastric livestock feed were published by Pomalegni et al. [2], while Daouda et al. [3] published non-conventional plant resources that can be used in monogastric feed.

2. Zootechnical performance of traditional chickens in Africa

2.1. Reproductive parameters

Due to their low genetic potential and difficult rearing conditions, local African hens have a lower productivity than that of exotic breeds. A single foraging hen lays only 30 to 50 eggs per year, or up to 90 under improved feeding and rearing conditions. However, they show great genetic variability and are characterized by hardiness and disease resistance, good brooding ability, and protection of their offspring from predators and weather [23, 24, 25]. The reproductive performances of traditional hens in Africa are variable depending on the rearing conditions, the seasons and/or the rearing regions, and the strains. Some of the reproductive parameters found by different authors in the field or on the station are summarized in Table 1.

2.2. Age of entry into egg-laying

The age of onset of egg laying in the local African hen in Mali is 6 months (24 weeks) and seems to be influenced by dietary factors [26]. Comparable results have been obtained in Côte d'Ivoire and Senegal according to different surveys [27, 28], which situated the age at the beginning of laying around 22-25 weeks. This age was higher in some East African countries such as Ethiopia (26-32 weeks) [29], Sudan (32 weeks) [30], South Kivu (7.6 ± 0.6 months) [31] and Tanzania (24-32) [32]. Compared to exotic hens that start egg laying around 19-23 weeks of age, local hens are late. The difference in age at first laying observed in hens from one country to another can be explained by climatic and husbandry conditions [24]. According to [33], one of the main causes of the low sexual precocity reported by several authors could be undernourishment which, by slowing down the growth rate of chicks, delays the moment when the bird reaches a sufficient weight to start laying. Thus, most reductions in the age at which chicks start laying have been obtained on the station by improving the breeding system. In Ivorian chicken raised in semi-divagation, the first cock crowing at 8 weeks and the first laying at 19 weeks of age [34]. In addition, the East Cameroonian chicken ecotype the first laying was obtained at 22.25 weeks old [35]. In Senegal, Nahimana et al. [36] used to improve family poultry farming, two treatments such as A- mother hens partially reared in confinement and B- mother hens reared in rambling in order to reduce the reproductive cycle of hens. The results of this study showed a reduction in the reproductive cycle from 113.5 to 62.2 days.

2.3. Egg production and hatching rate

Various authors reported that local hens produced 40 to 80 eggs/year/subject in sub-Saharan Africa. The average number of eggs per clutch was 8-13 eggs and the number of clutches varied from 2-3 per year [37]. In South Africa, the egg production of the local hen is 91 eggs/brood compared to 127 in Tunisia [38]. This disparity is linked to undernourishment and poor rearing conditions [24]. For example, Bulgen et al. [28] were able to increase the number of eggs laid per hen per year in Senegal from 40-50 to 90-100 by improving the feed. In Tanzania, improved feeding of hens combined with daily egg collection resulted in up to 150 eggs/hen/year [39]. Other study in Beniness local chicken reported a fertility rate over 90%, with a hatching rate of 76 to 86% using nesting boxes and feed supplements [40]. This rate is higher than that reported by the same author (74.0%) with local hens in Nigeria. Hatching rates reported in two areas (urban and rural) ranged from 80-90% [41]. This was explained by either clean egg quality or incubation conditions. In southern Tchad, hens layed 3 to 4 times per year with an average of 13.7 eggs and the hatchability varied between 38 and 90% [42]. In South Kivu, 14 eggs per cycle lasting 18 days and a hatchability of 88.8% were found while weaning occurs at 3.6 ± 1.9 months [31]. In a partial confinement system of mother hens, an increase in reproductive cycles from 3.4 to 5.6 per year and annual egg production from 35.3 to 57.6 were found while weaning occurs at 3.6 ± 1.9 months [36]. The quick return to laying did not affect the number of eggs laid per clutch compared to the parent hens reared in rambling (10.3 vs. 10.2) and the hatch rate (82.4% vs. 79.5%). In general, the hatching rate, which is nothing more than the number of eggs hatched per clutch, varied among countries and ranged in 42-90%, with an average of around 80% while weaning occurs at 3.6 ± 1.9 months [28, 35]. These variations are mainly due to the seasons. The warmest seasons were the most unfavorable, probably because of the less good conservation of eggs at high ambient temperatures [26].

