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Use of fly larvae *Hermetia illucens* in poultry feeding: A review paper

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Abstract

The paper presents the review of scientific publications of world literature on the use of the larvae of black soldier fly (*Hermetia illucens*) when feeding poultry. Nowadays, the issue of replacing traditional sources of protein when feeding poultry is very urgent, especially in connection with the global food crisis. Insects are the natural food of most birds; thus, the use of fly larvae for feed production has a biological basis. The research results presented in published works show that there are no negative effects on bird health and meat quality when feeding poultry, quail and other birds. In some cases, the experimental groups of birds gained weight slightly more slowly than the control group. Other reports indicate that birds grew at the same rate as normal birds. The quantity and quality of eggs did not differ significantly, but dietary changes affected the colour of yolks and eggshell. The effect of the addition of live larvae to the diet of young turkeys on the weight characteristics of was studied. Replacing 10% of the daily amount of feed with live *Hermetia illucens* larvae in the diet of turkeys showed that the daily feed intake and body weight gain of the experimental birds were significantly higher compared to the control groups, which led to a significantly higher body weight of chicks at the age of five weeks (2.19 kg vs. 2.015 kg, respectively) and a significantly lower feed conversion rate. Most researchers agree that replacing protein in poultry feed with insect flour should be partial, in the 15–30% range. Feeding with larvae that have undergone processing – grinding, chitin removing, heat treatment – is more preferable than using whole larvae, since the chitinous membrane makes larvae difficult to be digested in the digestive tract of birds.

Key words: *feed, Hermetia illucens, insect feed, poultry, protein flour*

INTRODUCTION

Insects, such as black soldier flies (BSF) and their larvae, have been proposed as alternative sources of maize and soybean meals for protein and, thus, as possible chicken feed ingredients. In addition, the authorisation of insects as animal protein for the European poultry industry is scheduled to be released in 2020–2022. There are many businesses around the world developing BSF larvae as feed. Since BSF larvae do not consume pesticides or mycotoxins, the cereal by-products of BSF larvae are now commercially cultivated. Nonetheless, larvae may also be raised on animal manure and household organic waste, aside from agricultural by-products. While growth output and meat quality have been previously investigated for poultry fed on BSF larvae raised on horse manure [LIU *et al.* 2019; MOULA *et al.* 2018; SCHREVEN *et al.* 2020; TOMBERLIN, VAN HUIS 2020; VILLAZANA, ALYOKHIN 2019].

The issue of the production of balanced and inexpensive components of compound feed is becoming more acute annually, as the number of their main consumers (pigs and poultry) continues to grow. Insects are common food for many animals [GAŁCZYŃSKA *et al.* 2019; SOLOVIY *et al.* 2020]. Their protein can replace 25% to 100% of existing

feed, depending on the animal species. This protein is easily digestible and is equal in its nutritional properties to analogs [JÓZEFIAK *et al.* 2016; VAN HUIS 2016]. The global community is actively discussing the prospects for the use of protein of edible insects as an alternative to soy flour [RAHEEM *et al.* 2019].

The food reserve is the defining expense item in raising farm animals. It is represented by components of plant and animal origin, as well as feeds obtained through microbiological synthesis. The use of high-protein components is necessary for the full development of animals and ensuring their high productivity while minimizing feed costs [NEKRASOV *et al.* 2018; WOYENGO *et al.* 2014].The world is actively discussing the possibility of using insects as feed and feeds additives [DIENER *et al.* 2009; NEKRASOV *et al.* 2019].

