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Influence of soybean meal replacement with high-protein sunflower meal on "Clarcs of energy distribution/protein transformation" in broiler chickens

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Abstract. *The aim of the study is to compare the net utilization of energy and protein in the eco-technical chain „feed-meat" when replacing part of the soybean meal with high-protein sunflower meal in broiler fattening. One control and 3 experimental groups, 4-phases fattening with isoenergetic and isoprotein combined fodders. Main protein source in the fodders for the control group is soybean meal. Replacement with sunflower meal: First experimental group: Starter - 5%, Grower - 8%, Finisher 1 - 10% and Finisher 2 - 10%; Second experimental group: 15, 18, 25 and 25%, respectively; Third experimental group: 34.25, 27.27, 27.27 and 26%, respectively. Clarcs of energy distribution/protein transformation (CED/CPT) are the ratio between accumulated gross energy/crude protein in breast and thigh muscles and consumed metabolic energy/crude protein throughout life. The following results were established: CED "fodder – breast+thigh muscles": Control - 0.2430, first experimental group - 0.2394, second experimental group - 0.2505, third experimental group - 0.2334; CPT - 0.6080, 0.5050, 0.5280 and 0.5490, respectively.*

Keywords: broilers, Clarc of energy distribution, Clarc of protein transformation, soybean meal, sunflower meal

Introduction

The net utilization of the energy and the protein in the chain "feed-farm animals-human food" becomes of an increasing interest in the scientific community (Pirgozliev and Rose, 1999). In this regard, in meat poultry farming it was proposed to introduce two objective criteria to describe and calculate mathematically these transformations - Clarc of energy distribution and Clarc of protein (amino acids) transformation (Penkov and Genchev, 2018).

Soybean meal is a major protein component in compound feed for poultry, which is also highly priced for countries that do not have serious production of it. Many countries cannot meet their own production needs and import large quantities from it. Replacing it with cheaper high-protein sunflower meal produced in those countries (including Bulgaria) could reduce the costs of poultry production. Senkoylu and Dale (1999) reviewed more than 100 scientific publications on the use of SFM in rations for birds and concluded that it could be successfully included in their rations by replacing 50-100% of soybean meal, depending on the type of other feed materials.

The data about the replacement of the soybean meal with sunflower meal/seeds are contradictory. Raiesh et al. (2006) reported that the replacements with 25, 50, 75 and 100% of the two meals don't influence significantly the abdominal fats and the edible carcass parts. Similar opinions are expressed by Fouzder et al. (2000) and Salari et al. (2009) who have conducted experiments with quails. Other authors (Ologhobo, 1991; El-Sherif et al., 1995; Brenes et al., 2008) report that the diets with sunflower meal affect negatively the edible parts, abdominal fats and internal organs growth. Araújo et al. (2011) conclude that the replacement of the soybean with sunflower meal up to 15% does not influence significantly the broiler's productive indices, but the highest amounts of replacement show negative effect.

It is very important how the replacement of the two meals will affect the biotransformation of nutrients in the chain "feed - broiler chickens".

The aim of the present study is to compare the net utilization of energy and protein in the eco-technical chain "feed-meat" when replacing part of soybean meal with high-protein sunflower meal in broiler fattening, using the indices "Clarc of energy distribution" and "Clarc of protein transformation".

Material and methods

The study was conducted in the Poultry Unit, Faculty of Agriculture, Trakia University, Stara Zagora, Bulgaria, during September - October 2020. The completely randomised experimental design included 120 one-day-old Cobb 500 broilers obtained from a local commercial hatchery. Upon arrival all chicks were individually weighted, wing-banded, and assigned randomly in four groups (control, experimental I, experimental II, and experimental III) of 30 birds each, with six subgroups (replicates) of 5 birds each. They were housed in experimental cages (complying with Directive 1999/74/EU) that were placed in an environmentally controlled experimental poultry house. Pens were equipped with

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plastic feeders and drinkers. All broilers were kept under the same management, hygienic and environmental conditions. The rearing environment complied with the breeder's recommendations (Cobb Broiler Management Guide, 2018). Water and feed were provided *ad libitum* throughout the experimental period. The experimental design covered broiler fattening up to 42 days of age.