2.4. Chick mortality rate

Mortality of chicks before one month old is in order of 30-50% [33] and can reach 66% [28]. Chicks remain with their mothers for the first two weeks with a relatively low mortality rate of 14%. As soon as they leave their mothers, mortality increases to 40% at 3 to 4 weeks old and to 66% at three months old. Several authors mentioned an infectious etiology, particularly Newcastle disease, to explain this low viability of chicks without agreeing on the importance to be given to each disease [33]. Among the noninfectious causes of chick mortality, Bulgen et al. [28] reported inadequate rearing equipment and consequent dehydration. Several authors have been able to reduce chick mortality considerably by improving the rearing conditions (feed and habitat) of local chickens. Indeed, Gbégo [40] obtained 66% as mortality rate of chicks with the farming practice and 26-31% with the improved practice. On-station, 17% of mortality rate was found with Fulani ecotype chicks of 0 to 8 weeks old in the semi-intensive system against 41.67% in rambling [43]. In semi-clawing up to one (1) month old, Nahimana et al. [36] improved the chick's viability by 41.2% compared to leading chicks in rambling.

2.5. Interval between spawning

Laying is cyclical and the interval between layings includes the durations for laying, brooding, and management of the chicks. In Mali, the interval between layings is 66 days [26] while in Senegal and in some African countries, this interval was on average 3.25 months and varied from 2.1 to 5.7 months [33, 44]. The duration of egg laying (15-18 days) and natural brooding (21 days) being at the end of each laying cycle, these authors estimated the duration of chicks rearing at 2.5 months, which seems to be the main cause of the extension of the interval between layings. Indeed, the hen accepts a rooster with great difficulty during the rearing of her chicks. The longer she spends raising them, the later she can enter a new fertile laying cycle [33]. To reduce this interval, some researchers have recommended eliminating of brooding phase or shortening the chick-rearing period by setting up collective mini hatcheries and rearing chicks in confinement before their ideal weaning phase [45, 46]. According to these authors, this practice allows the hen to resume her reproductive cycle more quickly, and also allows the breeder to follow the chicks and reduce mortality related to accidents and predators.

2.6. Egg Characteristics

2.6.1. Egg weight

The different rearing systems have considerable effects on egg quality, including their physico-chemical properties. No significant between the egg weight from the rural area (44.89 g) and that of crossbreeding hens from the urban area (45.94 g) was reported by [41]. However, the egg weights of their sample in both zones were higher than the 30.7 and 37.5 g obtained by Missohou et al. [44], but close to the 44 g found by Muwalusanya et al. [32]. These authors explained these weight discrepancies through genetic differences and slightly improved rearing conditions in urban areas [46]. The residual peckable feed resource was influenced by local climate and seasons, which in turn affects the weight of birds and their eggs [47]. Other parameters for measuring egg quality are haugh unit, yolk, and carotenoids.

2.6.2. Hatching weight of chicks

In Benin, the average birth weight of Holli, Fulani, Sahouè, North, and South male chicks were respectively 29.72 g; 28.31 g; 27.81g; 26.08 g, and 24.21 g. Globally, the live weight of chicks at birth, without distinction of sex, varied from 23 to 31 g with an average weight of 28 g/chick [48, 49]. However, lower live weights (21-23 g/chick) were reported in Burkina Faso and Guinea [50, 51].

Table 1 Reproductive performance of the local African hen

Authors/Countries	Parameters						
	Age at 1st clutch (sem.)	Number of eggs/hen/ brood	Number broods / year	Number of eggs/ hen / year	Weight of eggs (g)	Rates hatching of eggs (%)	Rate of mortality chicks 0-3 months (%)
[52]/ Ethiopia	20 - 32	9.0 - 19.0	2.0 - 3.0	18 - 57	-	83 - 88	58 - 87
[53]/Ethiopia	21.64 ± 5.74	15.39 ± 5.05	4.6 ± 0.2	70.84 ± 3.10	38.1	84	-
[54]/Benin	27 - 28	7.97 - 11.43	3.31	37 - 40	-	87 - 89	27 - 29
[55]/Cameroon	-	12.74 - 14	3.9 - 4	49.3 - 54	43 - 44	80 - 90	44.12
[34] Ivory Coast	19	-	-	-	33 - 42	-	-
[56]/Ivory Coast	-	14 - 16	-	82 - 93	-	82 - 91	-
[36]/Senegal	-	10.3 ± 1.6	5.6 ± 0.8	57.6 ± 11.4	-	82 ± 7.1	29.1 ± 10.0
[57]/Benin	23	20.18	9.96	201	39.41	-	-