In literature, there is a lot of information on the use of larvae and pupae of black soldier fly for feeding and raising poultry, mainly chickens and hens. Chicken feeding with BSF larvae is especially appropriate for conventional poultry production systems, but only a few studies have recorded the effects of BSF larvae on the growth rates of chicken and on the fatty acid profiles of BSF larvae and chicken meat [ALTMANN *et al.* 2018; BARRAGAN-FONSECA *et al.* 2019; BOVERA *et al.* 2018; BREDE *et al.* 2018; CULLERE *et al.* 2019a; CUTRIGNELLI *et al.* 2018; DABBOU *et al.* 2018; DE MARCO *et al.* 2015; LEIBER *et al.* 2017; MARONO *et al.* 2017; MONIELLO *et al.* 2019; NERY *et al.* 2018; NEUMANN *et al.* 2017; 2018; SCHIAVONE *et al.* 2017a, b; SCHIAVONE *et al.* 2018; SECCI *et al.* 2018a; VELTEN *et al.* 2018a, b]. All authors agree that the larvae of black soldier fly are a valuable and economically beneficial addition to poultry diet, but they differ in the optimal amounts of this component: up to 10% [KAWASAKI *et al.* 2019], up to 15% [DALLE ZOTTE *et al.* 2019; PIETERSE *et al.* 2019; VAN SCHOOR 2017] up to 33% of the amount of proteins [MOHAMMED *et al.* 2017].

In the current study, it was tried to present the study of world literature scientific publications on the use of black soldier fly larvae *Hermetia illucens* when feeding poultry.

RESULTS AND DISCUSSION

THE PHYSIOLOGICAL FEATURES OF BLACK SOLDIER FLY *Hermetia illucens*

Black soldier fly (*Hermetia illucens* L.) is a species of dipterans from the family of soldier flies (*Stratiomyidae*), a synanthropic insect belonging to polysaprophages, a natural inhabitant of the tropics, subtropics and the warm temperate zone of North and South America, subsequently spread to all continents, with the exception of Antarctica. It is supposed that it was brought to Europe about 500 years ago. In recent years, there are the cases of the discovery of natural colonies of insects in regions with a temperate climate, for example, in the Czech Republic [GLIGORESCU *et al.* 2019;MARSHALL *et al.* 2015; ROHÁČEK, HORA 2013], as well as in France, Switzerland, Albania, Croatia, Portugal, Germany, Slovenia, Montenegro, Greece, etc. [BENELLI *et al.* 2014; JEONG *et al.* 2018; MORIMOTO, KIRITANI 1995; ÜSTÜNER *et al.* 2003].

A wide range of feed substrates suitable for feeding the larvae of this species allows them to penetrate into new areas and regions. Earlier in literature, the easternmost region of habitation of this species – southeastern Turkey was indicated [ÜSTÜNER *et al.* 2003]. However, the representatives of *Hermetia illucens* were found in Russia, in the Krasnodar Territory, in the Utrish State Nature Reserve [GLADUN 2019]. The adults of *Hermetia illucens* are between 15 and 20 mm long and have an ill-defined, licking mouth apparatus designed only to lick off liquid droplets (for example, dew). Females are slightly larger than males. Their body is completely black, the legs and white.

The biology of *Hermetia illucens* has a number of distinctive features: adult flies are not attracted to human habitation; they do not feed and are not carriers of diseases. In appearance and behaviour, it is similar to a wasp. However, unlike a wasp, it has only one pair of wings, no sting, and a dark one-colour body colour [GOBBI *et al.* 2013]. The head of adult flies is short and wide, the eyes are wide apart, regardless of the sex of an insect. Antennae twice as long as head, they are presented by elongated flagella and have a long terminal segment [GLADUN 2019; ROZKOSNÝ 1983; SHEPPARD *et al.* 2002].

The developmental cycle of *Hermetia illucens* is typical for dipterans and includes the following phases: embryonic (egg), postembryonic: larvae, pupa, and imago (adult). The ages of the larvae are separated by moults. According to modern research, the larvae pass six instars, the 1st and 2nd instars of which are very similar in size and do not differ by some researchers. The larva of the last 6th instar (prepupa) does not feed and differs from the larvae of younger instars in a darker colour. Larvae of different ages differ in the width of the head capsule [KIM *et al.* 2010; OLIVEIRA *et al.* 2016].

Under natural conditions, individuals of *Hermetia illucens* lay their eggs in moist, dead organic material. These insects are often found in agricultural regions, as organic waste is a favourable environment for them. In urbanized areas, the fly lays its eggs in garbage cans or plant compost.

