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Influence of the inclusion of insect meals on the net utilization of energy and protein in broiler chickens

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Abstract

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The aim of the present research was to compare the net utilization of the energy and the protein in the chain "fodder – breast+tight muscles", when replacing part of soybean meal with 10% insect meals from defatted Black soldier fly larvae (BSFd) and silkworms (SW) in the fattening of broiler chickens. The experiment was conducted with 180 Ross day-old male broiler chickens, in 3 groups, with 3 replicates (20 birds/replicate), throughout 49 days. The groups were: control (C), where the soybean meal was the main protein source in all the diets; BSFd – fed 10% defatted larvae meal instead of part of soybean meal; SW – fed 10% silkworm pupae meal instead of part of soybean meal. The diets were isoprotein and isoenergetic in all the 3 phases of fattening. Two indexes were used: Clarc of energy distribution (CED) = Accumulated gross energy in lean breast+thigt meat/consumed metabolizable energy and Clarc of protein transformation (CPT) = Accumulated crude protein in lean breast+thigt meat/consumed crude protein.

The following results were obtained: CED: C group – 0.1774 (17.74%); BSFd group – 0.1844 (18.44%); SW group – 0.1989 (19.89%). CPT: C group – 0.4394 (43.94%); BSFd group – 0.4608 (46.08%); SW group – 0.4723 (47.23%). The described replacement of fodder components has a positive effect on the net utilization both of energy and protein.

Keywords: black soldier fly meal (BSFd); broilers; Clarc of energy distribution; Clarc of protein transformation; silkworm pupae meal (SW)

Introduction

Regional disparities in the nutrition of the human population and the problems of global pollution necessitate the search for ways to utilize nutrients from natural sources and waste products from human activities in the diet of domestic animals (FAO, 2011). However, these sources should not be used directly for human nutrition.

For industrial poultry farming, potential (mainly energy) sources are the cereal-based table wastes (Yadav et al., 2014; Al Tulaihan et al., 2004; Krička et al., 2019).

More complicated is the problem with plant protein components (mainly soy-based), which are increasingly used for direct human consumption, which increases their price and makes them unprofitable for animal feed.

Insects have been found to be part of the natural foods for birds in the wild (Bovera et al., 2015), so they can be a potential source of protein and energy for poultry, due to their high fat (30-40% in the dry matter (DM) and protein content (40–60% in DM). They are compatible not only to soybean, but also to fish meal (Makkar et al., 2014; Khatun et al., 2003; 2005; Okah & Onwujiariri, 2012). An additional positive effect is the more efficient use of natural resources and lower greenhouse gas emissions (van Zanten et al., 2014).

Of particular interest in broiler feeding has recently been research into the replacement of traditional protein sources with those, based on fly flours (Schiavone et al., 2017; Elahi et al., 2022; Gutierrez et al., 2004) and silkworms (Fagoonee, 1983; Khatun et al., 2003; Konwar et al., 2008; Sheikh & Sapcota, 2010; Jintasataporn, 2012).

Establishing the net utilization of the energy and the nitrogen/protein in the eco-technical chain "fodder – direct consumable products", has advantages both from a zootechnical (selectional, technological) and from an ecological point of view. Penkov & Genchev (2018), introduce objective criteria for their calculation – „Clarc of energy distribution"and „Clarc of protein transformation".

The aim of the present research is to compare the net utilization of energy and the protein in the chain "fodder – breast+tight muscles", when replacing part of soybean meal with 10% insect meals from defatted Black soldier fly larvae (BSFd) and silkworms (SW) in the fattening of broiler chickens.

Material and Methods

General

The experiment was conducted in the Experimental farm of the Agricultural Institute – Stara Zagora, with 180 Ross day-old male broiler chickens, with uniform live body weight, divided in 3 groups with 3 replicates (20 birds/replicate), throughout 49 days. The groups were: control (C), where the soybean meal was the main protein source in all the diets; BSFd – fed 10% defatted larvae meal instead of part of soybean meal; SW – fed 10% silkworm pupae meal instead of part of soybean meal. The diets were isoprotein and isoenergetic in all the 3 phases of fattening and formulated, according to requirements for nutrition of the hybrid (Kabakchiev et al., 2014), (Table 1). The chemical composition and the content of metabolizable energy of both the insect meals are presented in Table 2.