3. Potential used insects

Out of nearly 2,000 edible insect species, less than 10 are under study by industries. In particular, the following two species seem to be a great interest today for livestock feed:

3.1. The black soldier fly Hermetia Illuscens

The larvae of the black soldier fly are very rich in protein and calcium. Currently, *Hermetia Illuscens* larvae are used live or dried to feed reptiles, insectivorous birds, pond fish, monkeys, and other insectivorous or omnivorous animals. The fly lays and produces the larvae on a 100% vegetable substrate. *Hermetia Illuscens* larvae meals have been tested in zootechnical experimentation and were studied in the DESIRABLE project in France. In some countries such as the United States, *Hermetia Illuscens* rearing has already been practiced for a long time. This larva is widely used for domestic composting and is even patented as a production method [6].

3.2. The Tenebrio Molitor meal

The protein quality of this worm is similar to that of soy meal but the methionine content is low for poultry [58]. Females lay eggs on a wide variety of decaying plant and animal substrates. The larvae develop by consuming these wastes which makes it a host of composts and explains its use for bioconversion. The advanced larval stages are a source of macronutrients for humans and animals [59]. Nutrition is only one of the many aspects of insect valorization, as insect production yields several derivatives (Figure 1), which leads to industries interested in this speculation [60]. The chitin, oils, and proteins that make up the bulk of the insect body can be valorized.

3.3. Lipids

Insect larvae contain up to 40% of lipids rich in polyunsaturated fatty acids, similar to the oils produced by sunflowers. Biofuel could therefore be produced by insects proliferating, for example, on mixed municipal waste that is difficult to methanize. The oils can be used for animal feed, heating, or as diesel fuel.

3.4. Biogas

Some insects have the ability to produce methane when they break down cellulose. Long-term prospects are to use this ability to create energy from the degradation of plant waste. Termites are good candidates.

3.5. Chitin derivatives

A molecule of the carbohydrate family, chitin, the main component of insect shells, has a composition similar to cellulose. One of its compounds, chitosan, is already used in parapharmacy as an anti-cholesterol emollient. Made from the shells of crustaceans, chitin could just as easily come from insects. Applications are planned in bioplastics and cosmetics.

3.6. Environmental services

The pollination of plants by bees is becoming a real problem, due to diseases and pesticide damage to the hives, so it is proposed to raise wild pollinators that would be released on demand on crops while not generating waste. The insects produce excrement rich in nitrate, phosphate, and potash which constitute an excellent organic fertilizer.

3.7. Other molecules

The services provided by certain insects are well known. The cochineal has been producing carmine red for centuries and Bombyx mori generates silk, but other insects could provide invaluable services if we took the time to study their virtues [60]. Figure 1 shows the perspective diagram of the insect industry.