Approximately in two days after hatching, *H. illucens* flies couples, after another two days, eggs are laid as a single clutch. Usually, the number of eggs laid by females varies from 320 to 1000. Adults die when their fat reserves are depleted, that is, usually a few hours after laying the eggs.

The eggs are laid close to the nutrient material so that the larvae can immediately access it. Females prefer to lay eggs in small cavities where eggs can be hidden from predators and protected from direct sunlight. The larvae hatch after about four days.

The larvae are white or yellow with a yellow-brown head up to 27 mm long. They grow in a variety of decaying organic matter of plant and animal origin. A small yellowish-brown head with a mouth apparatus can be distinguished on the body of the larva. Light yellow ocular prominences are located on the lateral side of the head [DICLARO, KAUFMAN 2009; ROZKOSNÝ 1983]. The head capsule, unlike the body, is narrow and small and can be retracted into the thoracic section [ANTONOV *et al.* 2017]. The chest consists of three segments.

The dorsal segments are densely haired with several rows of fine hairs well developed in the anterior segments a, b, c, d. The abdominal region consists of 8 segments formed by roughly rectangular plates, which are covered with numerous small bristles. Segments 1 to 7 are characterized by the presence of spiracles on both sides. The 8th abdominal segment is the last, rounded.

The development to pupa occurs under favourable conditions within 14 days, at the end of the stage of "fattening" the larva reaches about 27 mm in length and 6 mm in width. *Hermetia* adult insects may not feed, consuming fat accumulated in the larval stage, but they need water to drink. The coupling can take place two days after the hatching of an adult insect.

Hermetia illucens pupae contain 35% fat, for comparison, house fly pupae contain only 9–15% fat, and adult insects need food for successful reproduction [BARROS *et al.* 2019; BARROS-CORDEIRO *et al.* 2014; SHEPPARD *et al.* 2002; SHOLIKIN *et al.* 2019; SRIKANTH *et al.* 2019; VAN HUIS 2019].

Flies *Hermetia illucens*, in general, harmless to humans and animals; however, in conditions of insufficient hygiene and the use of unprocessed food, they can serve as a source of myiasis. Similar cases were reported in Costa Rica [CALDERÓN-ARGUEDAS *et al.* 2005], Cuba [FUENTES GONZÁLEZ, RISCO OLIVA 2009], Malaysia [LEE *et al.* 1995] and other countries [YANG 2014].

Figure 1 shows the average composition of the larva at the final stage of development [JOLY, NIKIEMA 2019].

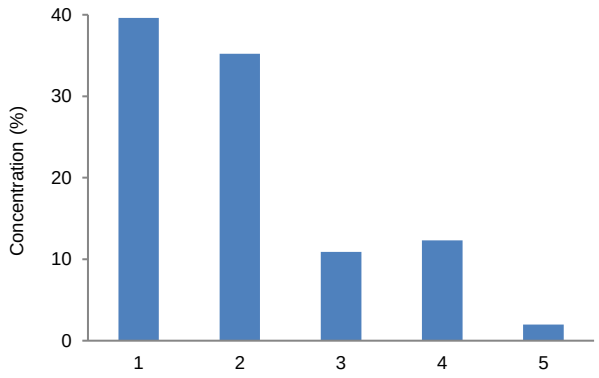

Fig. 1. The averaged chemical composition of the adult larva *Hermetia illucens*: *1* = crude protein, *2* = fats, *3* = shell, *4* = ash, *5* = other; source: own elaboration based on JOLY and NIKIEMA [2019]

Adults are calm and do not fly very well. Since there is a rather long time between the hatching of a fly and laying of eggs, and eggs are never laid directly in an organic substrate, an adult does not come into contact with potentially toxic and bacteriologically pathogenic media and is not a carrier of infections [DIENER *et al.* 2009].