Slaughter procedures, carcass evaluation and chemical analyses

At 49 days of age, slaughter analysis was performed on six chickens (3 males and 3 females) from each group, with live weight equal to group average. After 12-hour fasting, birds were stunned and slaughter in line with the requirements of Ordinance 22 (SNP, 2006) of the Ministry of Agriculture and Food, to reduce suffering of animals, during slaughter, or killing to a minimum. The cleaned carcass, without the neck and edible offal, was cut after 24-hour cooling at 0-4 ^{0}C. The breast and thigh muscles (without bones) were separated and measured acc. procedure described of Genchev & Mihaylov (2008). The chemical composition of the fodders and meat was determined acc. Weende – methods (AOAC, 2007).

Table 1. Composition of diets and nutritional values of the fodders

Indexess	Starter			Grower			Finisher		
	C	BSFd	SW	C	BSFd	SW	C	BSFd	SW
Ingredients: Control group (C): Corn, wheat, soybean meal, sunflower meal sunflower oil, DL-methionine, L-lysine, salt, limestone, dicalcium phosphate, Vitamin-mineral premix, optizyme®, salgard®. Group (BSFd)*: Part of the soybean meal is replaced ISOENERGIC and ISOPROTEIN with 10% defatted black soldier fly larvae's meal in all the combined fodders (starter, grower, finisher). Group (SW)*: Part of the soybean meal is replaced ISOENERGIC and ISOPROTEIN with 10% silkworm pupae meal in all the combined fodders (starter, grower, finisher). *The isoenergy of the fodders is achieved by changing the amount of sunflower oil too.									
Nutritional value in 1 kg combined fodder – native substance (87%DM)									
Metabolizable energy (ME) – MJ	12.66	12.65	12.66	13.30	13.30	13.29	13.44	13.44	13.44
Crude protein, %	22.53	22.23	22.22	20.27	20.28	20.26	18.00	18.00	18.00
Fat, %	5.83	9.58	5.51	9.20	11.36	7.31	9.71	11.80	7.85
Crude fiber, %	4.67	3.90	4.11	4.49	3.84	4.00	4.16	3.48	3.64
Avail. phosphorus, %	0.49	0.50	0.50	0.45	0.45	0.45	0.42	0.42	0.43
Calcium, %	1.03	1.02	1.02	0.90	0.90	0.90	0.85	0.86	0.85
Lysine %	1.52	1.49	1.49	1.32	1.33	1.32	1.16	1.16	1.16
Methionine, %	0.74	0.73	0.74	0.71	0.71	0.71	0.69	0.70	0.69

Table 2. Chemical composition of insect meals

Parameters	BSFd	SW
Crude fat, %	7.79	24.50
Crude protein, %	56.16	57.14
Moisture , %	1.03	11.50
Metabolizable energy (ME), MJ/kg	16.10 (acc. Schiavone et al., 2017)	18.21 (acc. Penkov, 2005)
Calcium, %	0.84	0.55
Phosphorus,%	0.67	0.75

Calculation procedures

The consumed metabolizable energy (ME) and crude protein (CP) were calculated acc. the formula:

[(content in starter*consumed starter from 1 chick) +
(content in grower*consumed grower from one chick) +
(content in finisher*consumed finisher from one chick)] (1)

The produced gross energy (GE) and crude protein (mean from 1 chick) were calculated, as follow:

Mass of breast and thigh muscles (kg in native substance mean from 1 chick)* content of GE (J) and CP (kg) in one kg breast and thigh muscle – mean from one chick in day 49 (2)

The GE content in breast/thigh muscles is calculated acc. the formula (Schiemann et al., 1971):

$$GE\ (MJ*kg^{-1}) = 0.0242*CP + 0.0366*CFats + 0.0177*CFiber + 0.0170*NPE \quad (3)$$

The "Clarcs" of energy distribution/protein transformation (CED/CPT) were calculated acc. the formula (Penkov & Genchev, 2018):

Content of GE(CP) in breast and thigh muscles/ consumed ME(CP) for the whole period (4)

Data were statistically analyzed by one-way analysis of variance (ANOVA) using SPSS v. 19 software, according to the model: $Yij = \mu + CPi + eij$

When factor effect was significant, the least significant difference post-hoc test (LSD-test) was also performed at $P < 0.05$.

