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Net energy and protein utilization along the "feed with different protein sources – meat" chain in fattening female hybrid Turkeis during the grower and finisher periods

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Abstract

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The aim of the study was to establish the net utilization of energy and protein in the chain "feed – meat without bones and skin" in the fattening of female turkeys between 56 and 130 days of age. Fattening is four-phase. Three groups were formed – control, in which the main source of protein is soybean meal, BSFd group, in which during all phases, part of soybean meal was replaced with defatted flour from black fly larvae and SW – group in which the replacement is with 10% whole fat meal flour from *B. mori L.* larvae. The feeds were isoenergetic and isoprotein in phases. Specific indices of calculation were used – Clarc of Energy Distribution (CED) and Clarc of Protein Transformation (CPT), reflecting mathematical the transformations of energy and protein along the „feed-edible animal products" chain.

The following net utilizations of the metabolizable energy in the feed to the accumulated gross energy in the breast + thigh muscles (CED) have been established: Control – 0.0822 (8.22%); BSFd group – 0.0773 (7.73%); SW group – 0.0819 (8.19%).

For protein (CPT) the results are as follows: Control – 0.1880 (18.80%); BSFd group – 0.1742 (17.42%); SW group – 0.1961 (19.61%).

Keywords: black soldier fly meal (BSFd); Clarc of energy distribution; Clarc of protein transformation; silkworm pupae meal (SW); female turkey's fattening

Introduction

As a branch of poultry farming, the global turkey farming industry produces a valuable and dietetic meat. Numerous studies have confirmed that turkey poults are characterized with high growth rates, good feed conversion and high slaughter yields from 70.08% to 81.35% (Lalev, 1993; Hristakieva, 2006; Oblakova et al. 2008; Oblakova et al. 2009; Lalev et al. 2018; Lalev et al. 2021). It is acknowledged that turkey meat is a very good source of animal proteins as its protein content is high (up to 28% vs 14-18% in other poultry meats) and fat content is moderate (1–5%); moreover, its cholesterol content is the lowest as compared to other meats (Oblakova et al. 2016; Okuskhanova et al., 2017; Amirkhanov et al., 2017).

Recently, the interest to use of insects as source of highly digestible feed protein and fats with antioxidant and immunostimulating properties in turkey nutrition (Allegratti et al, 2018).

The studies on the effect from the addition of live BSFL

on productive traits of turkeys are relatively scarce. Zuidhof et al., 2003 reported the following values for gross energy, metabolizable energy and crude protein ratio in turkey poults fed dehydrated *M. domestica* larvae (MDL): 23.1, 17.9 MJ / kg and 593 g/kg respectively and values in standard diet (SD) of 17.0, 13.2 MJ/kg and 318 g/kg ($P < 0.05$). Apparent digestibility coefficients in the entire digestive tract were higher for MDL. The authors concluded that dehydrated fly larvae may replace successfully soybean meal as protein supplement in turkey poults rations.

Despins and Axtell, 1994 have conducted experiments to evaluate the effects from feeding darkling beetle larvae (*Alphitobius diaperinus (Panzer) [Coleoptera: Tenebrionidae*]), to turkey poults on their growth performance and feed consumption. It was reported that at an early age, the turkey poults consumed the larvae willingly but exhibited reduced growth if other food is lacking; this reduction was not compensated if normal feeding was not restored.

In the Russian Federation, data on the efficacy of inclusion of 5-7.5 % dried whole *Lucilia spp.* larvae in diets for industrially fattened turkeys are provided. Higher growth intensity, lower feed costs and improved meat quality traits due to content of highly valuable protein, essential amino acids and unsaturated fatty acids were found out (Romanenko and Istomin, 2020).

In our preliminary study (Lalev et al., 2020), the effect of including 10% of Black soldier fly larvae (*Hermetia illucens*) and silkworm (*Bombyx mori L.*) in turkey diets was investigated. A positive impact on growth and productivity indexes but no significant differences in slaughter indexes were found.

It is of growing importance in modern animal husbandry, the nutrients from the feed to be used with the highest efficiency of conversion into nutrients in farm animals and birds, consumable from people. Newly proposed in this direction by Penkov and Genchev (2018) are the indicators „Clarc Energy Distribution (CED)" and „Clarc Protein Transformation (CPT)".

The aim of the study is to investigate the effect of replacing soybean meal with Black soldier fly insect (*Hermetia illucens*) and silkworm (*Bombyx mori*) meals in compound feed for turkeys on the net utilization of energy and protein in the eco-technical feed chain "directly human-consumable animal products" in the fattening of female hybrid turkeys during the grower and finishing period, expressed in CED and CPT.