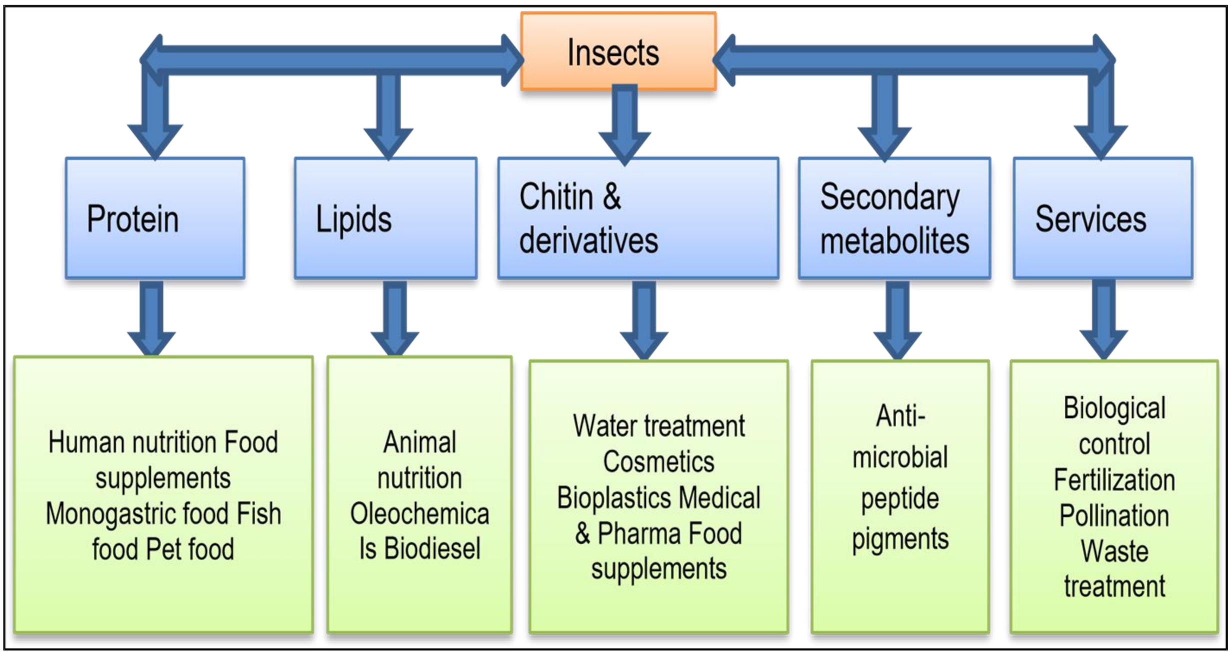

Figure 1 Perspective diagram of an insect industry

4. Insects used in diets of farmed monogastric animals

The most commonly used insect orders in the diet of farmed monogastric animals were Diptera, Blattoptera, Orthoptera, and Hymenoptera [61]. Fly species such as housefly *M. domestica* (Muscidae) and black soldier fly *H. illucens* (Stratiomyidae) were used in the diet of farmed monogastric animals [22]. The housefly is favored in many parts of the world due to its permanent presence, and prolific maggots on various substrates [22, 62, 63]. Cockroaches (*Blatta orientalis*) and termites have been used as potential meat meal substitutes in broiler feeds in South Kivu, Democratic Republic of Congo [64]. Similarly, termites were valued in the diet of both broilers and local chickens and guinea fowl [63, 65]. Techniques were developed and reported for controlled production of termites for feeding chicks and guinea fowl in traditional systems in Benin, Burkina Faso and Togo [65, 66]. Grasshoppers (Acrididae and Pyrgomorphidae), locusts (Gryllidae) locusts, migratory, house, and field locusts were the orthopterans widely consumed by birds and other monogastric animals. Chickens have been reared in open range to control grasshopper populations [67]. In the Philippines, free-range chickens fed on grasshoppers had a preferred taste and a higher market price than those fed on conventional commercial feed [67]. Hymenoptera such as bees (*Apis mellifera*) were processed into meals after drying to feed farmed monogastric animals. For example, Salmon and Szabo [68] produced dried bee meal from bees killed after the honey production season for incorporation into diets to grow turkeys. Due to a high protein content (68%), the amino acid composition was lower than fish meal but comparable to soybean. Replacing soybean meal with 15%

and 30% dried bee meal linearly decreased turkey performance. The authors attributed the underperformance of the turkeys to the toxicity of dried bee venom.

5. Other invertebrates and animal products used in monogastric animal diets

Broiler chickens can be fed with 3.6% earthworm meal (*Eudrilus eugenia*) instead of 5% meat meal without affecting their zootechnical performance [69]. The introduction of snail meal or meat has also been studied by different authors. The *Pila leopoldvillensis* contents in crude protein, calcium, and phosphorus were respectively 53%, 6.0%, and 0.5% [70]. These snail meals or meats give similar results to those obtained with fish meal. June et al. [71] studied the performance of broilers fed with snail meal (*Pomacea caniculata*) as a substitute for fish meal, meat, and bone meal and obtained excellent results. Feed intake and live weight gain were not different between protein sources, which means that snail meal is suitable to replace fish meal and meat and bone meal at incorporation rates ranging from 4 to 12%. However, the high calcium content of these flours may affect their nutritional value, especially in broilers. Other authors used *Achatina fulica* snail meal in the diet of 16-week-old Isabrown laying hens at rates of 0, 1, 2, 3, 4, 5, and 6 percent [72]. They found that laying rates, egg weights, and feed conversion ratios were significantly ($p<0.05$) influenced by the rates of snail meal incorporation in the different diets. Earthworms were raised as a protein source for chicken feed [73]. The authors produced one (1) kg of fresh worms daily on an area of 25 m^2. This quantity of biomass would be sufficient to supplement a minimum of 50 chickens with high-quality protein.