Results and Discussion

The results for the input of the eco-technical chain are shown in Table 3. The lowest feed consumption in all three periods of fattening was shown by the control group – the total feed consumption per chicken is 5.90 kg. The consumption of fodder is higher in the BSFd group – 6.14 kg, and the highest -in the group consumed fodder with participating of pupae meal (SW-group) – 6.43 kg. The higher feed consumption can also be explained by the fact, that the compound feeds containing insect meals are more delicious for the chickens. They are evolutionarily adapted to insects as a natural part of their diet (Bovera et al., 2015). Black soldier fly (*Hermetia illucens* L.) larvae can provide high-value feed stuffs, as they are rich in protein (37% to 63%) and have a better amino acid (AA) profile than soybean meal (Barragan-Fonseca et al., 2017). The positive effect at live weight (LW) and daily feed intake (DFI) by dietary HI meal inclusion, partially agrees with what reported by Dabbou et al. (2018) and Loponte et al. (2017), who observed improved growth rate and higher LW in chickens and Barbary partridges, respectively, fed with HI meal, as a component of a complete diet, and as partial replacement (25% or 50%) of soybean meal. Khan et al. (2018) showed reduced feed consumption and FCR, as well as increased BWG, in broiler chickens fed diets, in which (*Tenebrio molitor*) TM larva meal used to completely replace SBM. In the same context, Ballitoc & Sun (2013), pointed out that an inclusion level of 10 g/kg TM in broiler chicken diets had a great impact on the growth performance of the animals, in terms of improved final LW, FI and FCR.

Jintasataporn, (2012), conducting an experiment with five dietary treatments: treatment I (10% fishmeal, FM and 0% silkworm pupae) (control), treatment 2 (0% FM and l0% SSP), treatment 3 (0% FM and 20% SSP), treatment 4 (0% FM and 5% SSP + 5% RSP), and treatment 5 (0% FM and l0% SSP + l0% RSP). They reported that treatment 2, 3, 4 and 5 had higher feed consume ($P < 0.05$) than control group because silkworm pupa contained a lot of chitin that may cause low digestibility and high feed consumption to fulfill the energy requirement.

In our previous study with turkeys (Lalev et al., 2020), we found that the Silk worm (SW) meals modulated turkeys' feeding behavior by stimulating feeding, while BSF (Black soldier fly) meals did not have this effect. When these results are put into context of LW and ADG (average daily gain), it can be suggested that BSF meal effects on LW and ADG are

Table 3. Consumed fodder, metabolizable energy (ME) and crude protein (CP) – main from one chick for the whole experimental period (entrance of the chain)

Indexes	Starter	Grower	Finisher	Total (1-49 day of age)
Fodder, control group, kg	0.26174	1.80368	3.83505	5.9005
ME, control group, kJ	3313.63	23988.94	51543.07	78845.64
CP, control group, g	58.97	365.61	690.31	1114.89
Fodder, BSFd- group, kg	0.27146	1.85333	4.01200	6.1368
ME, BSFd- group, kJ	3433.97	24649.29	53921.28	82004.54
CP, BSFd group, g	60.32	375.86	722.16	1158.34
Fodder, SW group, kg	0.28032	1.92610	4.22200	6.4284
ME, SW group, kJ	3548.85	25597.87	56743.68	85890.40
CP, SW group, g	62.29	390.23	760.00	1212.52

the result of qualitative mechanisms, such as improved assimilation of nutrients and growth promoting factors in BSF meals. These are reflected in greater FCR values: BSFd and BSFw fed groups, exhibited the most positive response with FCR 2.46 and 2.45 respectively, while the FCR in the control fed group was 3 kg/kg. FCR values in SW and SWpro groups were closer to that of the control.