The chickens from the control and experimental groups were fed in four phases: starter (1-7 days of age), grower (8-18 days of age), finisher I (19-28 days of age), and finisher II (29-42 days of age). Feed contained in all feeding phases the same amount of metabolizable energy: 12.45 MJ/kg, 12.66 MJ/kg, 12.96 MJ/kg, and 13.20 MJ/kg, respectively, crude protein (21.66, 20.02, 19.06, and 18.3%, respectively), lysine (1.23, 1.12, 1.02, and 0.97%, respectively), methionine+cysteine (0.90, 0.85, 0.80, and 0.76%, respectively), Ca (0.94, 0.84, 0.76, and 0.77%, respectively), and available P (0.45, 0.42, 0.39, and 0.39%, respectively).

For the birds of the control group, the main protein source was soybean meal, and in the experimental groups, it was replaced by high-protein sunflower meal as follow: First experimental group: Starter - 5%, grower - 8%, Finisher I - 10% and Finisher II - 10%; Second experimental group: 15, 18, 25 and 25%, respectively; Third experimental group: 34.25, 27.27, 27.27 and 26.00%, respectively.

Slaughter analysis was performed on 12 chickens (6 male and 6 female) with average live weight from each group at the end of the 42-day fattening period, according to Genchev and Mihaylov (2008).

The chemical analyses of breast and tight muscles were conducted according to the Weende methods (AOAC, 2007). The content of gross energy (GE) in the muscles was calculated by the formula of Schiemann et al. (1971):

GE = 0.0242*CP+0.0366*CF+0.017*NPE, where CP (Crude Protein), CF (Crude Fibre) and NPE (Non-Protein Extract) are in grams/kg native substance.

The metabolizable energy (ME) and crude protein (CP) input (from the fodder) were calculated by the formula:

(Content of ME/CP in consumed starter from 1 chicken*7 + Content of ME/CP in consumed grower from 1 chicken*10 + Content of ME/CP in consumed finisher I from 1 chick*10 + Content of ME/CP in consumed finisher II from 1 chicken*15) / 42.

The Clarcs of energy distribution and protein transformation (CED and CPT) were calculated according to the formula of Penkov and Genchev (2018):

CED (CPT) = Gross energy (Crude protein) accumulated in the breast and thigh muscles of 1 chicken/Metabolizable energy (Crude protein) consumed by 1 chicken for the whole life.

The statistical processing was done with the statistical package "Descriptive Statistic – Excel" - Microsoft.

Results and discussion

The consumed amounts of starter, grower and finishers from 1 broiler by feeding phases and groups, the content of ME and CP in each of the combined fodders so that the total consumed ME and CP by 1 chicken for the whole fattening period (entrance of the system) are shown in Table 1.

Table 1. Consumed fodder by periods, content of metabolizable energy (ME) and crude protein (CP), and ME and CP input at the entrance of the eco-technical chain (consumed ME and CP by 1 broiler for the whole fattening period)

Parameter	Group			
	Control	First experimental	Second experimental	Third experimental
Starter 1 - 7 day of age				
ME, MJ/kg	12.47	12.47	12.43	12.45
CP, %	21.70	21.64	21.68	21.68
Feed consumption per bird, kg	0.207	0.215	0.206	0.209
Grower 8 - 18 day of age				
ME, MJ/kg	12.68	12.69	12.69	12.70
CP, %	20.26	20.00	20.17	20.30
Consumed fodder by chicken for the period, kg	0.667	0.783	0.747	0.795
Finisher I, 19 - 28 day of age				
ME, MJ/kg	12.93	12.95	12.94	12.97
CP, %	19.01	19.02	19.01	19.06
Consumed fodder by chicken for the period, kg	1.167	1.098	1.110	1.115
Finisher II, 29-42 day of age				
ME, MJ/kg	13.21	13.22	13.20	13.22
CP, %	18.05	18.03	18.25	18.12
Consumed fodder by chicken for the period, kg	2.147	2.109	2.133	2.110
Consumed ME for the whole fattening period (MJ) - entrance of the system	54.49	54.72	54.56	55.05
Consumed CP for the whole fattening period (kg) - entrance of the system	0.7894	0.7922	0.7956	0.8015

On this base, the consumed amounts ME mean by 1 chicken vary insignificantly – from 54.49 (control group) to 55.05 MJ (third experimental group). The consumed amounts of crude protein were from 0.7894 kg (control group) to 0.8015 kg (third experimental group) without statistically proven significant differences (p>0.05). The consumed amounts of combined fodders by periods and groups do not show significant differences compared to the cited from Cobb Broiler Management Guide (2018) and the official for Bulgaria data (Todorov et al., 2016).