When larvae reach their final stage of development, they begin to move in search of a suitable place for pupation. At this age, they have the maximum mass, protein and fat content. The larvae develop a "beak" at the head end of the body, with which they help themselves to move, due to which they can crawl along inclined surfaces. When breeding these insects in captivity, this feature of the larvae is very convenient, since it facilitates the process of their collection. In containers, an inclined board is installed at an angle of 30–40°, along which the larvae crawl themselves and enter the container for collecting the "harvest" [DIENER *et al.* 2009].

The larvae can feed on a wide variety of organic matter, including manure and feces. For example, the larvae of *Hermetia illucens* flies can reduce the volume of cow manure by 58% (phosphorus content decreased by 61–70%, nitrogen by 30–50%), pig manure by 56%, nitrogen content in chicken manure by 56%.

In addition to the direct reduction of waste volumes, during bioprocessing with the use of *Hermetia illucens* larvae, many substances valuable for industry and agriculture can be obtained [DIENER *et al.* 2009; MOON, LEE 2015; NAFISAH *et al.* 2019; VAN HUIS 2019].

RESEARCH ON FEEDING LAYING HENS WITH INSECT SUPPLEMENTED FEED

SECCI *et al.* [2018a] studied the effect of feeding chickens of the Lohmann Brown Classic breed with *Hermetia illucens* fly larvae for 21 weeks on egg quality indicators. Soy flour, which is part of the feed, was replaced by 100% larvae. At the end of this period, it was revealed that the chickens that fed on insect larvae produce eggs with a greater proportion of yolk than individuals in the group fed with a compound feed based on soybeans. It was found that in the yolk of eggs of chickens fed on larvae, it was a higher content of γ-tocopherol (4.0 versus 2.4 mg·kg^{-1}), lutein (8.6 versus 4.9 mg·kg^{-1}), β-carotene (0.33 versus 0.19 mg·kg^{-1}) and total carotenoids (15 versus 10.5 mg·kg^{-1}) in comparison with control samples. In terms of the content of fatty acids in the composition of egg yolks, the control and experimental samples are almost identical. It is important that feeding on insect larvae helps to reduce cholesterol in the yolks of eggs by 11% compared to control samples.

In Switzerland, a group of researchers conducted an experiment to replace soy protein in the diet of laying hens with protein from larvae. The larvae for food were collected a little earlier than the final stage of development, since the shells of young larvae are not very hardened, as a result of which they are better absorbed.

The larvae were collected, killed by freezing, dried at a temperature of 60°C for 24–34 hours, crushed and defatted by pressing on a press. An industrial press KK 20 F Universal was used to squeeze out the fat, screw press (Germany). In the final product, the fat content was 0.11 kg·kg^{-1}, and the protein content was 0.59 kg·kg^{-1}.

Three types of feed, identical in nutritional and energy value, were produced using industrial apparatus for the production of compound feed: standard feed containing 36 g·(100 g)$^{-1}$ of soybean meal (control); feed containing 12 g·(100 g)$^{-1}$ of larval product (CHL 12) and 15.6 g·(100 g)$^{-1}$ of soybean meal (H 12) and feed containing 24 g·(100 g)$^{-1}$ of product from larvae with complete replacement of soybean meal (CHL 24).

Figure 2 presents the data on changes in the parameters of eggs of chickens that received different types of feed.

According to the results of the experiment, it was concluded that replacing protein with a product from larvae

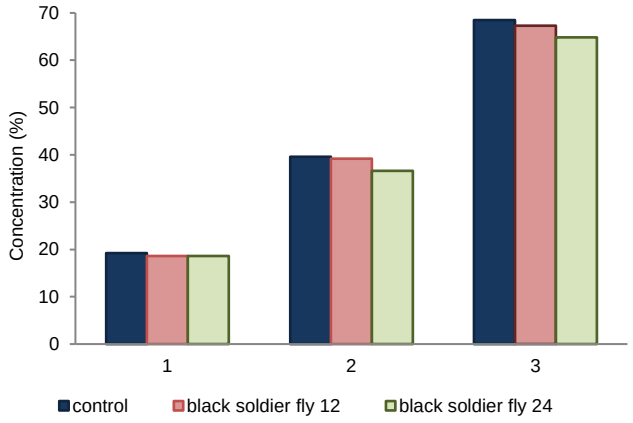

Fig. 2. Changing parameters of eggs from hens fed different types of feed: *1* = weight of yolk (g); *2* = weight of protein (g); *3* = total egg weight (g); source: own elaboration based on MAURER *et al.* [2016]

does not lead to any negative effects in laying hens and does not affect the quality and quantity of eggs laid [MAURER *et al.* 2016].