Due to the fact, that the feed for all groups is isoenergetic and isoprotein in all periods, it is logical that the groups that consumed feed involving insect meal received more ME (86.89 MJ for the SW-group, 82 MJ for the BSFd-group against 78.85 MJ for the control group) and CP (1213 and 1158 against 1115 g respectively).

In Table 4, the masses of breast and thigh muscles (without bones) mean from 1 chicken are presented. Highest mass of breast muscles is reported in SW group – 1305.38 g, followed by BSFd – group (1240.26 g) and the lowest – in control group – 1075.76 g. The differences under the three groups are statistically significant ($p<0.05$).

The same trend is observed in the thigh muscles – 1288.08, 1204.08 and 1141.56 g, respectively. The differences under the three groups are also statistically significant ($p<0.05$).

The chemical composition of the breast and thigh muscles does not show significant differences in comparison with the data presented by other authors, who have worked with broiler chickens (Baeza et al., 2001; Ahmed et al., 2015), but shows difference, compared with Guinea fowls (Nikolova, 2013) and the Japanese quails (Vasileva et al., 2014).

The gross energy accumulation is higher in the thigh muscles due to the higher content of fat compared to breast muscles. The highest difference is observed in SW-group (1 kJ/kg fresh substance). The basis for this high difference is the content of crude fat (4.18%), which is significantly higher, compared to the control (3.18%) and BSFd-group (3.11%). The higher content of crude fats in silkworm meal have positive effect on their accumulation in thigh muscles.

Although, the control group showed the lowest consumption of feed during the entire fattening period (Table 3), the higher contents of pure meat and the higher content of crude fat in the experimental groups compensate the utilization of energy and protein in both breast and thigh muscles (Table

Table 4. Mean mass and chemical composition of the breast and thigh muscles (without bones and skin) from one chick from all the groups – in native substance

Indexes*	Control group		BSFd – group		SW – group	
	X mean	SE	X mean	SE	X mean	SE
Mass of breast muscles – g	1075.76a	16.1	1240.26 ab	17.5	1305.38 ab	13.1
Mass of thigh muscles – g	1141.56a	14.2	1204.08 b	15.8	1288.08 ab	14.0
Crude protein in breast muscles – %	23.11	0.14	23.28	0.11	22.96	0.11
Crude protein in thigh muscles – %	21.14	0.09	20.98	0.14	21.11	0.14
Crude fats in breast muscles – %	1.18	0.01	1.19	0.01	1.36	0.02
Crude fats in thigh muscles – %	3.18 a	0.06	3.11 b	0.04	4.18 ab	0.02
Gross energy (GE)in breast muscles-MJ*kg^{-1}	6.08	0.01	6.12	0.01	6.09	0.01
Gross energy (GE) in thigh muscles-MJ*kg^{-1}	6.30	0.01	6.25	0.01	7.09	0.01

a-a – Statistical significance ($P<0.05$) between control and 2 experimental groups

b-b – Statistical significance ($P<0.05$) between the experimental groups

Table 5. Accumulated gross energy (GE) and crude protein (CP) in breast and thigh muscles (mean from one chick) and "Clarcs" of energy distribution/protein transformation

Indexes*	Control group		BSFd – group		SW – group	
	X mean	SE	X mean	SE	X mean	SE
Accumulated GE in native breast muscles – kJ	6540 a	100	7590 a	110	7950 a	80
Accumulated GE in native thigh muscles – kJ	7190 a	90	7530 ab	100	9130ab	100
Accumulated CP in native breast muscles – g	248.61a	3.72	288.73a	4.08	299.72a	3.01
Accumulated CP in native thigh muscles – g	241.33a	3.00	252.62	3.32	271.91a	2.96
Clarc of energy distribution "fodder-breast"	0.0829	–	0.0926	–	0.0926	–
Clarc of energy distribution "fodder-thigh"	0.0912	–	0.0918	–	0.1063	–
Clarc of protein transformation "fodder-breast"	0.2230	–	0.2490	–	0.2479	–
Clarc of protein transformation "fodder-thigh"	0.2164	–	0.2118	–	0.2244	–
Clarc of energy distribution "fodder-breast+thigh" (CED)	0.1741 (17.41%)	–	0.1844 (18.44%)	–	0.1989 (19.89%)	–
Clarc of protein transformation "fodder-breast+thigh" (CPT)	0.4394 (43.94%)	–	0.4608 (46.80%)	–	0.4723 (47.23%)	–