Material and methods

The present study was carried out in the poultry farm of the Agricultural Institute – Stara Zagora, Bulgaria. A total of 45 hybrid female turkeys at 56 days of age were individually weighed to form three groups, uniform with respect to live body weight ($P > 0.05$) (3 replications with 5 turkeys per group): control group – turkey fed feed containing soybean meal (C); SW group – turkey fed feed containing 10% silkworm pupae meal; BSFd group – turkey fed feed containing 10% defatted black soldier fly meal (BSFd). The experiment lasted 74 days (from 56 to 130 days of age). The birds in all groups were reared on floor, in three premises with three replications each.

The feed intake of turkeys (g) was registered at 56, 78, 94, 114 and 130 days of age, and on this basis, the average daily feed intake of one bird was calculated. The average intake of metabolizable energy (ME) and crude protein (CP) mean from one turkey was determined by the formula Penkov and Genchev (2018):

$$\sum \text{periods from (Consumed average quantity per day of 1 bird * content of OE / SP * number of days in the period)/number of days in the period} \quad (1)$$

At 56 and 130 days of age, three birds from each group were selected (on basis average live weight in the group) for slaughter analysis (according to Genchev and Mihaylov, 2008) and determination of the chemical composition of meat (according to Weende – method – AOAC, 2007).

The gross energy content of meat was calculated by Schiemann et al. (1971), and the content of metabolizable energy in fodders during the various phases – according to standards described by Todorov et al. (2021).

The "Clarcs" of energy distribution / protein transformation were calculated according Penkov and Genchev (2018):

$$\text{CED / CPT = gross energy/crude protein accumulated in boneless and skinless meat / consumed OE or SP from 1 fodder bird for the whole experimental period}^{a} \quad (2)$$

$$^{a}\text{ The accumulated energy and protein in feed = established on day 130 – established on day 55} \quad (3)$$

$$\text{The real mass accumulation in the breast and tight muscles only for the experimental period was calculated as the difference between their final (130 days) and initial mass (56 days of age).} \quad (4)$$

All results are processed variation-statistically by one-way analysis of variance – Descriptive statistics – Excel – Microsoft.

Results and discussion

The turkeys from all groups were fed in four phases (2 growers and 2 finishers), and the control and both experimental groups received a combined fodders of free, which were isoenergetic and isoprotein in all phases – Table 1.

The content of nutrients and metabolizable energy in the fodders in all phases strictly comply with the recommendations for fattening female turkeys – Kabakchiev et al. (2014); Lesson and Summers (2005). In the recipes compiling the nutritional values of insect meals have been taken into account – Table 2.

Table 3 shows the quantities of feed consumed by groups – in phases and total for the experimental period. The highest total feed consumption was in the group receiving mulberry

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

Indexes	**Grower 1 – 56-78 day of age**			**Grower 2 – 79-94 day of age**			**Finisher 1 – 95-114 day of age**			**Finisher 2 – 115-130 day of age**		
	C	**SW**	**BSFd**	**C**	**SW**	**BSFd**	**C**	**SW**	**BSFd**	**C**	**SW**	**BSFd**
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 (SW)*: Part of the soybean meal is replaced ISOENERGIC and ISOPROTEIN with 10% silkworm pupae meal in all the combined fodders (grower 1, 2, finisher 1,2). 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 (grower 1, 2, finisher 1,2). *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	12.35	12.44	12.36	12.99	13.05	12.98	13.46	13.46	13.46	13.60	13.61	13.61
Crude protein, %	22.75	22.64	22.73	20.80	20.82	20.82	18.38	18.36	18.32	16.62	16.62	16.67
Total phosphorus, %	0.95	0.90	0.91	0.88	0.83	0.83	0.79	0.74	0.73	0.74	0.70	0.70
Calcium, %	1.21	1.20	1.21	1.09	1.09	1.09	0.92	0.92	0.92	0.83	0.83	0.83
Lysine %	1.50	1.51	1.50	1.36	1.37	1.36	1.11	1.11	1.11	0.92	0.92	0.92
Methionine+cystine, %	0.96	1.0	0.80	0.85	0.95	0.86	0.75	0.92	0.60	0.68	0.86	0.50
Threonine, %	0.85	1.11	0.93	0.77	1.04	0.84	0.70	0.90	0.74	0.61	0.80	0.70

Table 2. Chemical composition of insect meals (native)

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

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

Indexes	Grower 1 (56-78 day of age)	Grower 2 (79-94 day of age)	Finisher 1 (95-114 day of age)	Finisher 2 (95-114 day of age)	**Total (56-130 day of age)**
Fodder, control group, kg	3.792	3.648	3.780	3.768	14.988
ME, control group, kJ	46831	47388	50879	51245	**196343**
CP, control group, g	862.68	758.78	694.76	626.24	**2942.46**
Fodder, SW group, kg	4.032	4.188	3.432	5.460	17.112
ME, SW group, kJ	50158	54653	46195	74311	**225227**
CII/CP, SW group, g	912.84	871.94	630.12	907.45	**3322.35**
Fodder, BSFd group, kg	3.756	2.808	3.972	4.608	15.144
ME, BSFd group, kJ	46424	36448	53463	62715	**199050**
CP, BSFd group, g	853.74	584.63	727.75	765.85	**2931.97**

silkworm larvae (SW)– 17.112 kg on average per turkey, while the control and BSFd groups consumed on average 14.958 and 15.144 kg of feed.