A comparison of poultry rations with the addition of larvae in an amount of 15% was made, using different types of processing: whole, after dry extraction of fat and extruded [JANSEN 2018]. Whole larvae and extruded diets showed better egg production than the control diet. The only difference in egg quality was the higher albumin content. The product with the melted fat had the highest protein content (48.18%), which is comparable to soybean meal. Chickens fed on this type of diet had the lowest egg production rates. The nutritional value of this larval product may have been influenced by heat treatment.

EFFECTS OF EXPERIMENTAL DIET ON WEIGHT GAIN AND POULTRY QUALITY

The researchers from Indonesia conducted an experiment to introduce *Hermetia illucens* larvae into the diet of chickens together with propolis. Chickens, which were raised on a diet containing 85% of the main feed +15% of CHL powder + 1 ml of 3% propolis extract, gained weight well, even better than in the control group and had the best blood value in terms of white blood cells content [KINASIH *et al*. 2018].

Replacing 50% of the soybean meal in broiler chickens' diets with *Hermetia illucens* fly larvae or dried *Spirulina algae* biomass results in a weight loss of 21-day-old broilers. The addition of the amino acids lysine and methionine to the diet contributes to the increase in the weight of both broilers and chickens [VELTEN *et al*. 2018a]. Histological studies did not show changes in the intestines of adult birds [VELTEN *et al.* 2018b]. It was concluded that flour from fly larvae and algae biomass promise food sources in the diet of chickens.

At the same time, it is noted that the complete replacement of soybean meal with dried biomass of the larvae of *Hermetia illucens*or algae *Spirulina platensis* in the diet of broiler chickens reduces the quality of protein in the feed. It is necessary to add amino acids to the nutritional formula, such as lysine, methionine, arginine, valine, tyrosine, etc. in order to achieve comparable indicators with the control diet [NEUMANN *et al.* 2017].

It was found that the addition of amino acids to the diet of broiler chickens with dried biomass of fly larvae contributes to higher protein content in the diet and, accordingly, to a higher weight characteristic of chickens [NEUMANN *et al.* 2018]. It was noted that the quality of chicken meat is improved when the biomass of *Spirulina platensis* algae replaces 50% of the soybean meal in the broiler diet. However, it was noted that this replacement resulted in a dark reddish, yellowish colour of meat. On the other hand, as a result of replacing soybean meal with an appropriate amount of *Hermetia illucens* larvae, a product that did not differ from the standard samples was obtained. The exception was that chicken breast fillets had a more intense flavour, which decreased with storage time [ALTMANN *et al.* 2018].

In addition, it was indicated that flour from dry biomass of *Hermetia illucens* fly larvae affects the optimal ratio of methionine and cysteine in the broiler chicken diet, which significantly affected the growth and livelihood of chickens. It was mentioned that excess methionine and cysteine deficiency in broiler chicks' diets could lead to poor feed intake and feed efficiency and reduced growth of young birds. The experimental results showed that 50:50 methionine:cysteine ratio provided excellent chicken growth and protein quality in the diet [BREDE *et al.* 2018].

For the first time, the use of the fat fraction obtained from the biomass of the larvae of *Hermetia illucens* flies instead of soybean oil in broiler chickens' diets was studied. The soybean oil used in the chicken diet was replaced with 50% or 100% of the fatty fraction from larval biomass. It was determined that feeding chickens with experimental diets contributed to the increase in the weight of broilers by 35 days [SCHIAVONE *et al.* 2017a]. It was determined that the quality of poultry meat, the nutrient composition was practically independent of diet. The inclusion of the fat fraction in the composition of feed instead of soybean oil promoted the increase in the proportion of saturated fatty acids and the decrease in the content of the fraction of polyunsaturated fatty acids in the meat.