6. Maggots as a source of animal protein for improving the zootechnical performance in poultry

A total substitution trial of soybean meal (SBM ration) with *Hermetia illucens* larvae meal (HILM ration) was carried out on 24 - 45 week old laying hens in southern Italy to assess productive performance and blood profiles in birds [74]. At the end of the experimentation, the SBM group had a higher average live weight ($P < 0.05$) than the HILM group. The use of HILM resulted in a more favorable feed conversion ratio ($P < 0.01$) in the hens, but the percentage of egg laying, feed consumption, average weight, and egg mass were higher ($P < 0.01$) in the hens fed the SBM diet. Hens fed the insect meal produced a higher percentage of eggs from the small (S), medium (M), and extra-large (XL) classes ($P < 0.01$) than hens fed the SBM diet, which gave a higher percentage of eggs from the (L) class ($P < 0.01$). Regarding blood parameters, globulin and albumin-globulin ratio levels were, respectively, higher ($P < 0.05$) in HILM and lower in the SBM group. Cholesterol and triglycerides were higher ($p < 0.05$) in SBM hens than in the HILM group ($p < 0.01$). Blood Ca concentrations were higher ($p < 0.01$) in hens fed with the insect meal, while creatinine was higher ($P < 0.01$) in the blood from hens fed with SBM. Thus, they concluded that *Hermetia illucens* larvae meal may be a suitable alternative protein source for laying hens, although complete replacement of soybean meal required further research to avoid negative effects on feed intake.

Through experimentation for which Hermetia meal completely replaced soybean meal in the diet of 64-week-old Lohmann Brown laying hens, the results showed that the hens' feed intake was 7.8% lower than that of the controls, while the egg weight of the trial group was 5.4% higher [75].

An average consumption of 24.91 ± 0.61 g of dry matter (DM) of boiled maggots per day per chicken over the different physical forms of maggots (fresh, dried, and boiled) was obtained with Holly ecotype chickens in Benin [76]. All three physical forms had an effect on the chicken's weight. Chickens supplemented with boiled maggots in the basal diet had the best weight gain. Even better, the chickens started laying earlier [76].

Some zootechnical parameters (live body weight, age at first laying, egg weight, number of eggs hatched, and live body weight of chicks hatched) from two weeks old birds fed with supplementary diet of fresh maggots (30 - 50 g) until laying and their first clutch of eggs, were compared to these of birds fed with conventional diet only [77]. The results showed significant differences ($p< 0.05$) in mean clutch size (11.5 ± 2.57 # 9.8 ± 2.21), mean egg weight (43.5 ± 25.53 # 34.2 ± 0.78), mean number of eggs hatched (9.5 ± 1.14 # 7.1 ± 0.70) and mean chick body live weights (33.6 ± 2.72 g # 29.8 ± 1.89 g) between the supplemented and control birds.

In broilers, a study revealed that at start-up and finishing, there was a significant increase in weight gain of birds fed with maggot meal [78]. The average weight gain of birds in the control lot was 1062.2 ± 59.9 g compared to 1209.4 ± 73.3 g for birds fed with maggot meal. Similar results were reported [79, 80]. Substitution of fish meal with fresh or dried maggots provided a positive effect on the production performance of the birds and their health status [63, 81]. A substitution of groundnut meal for maggot meal showed no significant difference in weight gain of broilers [82].

7. Other non-conventional protein resources for improving zootechnical performance in poultry

7.1. Non-conventional protein resources

In a recent study on the use of *Tenebrio molitor* larvae meal to feed broilers of 30-62 days old, a lower albumin to globulin ratio in the group receiving insect meal, although no difference was found in globulin content [19]. The authors attributed the result to the properties of the chitin in the insect meal.