* a-a – Statistical significance ($P<0.05$) between control and 2 experimental groups
b-b – Statistical significance ($P<0.05$) between the experimental groups

5). Regard to CED, the group receiving BSFd exceeded the control group by more than 1% (18.44 vs. 17.41%), and with the group receiving SW, the excess was 2.4% (19.89 vs. 17.41%). The differences in the net utilization of the protein are even higher – 43.94 (control), against 46.08% (BSFd – group) and 47.23% (SW – group).

Due to the fact, that the indicators introduced by us are new to the world practice, we do not find data for comparison in the available literature. The only data from similar experiments in Bulgaria are those of Chobanova & Penkov (2021).

The "Clarcs" found in the present study are significantly lower (average 17.5-20% vs. 23-25% for CED and 44-47% vs. 53-60% for CPT in the citation). The higher "Clarcs" in the cited source are explained by the lower feed consumption per bird (4.1-4.3 kg in the cited vs. 5.9-6.4 kg in the present experiment), while the obtained pure meat and it chemical composition are relatively comparable in both experimens.

The comparison between the data from the two experiments shows that "Clarcs of energy distribution / protein transformation" are sufficiently flexible indicators that can give an objective assessment of the broiler housing technologies/conditions.

Despite the differences, our study confirms the opinion of Todorov et al. (2021) that energy and protein in feed are transformed with relatively high net efficiency in (broiler) chicken meat.

Conclusions

Under the conditions of the experiment, the following "Clarcs" in the eco-technical chain "fodder – breast+thigh muscles" (lean meat) were obtained:

Clarc of energy distribution (CED): Control group – 0.1774 (17.74%); BSFd group – 0.1844 (18.44%); SW group – 0.1989 (19.89%).

Clarc of protein transformation (CPT): Control group – 0.4394 (43.94%); BSFd group – 0.4608 (46.08%); SW group – 0.4723 (47.23%).

Replacing of part of the plant (soybean) protein with one from defatted black soldier fly larvae and dry silkworm larvae has a positive effect on the net utilization both of the energy, and the protein.

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References

Ahmed, S. T., Islam, M., Bostami, B., Mun, H., Kim, Y. & Yang, C. (2015). Meat composition, fatty acid profile and oxidative stability of meat from broilers supplemented with pomegranate (*Punica granatum* L.) by-products. *Food Chemistry, 188,* 481-488. DOI:10.1016/j.foodchem.2015.04.140.

Al Tulaihan, A. A., Najib, H. & Al-Eid, S. M. (2004). The nutritional evaluation of locally produced dried bakery waste (DBW) in the broiler diets. *Pakistan Journal of Nutrition*, *3*(5), 294-299.

AOAC International (2007). Official methods of analysis of AOAC. (18 edition, rev. 2), *Association of Official Analytical Chemists Intern.,* Gaithersburg, MD, USA.

Baeza, E., Lessire, M., Berri, C. & Juin, H. (2001). Compared carcass and meat characteristics of label and standard fowl. In: *Proceeding* of the XV European Symposium on the Quality of Poultry Meat, Kusadusi, Turkey, 73-78.

Barragan-Fonseca, K. B., Dicke, M. & van Loon, J. J. A. (2017). Nutritional value of the black soldier fly (*Hermetia illucens* L.) and its suitability as animal feed. *J. Insect. Food. Feed, 3,* 105–120.

Bovera, F., Loponte, R., Marono, S., Piccolo, G., Parisi, G., Iaconisi, V., Gaco, L. & Nizza, A. (2015). Use of Tenebrio molitor larvae meal as protein source in broiler diet: Effect on growth performance, nutrient digestibility, and carcass and meat traits. *J. Anim. Sci., 94,* 639–647.