In the study of SCHIAVONE *et al.* [2018], it was found that the inclusion of the fat fraction of *Hermetia illucens* larvae in the diet of broiler chickens did not have a significant effect on the severity of histopathological findings. It was concluded that replacing soybean oil by 50% or 100% with the fatty fraction of larvae does not have a harmful effect on growth parameters or blood parameters of chickens.

The studies of the influence of the inclusion of partially defatted biomass of the larvae of the fly *Hermetia illucens* on the growing broiler chickens, blood parameters and morphology of their intestines were carried out. The biomass of the dried larvae was introduced in the amount of 5, 10, and 15% into the feed of Ross 308 chickens instead of soybean meal. It was determined that the introduction of biomass from the larvae of flies with the replacement of the soy supplement by 10% leads to a slight increase in the weight parameters of broiler chickens at 10, 24 and 35 days of their life. The addition of lower or higher dosages of the studied food source instead of soybean meal, on the contrary, results in the reduction of the weight characteristics of birds. It was

noted that no significant differences were observed in the blood parameters of the birds of the control and experimental groups, except for the concentration of phosphorus. The inclusion of fly larvae in the diet of chickens at low dosages also does not lead to histological changes in the intestines of adult birds [DABBOU *et al*. 2018].

Moreover, the effect of the addition of dried biomass of fly larvae *Hermetia illucens* in the previously indicated concentrations on the characteristics of poultry carcasses and meat quality indicators, approximate composition, fatty acid content and heavy metal content was assessed. As the content of fly larvae increased in the diet of birds, the moisture content in the carcasses decreased linearly, while the protein content increased. The content of monounsaturated fatty acids in poultry meat also increased, while the content of polyunsaturated acids, on the contrary, decreased. In addition, it was noted that increasing the dosage of the experimental supplement leads to an increase in the redness of breast meat.

The addition of a product from the biomass of fly larvae to the diet of broilers in the amount of 100 $g \cdot kg^{-1}$ of feed leads to the improvement in the parameters of chicken meat [DABBOU *et al.* 2018], and the remains of the fly larvae of *Hermetia illucens* after extraction of the fat fraction can be considered as a source of energy and assimilated amino acids in the diet for feeding birds for more efficient digestion [DE MARCO *et al.* 2015; SCHIAVONE *et al.* 2017b].

The research was carried out in order to study the effect of feeding chickens with dried biomass of the larvae of *Hermetia illucens* flies on histological changes in the internal organs of experimental birds. In particular, it was determined that chickens, in the diet of which 25 or 50% of soybean meal were replaced by the corresponding amount of meal from insect larvae, had changes in the morphometry of the small intestine, enzymatic and microbial activity of the cecum. It was found that the increase in the content of volatile fatty acids and butyrate in the diet with a 50% replacement of soybean meal with the larval meal had a positive effect on the gastrointestinal tract of experimental birds. It was determined that the intestinal activity of alkaline phosphatase decreased linearly in the duodenum and small intestine as the content of larvae in the diet of birds increased. In addition, the levels of Cd, Pb, Hg and as in insect rations and meal were found to be below the maximum values set by the EU Commission [MONIELLO *et al.* 2019]. It was concluded that the replacement of the protein supplement in the form of soybean meal by 25% with the feed from larvae of *Hermetia illucens* flies in the diet of laying hens was more optimal [BOVERA *et al.* 2018].

It was found that the complete replacement of soybean meal with flour from black soldier fly larvae led to histological changes in the body of the experimental chickens. In particular, it was revealed that in the duodenum maltase in experimental birds exhibited higher activity, while intestinal alkaline phosphatase had higher activity in the control group. It was also found that maltase and sackarase exhibited higher activity in the ileum of the experimental chickens. Complete replacement of soybean meal with larvae of *Hermetia illucens* flies in the diet of laying hens aged 24 to 45 weeks led to a higher production of butyric acid in the cecum, while the enzymatic activity of the brush limiting membrane was partially reduced [CUTRIGNELLI *et al.* 2018].