In quails (Cullere et al. 2016) and in broiler chickens (Onsongo et al. 2018), no effect from the feed supplementation with insect products on daily feed intake and feed conversion was reported.

Veldkamp and van Niekerk (2019), have investigated the inclusion of live black soldier fly larvae (BSFL) in the diet of turkey poults on their behaviour, with emphasis on damaging pecking and feed intake. The control groups were fed standard diets according to birds; species and age whereas BSFL groups received live BSFL in their rations. The researchers found out the daily feed intake and the increased live weight of BSFL-supplemented groups were substantially higher compared to control groups and feed conversion ratio – significantly lower. During the first week, a trend to higher feed intake was demonstrated by groups fed live BSFL, but during the third and fifth weeks, these groups consumed less feed compared to control groups.

Despite the unevenness of the average consumption by periods, as well as the differences in energy and protein content in the combined fodders by phases, LW – group differs significantly from the control and BSFd group, both in total energy consumption for the period (225.227 MJ vs. 196.343 and 199.05 MJ respectively) and crude protein – respectively 3.32235 kg against 2.94246 and 2.93127 kg. We assume that feed containing natural full fat silk worm's flour improves the taste and increases the appetite of birds, but the high fat content is a factor for less durability of the combined feed, so we recommend that it must be prepared in quantities which will be consumed quickly, or using of defatted product.

The basic data of the chain output are shown in Table 4. To calculate the "Clarcs" (Table 5), we took into account the

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

Indexes*	Control group		BSFd group		SW group	
	X mean	SE	X mean	SE	X mean	SE
Beginning of the experiment (day 56)						
Mass of breast muscles – g	560.25±28.46					
Mass of thigh muscles – g	230.85±8.54					
Crude protein in breast muscles – %	**22.18±1.34**					
Crude protein in thigh muscles – %	**18.67±0.68**					
Crude fats in breast muscles – %	1.06±0.02					
Crude fats in thigh muscles – %	5.93±0.04					
Gross energy (GE) in breast muscles – kJ*kg^{-1}	**5835±130**					
Gross energy (GE) in thigh muscles – kJ*kg^{-1}	**6703±88**					
End of the experiment (day 130)						
Mass of breast muscles – g	2348.25	31.82	2365.82	40.06	2349.28	48.85
Mass of thigh muscles – g	898.46	19.62	961.16	20.98	938.42	21.51
Crude protein in breast muscles – %	**23.96**	**0.10**	**24.16**	**0.20**	**24.10**	**0.19**
Crude protein in thigh muscles – %	**19.63**	**0.48**	**19.51**	**0.74**	**20.31**	**0.28**
Crude fats in breast muscles – %	1.18	0.28	1.44	0.39	1.02	0.16
Crude fats in thigh muscles – %	6.16a	0.63	8.49ab	0.37	5.45b	0.51
Gross energy (GE) in breast muscles – kJ*kg^{-1}	**6380**	**74**	**6424**	**48**	**6297**	**58**
Gross energy (GE) in thigh muscles – kJ*kg^{-1}	**7093a**	**68**	**7943a**	**69**	**7103**	**46**
Accumulated gross energy and crude protein only for the experimental period						
Accumulated crude protein in breast muscles only for the experiment. period – g	428.40	10.70	436.23	7.39	431.16	8.28
Accumulated crude protein in thigh muscles only for the experiment. period – g	124.64a	1.69	142.48a	3.11	143.71a	3.29
Accumulated gross energy (GE) in breast muscles only for the experimental period – kJ	11407.44	109.4	11598.98	86.7	11265.53	103.7
Accumulated gross energy (GE) in thigh muscles only for the experimental period – kJ	4735.36a	45.4	5800.85ab	50.4	5025.87ab	32.6

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

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

accumulated amounts of breast and thigh muscles (excluding bones and skin) only during the experimental period. In this case the values are: Breast muscles: Control – 1788 g, BSFd group – 1805.57 g, SW group – 1789.03 g. For the thigh muscles, the results are as follows: 667.71, 730.31 and 707.57 g.

In general, the chemical composition of breast and thigh muscles at the end of the trial showed no significant between-group differences except for crude fat content in native thigh muscles of BSFd-supplemented birds ($P < 0.05$) that was statistically significantly higher (8.49%) than both control group (6.16%) and SW group (5.45%).