Table 2 shows the masses of breast and thigh muscles (without bones) mean from 1 chicken from the control and experimental groups. For the breast muscles the highest value is conducted for second experimental group - 1146.8 g, and the lowest - for third group - 1070 g. The control group shows a breast mass from 1100.8 g. The differences among the groups are statistically insignificant (p≥0.05).

Table 2. Average breast and thigh muscles weight by groups

Indices	Group			
	Control	First experimental	Second experimental	Third experimental
	x±Sx	x±Sx	x±Sx	x±Sx
Mass of breast muscles (mean from 1 chick), g	1100.8±38.2	1123.2±31.78	1146.8±7.74	1070.0±11.51
Mass of thigh muscles (mean from 1 chick), g	999.6±24.15*	1002.8±17.45[a]	1008.4±12.9[b]	928.8±12.89[*ab]
Mass of breast and thigh muscles (mean from 1 chick), g	2100.4±31.4*	2126.1±24.8[a]	2155.2±10.5[b]	1998.8±12.14[*ab]

- Statistical significance by p≤0.05 between control and third experimental group; a-a – between first and third experimental group; b-b – between second and third experimental group

The control group accumulates an average of 999.6 g thigh muscles. The highest value shows the second experimental group - 1008.4 g native muscles, and the lowest - the third experimental group – 928.8 g. The differences in the masses are statistically significant (p≤0.05) between the control and third experimental and between the third and the other experimental groups.

The low mass of the thigh muscles in the third experimental group influences negatively the total accumulated breast+thigh muscles (1.9988 kg) which is significantly lower (p<0.05) compared to the control (2.1004 kg), first (2.1261 kg) and second experimental group (2.1552 kg).

The chemical composition, the gross energy and the accumulated amounts of gross energy and crude protein in breast and thigh muscles are presented in Table 3. 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 to Guinea fowls (Nikolova, 2013) and the Japanese quails (Vasileva et al., 2014; Lukanov et al., 2018).

Generally, the birds from the three experimental groups have accumulated insignificantly more gross energy in their breast muscles and less in the thigh muscles compared to the control group. Statistical differences were observed between the control and the experimental groups for the accumulated crude protein in the breast muscles and for the accumulated gross energy in the breast and thigh muscles.

The calculation of Clarcs of energy distribution/ protein transformation shows the following features (Table 3): The highest net efficiency of utilization of the fodder's metabolizable energy is shown in the breast muscles of the birds from the second experimental group - 13.45%, whilst the efficiency of the control group is 12.63%. For the thigh muscles the highest efficiency is reported for the control group (11.67%), and the lowest in the third group (10.86%). The total Clarc of energy distribution (CED-breast+thigh) is the highest for the birds from the second experimental group (25.05%), and the lowest in the third experimental group - 23.34%. For the control group it is 24.30%.

The efficiency of utilization for the gross energy is significantly higher for the control group (34.20%, 26.60% and 60.80% for the breast, thigh and mixed muscles, respectively). The highest Clarc of protein transformation (CPT) for the experimental groups is reported for the breast muscles of the third group - 31.19% and the thigh muscles - in the second group (26.40%). For the muscle's mix the highest CPT is calculated for the birds from the third group - 54.90%.

When comparing the CED and CPT for the four groups of broiler chickens with those established for farmed Japanese quails (Penkov and Genchev, 2018) and Guinea fowls (Penkov and Nikolova, 2020) it is visible that the broilers from the *Gallus gallus domesticus* species have significantly higher net utilizations of the metabolizable energy and the crude protein.