It was determined that the complete replacement of soybean meal with a meal from larvae led, in particular, to the increase in the level of calcium in the blood of hens feeding on insects, while creatinine was higher in the blood of hens, which were fed with food containing soybean meal. It was concluded that *Hermetia illucens* larvae might be a suitable alternative protein source for chickens [MARONO *et al.* 2017].

A general description of the existing advantages and disadvantages of using *Hermetia illucens* larvae in the diet of chickens is presented in Figure 3.

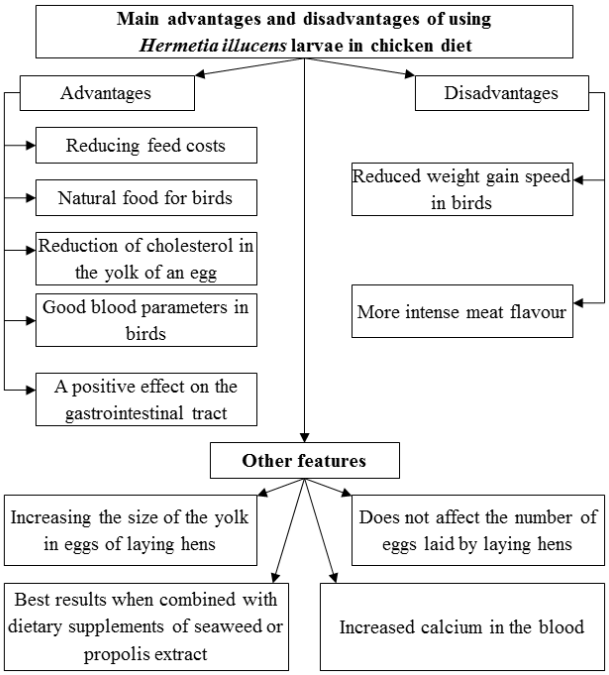

Fig. 3. Main advantages and disadvantages of using *Hermetia illucens* larvae in chicken diet; source: own study

USE OF HERMETIA ILLUCENS FLIES' LARVAE FOR FEEDING OTHER POULTRY

The larvae of the fly *Hermetia illucens* were studied as a feed additive in the diet of the Moskovskaya ducks. Soybean meal was replaced by fat-free fly larvae in the amount of up to 9% of the feed weight and fed to 3-day-old ducklings until the age of 50 days. It is summarized that the results are encouraging since the increase in the concentration of defatted larvae of *Hermetia illucens* does not worsen the growth indices of ducklings or the hematological signs of them.In addition, it is found that the functions of the liver and kidneys improved slightly. In particular, it is determined that no histological changes are observed in the internal organs of the experimental samples of ducks. The inclusion of up to 9% of partially defatted *Hermetia illucens* larvae in the duck's diet does not affect the growth rates, as well as the apparent digestibility of food. It is concluded that it is possible to replace soybean meal with partially defatted larvae

in the amount of up to 9% as a promising feed ingredient [GARIGLIO *et al.* 2019a, b].

The effect of the addition of live larvae to the diet of young turkeys on the weight characteristics of was studied. Replacing 10% of the daily amount of feed with live *Hermetia illucens* larvae in the diet of turkeys showed that the daily feed intake and body weight gain of the experimental birds were significantly higher compared to the control groups, which led to a significantly higher body weight of chicks at the age of five weeks (2.19 kg vs. 2.015 kg, respectively) and a significantly lower feed conversion rate [VELDKAMP, VAN NIEKERK 2019].