Dried worm meal incorporated up to 10% dry matter (DM) in a sorghum and soybean meal starter diet provided positive effects on feed intake, weight gain, and feed efficiency [58]. The use of 25% dried worm meal as an alternative to fish meal was found to be appropriate [83].

Fish meal was replaced with cricket meal at different concentrations (25%, 50%, 75%, and 100%) in the diet of layers hens and found that cricket meal improved egg yolk color [84]. More interestingly, egg laying rate, weight gain, and albumin level in egg white showed no significant difference compared to those of layers hens fed with conventional feed.

In Nigeria, by replacing 50% fish meal with cricket meal (1.7% in the diet), the broilers of 1 to 28 days old had increased body weight gain and feed intake [85]. In China, the using of 20% and 40% grasshopper (*Acrida cinerea*) meal to substitute fish meal in broiler diets provided a similar growth rate and feed consumption as the control diet [86].

In India, Japanese quails (*Cotornix japonica*), were fed a variety of diets in which grasshopper meal (*Oxya hyla*) gradually replaced fish meal. For a range of growth parameters, the best results were obtained with the diet in which 50% of fish meal was replaced by grasshopper meal. Fecundity (i.e., the number of eggs laid per female) was significantly higher compared to the control treatment [87].

7.2. Non-conventional plant resources

In tropical areas, several legumes have been identified as potential sources of energy and nutrients for human and animal feed, but the presence of toxic factors in the seeds was a handicap to their valorization [3]. Apart from mucuna seeds which have been extensively tested in poultry, other seeds have been tested. In general, although egg-laying and growth performance were not yet very conclusive for intensive speculations, these seeds can be very useful to small-scale, low-income village poultry farmers [3].

Dried *Moringa oleifera* leaf meal as a substitute for wheat bran in cockerel feed at 10% incorporation rate gave superior growth performance than that induced by wheat bran incorporated at the same rate [88]. *Moringa oleifera* leaf meal can be used as a supplement in broiler feed up to 2.5% without negatively affecting production performance [89]. A previous experimentation showed that 25‰ of *Moringa oleifera* meal incorporation in the diet of laying hens, better results in laying rate, feed conversion ratio, average egg weight as well as external and internal qualities of the eggs laid [90]. Incorporation of *Moringa oleifera* leaf meal into the feed rations of local chickens as a substitute for groundnut meal at 0, 8, 16 and 24%, provided an improvement in live weight of the chickens from 17^{th} weeks [91]. *Moringa oleifera*, leaves of *Leuceana leucocephala* and *Cassia tora* rations have been used for improving the diet to have good performance in traditional chickens [4].

Aquatic plants have been experimented in the search for animal protein sources for both human and animal feed. Thus, according to some authors, dried Azolla can be incorporated in broiler feed up to a rate of 5% without affecting their growth [92]. Another study to evaluate the feed value of Azolla on the laying performance of hens showed the possibility of incorporating it at rates up to 15% without affecting egg production, conversion index, or egg size and color [92].

Incorporation of dried cassava leaves into the diet of 21-week-old, Isabrown laying hens showed a decrease in hen laying rate and an improvement in egg weight [93]. The study revealed that external egg quality (shape index, thickness, and shell weight) was not affected and yolk coloration and Haugh unit were better at 5% incorporation of dried cassava leaves.

8. Conclusion

The feeding with environment requirements today, made humanity discover the capacity of insects and other food resources to provide monogastric livestock with animal protein of high nutritional value. The multiplication of technics for the use of such resources, which do not compete with human food, constitutes a means of reducing the pressure on the use of traditional protein resources in animal feeding. Insects have nutritional qualities comparable to fish meal, soybean, and other common nitrogenous materials. Among the insects that can be used as protein resources in the formulation of feed rations with appreciable nitrogen value in terms of quality to feed monogastric livestock, are the housefly (*Musca domestica*) and the black soldier fly (*Hemettia illucens*). The promotion of production and use practices of these insects and other non-conventional feed resources to improve the productivity of monogastric animals in particular poultry, is a spearhead to boost traditional poultry production. Better still, the adoption of fly larvae, other insects, and other non-conventional food resources in animal feed will help reduce the organic waste produced daily by man, as many insects thrive on a variety of substrates ranging from household organic waste to residues from food production, which promotes the recycling of these residues and thus the protection of the environment.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflict of interest.

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