Bovera, F., Piccolo, G., Gasco, L., Marono, S., Loponte, R., Vassalotti, G., Mastellone, V., Lombardi, P., Attia, Y. A. & Nizza, A. (2015). Yellow mealworm larvae (*Tenebrio molitor* L.) as a possible alternative to soybean meal in broiler diets. *British Poultry Science, 56* (5), 569-575.

Chobanova, S. & Penkov, D. (2021). Influence of soybean meal replacement with high protein sunflower meal on "Clarcs of energy distribution/protein transformation" in broiler chickens, *Agric. Science and Technology*, *13* (3), 255-259, ISSN 1314-412X, DOI: 10.15547/ast2021.03.040.

Dabbou, S., Gai, F., Biasato. I., Capucchio, M. T., Biasibetti, E., Dezzutto, D., Meneguz, M., Plachà, I., Gasco, L. & Schiavone (2018). A. Black soldier fly defatted meal as a dietary protein source for broiler chickens: Effects on growth performance, blood traits, gut morphology and histological features. *Journal of Animal Science and Biotechnology, 9* (9), 49 – 59. doi: 10.1186/s40104-018-0266-9.

Elahi, U., Chang-Chun Xu, Jing Wang, Jing Lin, Shu-Geng Wu, Hai-Jun Zhang & Guang-Hai Qi (2022). Insect meal as a feed ingredient for poultry. *Anim. Biosci., 35*(2), 332-346, doi: 10.5713/ab.21.0435.

Fagoonee, I. (1983). Possible growth factors for chickens in silkworm pupae meal. *British Poultry Science, 24*(3), 295–300.

Food and Agriculture Organization of the United Nations – FAO, (2011). Global Food Losses and Food Waste – Extent, Causes and Prevention; *Food and Agriculture Organization of the United Nations*: Rome, Italy.

Genchev, A. & Mihaylov, R. (2008). Slaughter analysis protocol in experiments using Japanese quails (*Coturnix japonica*). *Trakia Journal of Sciences*, *6*(4), 66-71.

Gutierrez, A. G. P., Vergara Ruiz, R. A. & Mejia Velez, H. (2004). Compositional, microbiological and protein digestibility analysis of larval meal of Hermetia illucens (Diptera:Stratiomyidae) at Angelopolis-Antioquia, Colombia. *Revista Facultad Nacional de Agronomia Medellin, 57*(2), 2491–2499. *Journal of Central European Agriculture, 20(3),* 788-795.

Jintasataporn, O. (2012). Production performance of broiler chickens fed with silkworm pupa (*Bombyx mori*). *J. Agric. Sci. Tech., 2,* 505-510.

Kabakchiev, M., Alexieva, D., Genchev, A., Nikolova M. & Gerzilov, V. (2014). Poultry Breeding. Acad.Pub. house AU – Plovdiv, ISBN 9789545172076, 488, (Bg).

Khan, S. Khan, R. U., Alam, W. & Sultan, A. (2018). Evaluating the nutritive profile of three insect meals and their effects to replace soya bean in broiler diet. *J. Anim. Physiol. Anim. Nutr., 102,* e662–e668.

Khatun, R., Azmal, S. A., Sarker, M. S. K., Rashid, M. A., Hussain, M. A. & Miah, M. Y. (2005). Effect of silkworm pupae on the growth and egg production performance of Rhode Island Red (RIR) pure line. *International Journal of Poultry Science, 4*(9), 718–720.

Khatun, R., Howlider, M. A. R., Rahman, M. M. & Hasanuzzaman, M. (2003). Replacement of fish meal by silkworm pupae in broiler diets. *Pakistan Journal of Biological Sciences, 6*(11), 955-958.

Konwar, P., Konwar, B. K., Ahmed, H. F., Nath, N. C. & Ghosh, M. K. (2008). Effect of feeding silkworm pupae meal with enzyme supplementation on growth performance of broilers. *Indian Veterinary Journal, 85*(1), 47-49.

Kricka, T., Janjecic, Zl., Anjecic, N., Bilandzija, N., Bedekovic, D., Voca, N., Matin, A., Jurisic, V. & Grubor, M. (2019). Nutritional usability of thermal treated white and brown bread in broiler feed. *Journal of Central European Agriculture*, *20*(3), 788-795.