Soybean meal was 25 or 50% replaced by the protein fraction from the larvae of *Hermetia illucens* and was used to feed white grouse (*Alectoris barbara*) at the age of 7 to 64 days from the beginning of birth. It was determined that by the end of the experiment, the experimental partridges had a higher weight compared to the birds in the control group, receiving food with the replacement of 50 meals (249 g and 270 g, respectively). It was indicated that in the control group the weight of the cecum, the length of the intestine and the cecum were the highest and the ratio of albumin/globulin and creatinine content was higher than in birds from the experimental groups [LOPONTE *et al.* 2017]. It was found that the pH value, colour and shear strength of raw meat did not differ greatly depending on the diet while feeding partridges with insects increased the yellowness index of the meat. It was also determined that the inclusion of insects in the feed composition did not affect the cholesterol content in birds [SECCI *et al.* 2018b].

In the paper by CULLERE *et al.* [2016], the effect of replacing soybean meal and soybean oil with defatted dried larvae of *Hermetia illucens*for growing broiler quails (*Coturnix coturnix japonica*) was studied. In the experimental diets, 10% and 15% of quail feed were replaced with flour from fly larvae. Accordingly, 28.4% soybean oil and 16.1% soybean meal (10%) and 100% soybean oil and 24.8% soybean meal (15%) in the diet were replaced. It was determined that the performance, mortality and characteristics of quail carcasses were consistent with the standards and similar in all experimental groups. It was concluded that defatted flour from *Hermetia illucens* larvae could partially replace conventional soybean flour and soybean oil in the diet for growing quail broilers.

The eggs of quail fed with 10% and 15% replacement of meal from fly larvae had the highest shape index, shell weight and percentage and the most intense yolk colour. In addition, it was determined that feeding the quail with defatted larvae of *Hermetia illucens* increased the content of saturated fatty acids in eggs and decreased the polyunsaturated fraction of fatty acids. It was concluded that fat-free meal from fly larvae could be considered a possible alternative ingredient instead of soybean meal in the diet of quails [DALLE ZOTTE *et al.* 2019].

The influence of the substrate on which the larvae of the fly *Hermetia illucens* were raised on the feeding of quail broilers was studied. Ordinary feed for quail soy flour and with a 50% substitution for fish flour used as a substrate. Fly larvae grown on the indicated substrates were dried in the amount of 10% by weight of the feed. The results of tests on the digestibility of the feed showed that the feed containing dried larvae has high metabolizable energy (14.0 and 13.9 $MJ \cdot kg^{-1}$ for the experimental diet and 12.9 $MJ \cdot kg^{-1}$ for the control). At the same time, the results of the choice of food showed that quails preferred the control diet compared to diets containing dried *Hermetia illucens* larvae in their composition. According to the results of this study, it was found that the inclusion in the diet of quail of 10% of *Hermetia illucens* larvae grown on a substrate rich in omega-3 fatty acids did not have a negative effect on the apparent absorption of nutrients, mortality and carcass weight. The choice of feed, broiler growth rate and final quail carcass weight were negatively influenced by a diet of black soldier fly larvae grown on a substrate containing 50% fish flour [CULLERE *et al.* 2019b; WOODS *et al.* 2019].

The protein product from the larvae of black soldier fly can also be used in feeding other animals [GASCO *et al.* 2019; VELDKAMP, BOSCH 2015], and even, possibly, in the production of food for humans.

CONCLUSIONS

Today there is enough research in the world to state that the larvae of the fly *Hermetia illucens* are a safe substitute for traditional protein meal in the diet of poultry. Individuals fed on experimental feed with the addition of whole or treated insects were not susceptible to diseases to a greater extent than the control groups. The quality of meat developed in accordance with breed characteristics did not differ from ordinary poultry. In some cases, there was a slightly slower weight gain compared to the control group. On the other hand, when using *Hermetia illucens* larvae to feed white grouses (*Alectoris barbara*), birds fed with insects gained weight better than individuals fed with traditional food. Most researchers agree that replacing protein in poultry feed with insect flour should be partial, in the 15–30% range. Feeding with larvae that have undergone processing – grinding, chitin removing, heat treatment – is more preferable than using whole larvae, since the chitinous membrane makes larvae difficult to be digested in the digestive tract of birds.

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