Table 4 presents gross energy and crude protein by groups and by muscle type (chain output). Again, significant differences ($P < 0.05$) were present between cumulative gross energy in the BSFd group (5801 kJ) and those of controls (4375 kJ) as well as SW group (5026 kJ).

Kim et al. (2021) and Murawska et al. (2021) reported that after substitution of soybean protein with BSF products, the share of thigh was similar in control group and groups with 50 and 100% substitution, whereas the share of breast meat was lower in groups with 75 and 100 % soybean meal substitution, which suggested a greater effect of the used protein source on breast muscles.

Altmann et al. (2018) found no influence from the inclusion of *Hermetia illucens* larvae meal in the chemical composition of chicken meat whereas other authors demonstrated increased protein content in groups fed compound poultry feeds containing partially defatted and full-fat larvae (Schiavone et al., 2019; Popova et al.2020).

In our belief, the Clarcs of energy distribution/protein transformation, presented in Table 5, are the first of their kind in turkeys (here, in female fattening turkeys). Similarly, to the other domestic poultry species, major part of the accumulated energy and protein was in the breast muscle. The results for CED varied from 5.15% (BSFd group), 5.66% (SW group) to 5.81% in control group. In CED – thigh muscle, the range was from 2.41% in the control group, through 2.53% (SW group) to 2.58% in the BSFd group. It should be noted that differences with respect to muscle type were relevant, yet between-group differences for a given muscle type were negligible. It could be concluded that the replacement of studied protein component in the diet of turkeys had no substantial effect on the accumulation of energy in both breast and thigh muscles.

The changes in Clarcs of protein transformation were in the same direction. CPT for breast muscles were as followed: BSFd group – 13.13%, control group – 14.56% and SW group – 14.71%, while the respective values for thigh muscles were 4.29, 4.24 and 4.90%.

The combined Clarcs to breast+thigh were the following − CED: control group – 8.22%, BSFd group – 7.73% and SW group – 8.19%; CPT –18.80, 17.42 and 19.61%, respectively. Obviously, the pupae meal showed a tendency towards positive effect with better (by about 1.3 – 2%) utilization of protein in meat.

There are no data about energy distribution and protein transformation in turkeys in the available literature, so our data are suggested as baseline for comparison with other comparable data. With regard to the same parameters established for other species of fattening poultry, the turkeys utilized the energy and protein at a substantially lower extent than broiler chickens (Chobanova and Penkov, 2021) – for protein: 18-20 vs 51-61%, for energy: 7.7–8.5 vs 23-25%. The CED and CPT data between turkeys and Japanese quails (Penkov and Genchev, 2019) were significantly closer, and similarity with fattening guinea fowl (Penkov and Nikolova, 2020) – the closest.

Conclusions

In female turkeys fattened during the grower and finisher periods by replacing part of the soybean meal (control – C) with 10% skimmed flour from black soldier fly larvae (BSFd) and 10% full-fat flour from mulberry silkworm larvae (SW), the following net utilizations of energy and protein in the chain fodder-breast and thigh muscles" have been identified:

Clarc of energy distribution: „fodder – breast", „fodder – thigh", "fodder – breast + thigh":

– Control (C) – 0.0581, 0.0241 and 0.0822 respectively.
– BSFd – 0.0545, 0.0258 and 0.0773 respectively.
– SW – 0.0566, 0.0253 and 0.0819 respectively.

Table 5. "Clarcs" of energy distribution/protein transformation

Indexes*	**Control group**	**BSFd – group**	**SW група**
Clarc of energy distribution "fodder-breast"	0.0581 (5.81%)	0.0515 (5.15%)	0.0566 (5.66%)
Clarc of energy distribution "fodder-thigh"	0.0241 (2.41%)	0.0258 (2.58%)	0.0253 (2.53%)
Clarc of protein transformation "fodder-breast"	0.1456 (14.56%)	0.1313 (13.13%)	0.1471 (14.71%)
Clarc of protein transformation "fodder-thigh"	0.0424 (4.24%)	0.0429 (4.29%)	0.0490 (4.90%)
Clarc of energy distribution "fodder-breast+thigh" (CED)	**0.0822 (8.22%)**	**0.0773 (7.73%)**	**0.0819 (8.19%)**
Clarc of protein transformation "fodder-breast+thigh" (CPT)	**0.1880 (18.80%)**	**0.1742 17.42**	**0.1961 (19.61%)**

– Clarc of protein transformation (respectively):
– C – 0.1456, 0.0424 and 0.1880.
– BSFd – 0.1313, 0.0429 and 0.1742.
– SW – 0.1471, 0.0490 and 0.1961.

We recommend the relevant coefficients as a basis for comparison in future studies that will use similar experimental methods.

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