Lalev, M., Mincheva, N., Oblakova, M., Hristakieva, P., Ivanova, I., Atanassov, A. & Petrova, A. (2020). Effects of insect- and probiotic-based diets on turkeys' production, health, and immune parameters. *Bulg. J. Agric. Sci., 26* (6), 1254–1265.

Loponte, R., Nizza, S., Bovera, F., De Riu, N., Fliegerova, K., Lombardi, P., Vassalotti, G., Mastellone, V., Nizza, A. & Moniello, G. (2017). Growth performance, blood profiles and carcass traits of Barbary partridge (*Alectoris barbara*) fed two different insect larva meals (*Tenebrio molitor* and *Hermetia illucens*). *Res. Vet. Sci., 115,* 183–188.

Makkar, H. P. S., Tran, G., Heuzé, V. & Ankers, P. (2014). State of the art on use of insects as animal feed. *Animal Feed Science and Technology, 197*, 1–33.

Nikolova, M. (2013). Guinea fowl – a perspective species domestic bird. *Ptizevadstvo (Poultry Farming*), *1*, 6-10, (Bg).

Okah, U. & Onwujiariri, E. B. (2012). Performance of finisher broiler chickens fed maggot meal as a replacement for fish meal. *Journal of Agricultural Technology, 8*(2), 471–477.

Ordinance 22 of the Ministry of Agriculture and Food (2005) *SNP*, 42/23.05.2006, (Bg).

Penkov, D. & Genchev, A. (2018) Methods for introduction of objective criteria for bioconversion of energy and nutrients along the feed – animal products chain in meet-type poultry farming. *Journal of Central European Agriculture*, *19*(2), 270-277.

Penkov, D. (2005). Methods for balance experiments for geese, metabolizable energy and true amino acid digestibility of major forage ingredients in feeding them. *Journal of Central* Europ. *Agric*., *3,* 277-285.

Schiavone, A., De Marco, M., Martinez, S., Dabbou, S., Renna, M., Madrid, J., Hernandez, F., Rotolo, L., Costa, P., Gai, F. & Gasco, L. (2017). Nutritional value of a partially defatted and a highly defatted black soldier fly larvae (*Hermetia illucens* L.) meal for broiler chickens: apparent nutrient digestibility, apparent metabolizable energy and apparent ileal amino acid digestibility. *Journal of Animal Science and Biotechnology, 8,* 51.

Schiemann, R., Niering, K., Hoffmann, L., Jench, W. & Chudy, A. (1971). Energetische Fuetterung und Energienormen. VEB Deutscher Landwirtschaftsverlag, Berlin, (orig.-D) Energetic nutrition and energy requirements.

Sheikh, I. U. & Sapcota, D. (2010). Effect of feeding silkworm pupae meal on nutrient and mineral retention in broilers*. Indian Veterinary Journal, 87*(10), 1049-1050.

Todorov, N., Marinov, B., Ilchev, A., Kirilov, A., Chobanova, S. & Ganchev, G. (2021). Basics of Animal Nutrition. Kota-print, St.Zagora, 464, ISBN 9789543381760, (Bg).

Van Zanten, H. H. E., Oonincx, D. G. A. B., Mollenhorst, H., Bikker, P., Meerburg, B. G. & deBoer, I. J. M. (2014). Can the environmental impact of livestock feed be reduced by using waste-fed housefly larvae? In: *Proceedings of the 9th International Life Cycle Assessment of Foods Conference (LCA Food 2014),* 1455-1461.

Vasileva, P., Lukanov, H. & Genchev, A. (2014). Meat quality traits in Japanese quails with regard to storage conditions and duration. *Agricultural Science and Technology*, *6*(4), 475-479.

Yadav, D. S., Shrivastava, M., Singh, J. P. & Mishra, A. K. (2014). Effect of replacement of maize with bakery waste in broiler ration. *International Journal of Agricultural Sciences and Veterinary Medicine*, *2*(1), 28-33.

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