Table 3. Chemical composition and gross energy content of the native meat (12 samples) and Clarcs of energy distribution (CED) and protein transformation (CPT)

Indices	Group			
	Control x±Sx	First experimental x±Sx	Second experimental x±Sx	Third experimental x±Sx
Crude protein in breast muscles (native), %	24.11±0.07	23.20±0.15	22.90±0.11	23.48±0.28
Crude protein in thigh muscles (native), %	21.02±0.10	20.54±0.15	20.69±0.11	20.78±0.14
Crude fats in breast muscles (native), %	1.29±0.06	1.33±0.03	1.39±0.05	1.21±0.02
Crude fats in thigh muscles (native), %	3.70±0.10	2.70±0.08	3.44±0.09	3.92±0.06
NPE in breast muscles (native), %	0.10±0.01	1.01±0.24	2.04±0.21	1.75±0.06
NPE in thigh muscles (native), %	0.10±0.01	2.70±0.08	0.10±0.01	0.1±0.01
Gross energy content in 1 kg native breast muscles (native), MJ	6.25±0.02	6.27±0.04	6.40±0.05	6.42±0.06
Gross energy content in 1 kg thigh muscles (native), MJ	6.39±0.02	6.04±0.07	6.28±0.05	6.44±0.05
Accumulated GE in breast muscles from 1 chick, MJ	6.88±0.05[a]	7.04±0.04	7.34±0.04[a]	6.87±0.03
Accumulated GE in thigh muscles from 1 chick, MJ	6.36±0.02[a]	6.06±0.02[a]	6.33±0.02	5.98±0.02[a]
Accumulated CP in breast muscles from 1 chick, kg	0.27±0.01[a]	0.20±0.01[a]	0.21±0.01[a]	0.25±0.01
Accumulated CP in thigh muscles from 1 chick, kg	0.21±0.02	0.20±0.02	0.21±0.01	0.19±0.01
CED (fodder – breast muscles)	*0.1263 (12.63%)*	*0.1287 (12.87%)*	*0.1345 (13.45%)*	*0.1248 (12.48%)*
CED (fodder – thigh muscles)	*0.1167 (11.67%)*	*0.1107 (11.07%)*	*0.1160 (11.60%)*	*0.1086 (10.86%)*
CED (fodder – breast + thigh muscles)	*0.2430 (24.30%)*	*0.2394 (23.94%)*	*0.2505 (25.05%)*	*0.2334 (23.34%)*
CPT (fodder – breast muscles)	*0.3420 (34.20%)*	*0.2525 (25.25%)*	*0.2640 (26.40%)*	*0.3119 (31.19%)*
CPT (fodder – thigh muscles)	*0.2660 (26.60%)*	*0.2525 (25.25%)*	*0.2640 (26.40%)*	*0.2371 (23.71%)*
CPT (fodder – breast + thigh muscles)	*0.6080[a] (60.80%)*	*0.5050[a] (50.50%)*	*0.5280[a] (52.80%)*	*0.5490[a] (54.90%)*

Note: NPE- Non-Protein Extract; GE- gross energy; [a-a] - the differences between the control and experimental group are statistically significant by p≤0.05; the differences were calculated only for the important for the calculation of Clarc's indices.

Conclusion

The following Clarcs along the eco-technical chain "fodder-broiler's meat" have been established: (i) Clarc of energy distribution for the control group - 0.1263, 0.1167 and 0.2430 for the breast, thigh and breast+thigh muscles, respectively; (ii) Clarc of energy distribution for the first experimental group - 0.1287, 0.1107 and 0.2394 for the breast, thigh and breast+thigh muscles, respectively; (iii) Clarc of energy distribution for the second experimental group - 0.1345, 0.1160 and 0.2505 for the breast, thigh and breast+thigh muscles, respectively; (iv) Clarc of energy distribution for the third experimental group - 0.1248, 0.1086 and 0.2334 for the breast, thigh and breast+thigh muscles, respectively; (v) Clarc of protein transformation for the control group - 0.3420, 0.2660 and 0.6080 for the breast, thigh and breast+thigh muscles, respectively; (vi) Clarc of protein transformation for the first experimental group - 0.2525, 0.2525 and 0.5050 for the breast, thigh and breast+thigh muscles, respectively; (vii) Clarc of protein transformation for the second experimental group - 0.2640, 0.2640 and 0.5280 for the breast, thigh and breast+thigh muscles, respectively; (viii) Clarc of protein transformation for the third experimental group - 0.3119, 0.2371 and 0.5490 for the breast, thigh and breast+thigh muscles, respectively. For the net energy utilization, the differences by groups are not significant. The control group shows significantly higher net utilization of the protein compared to the experimental groups.

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