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Examination of the influence of conjugated linoleic acid in broiler nutrition on the economic efficiency of fattening

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Abstract. The aim of this study was to examine the influence of the use of CLA (2%), from days 1, 11 or 22 of fattening, on selected production results (broiler weight after each fattening phase including at the end of fattening, viability, average daily gain and feed conversion) on the efficiency of fattening during the whole fattening period (42 days). The obtained production results were used to calculate the European production efficiency factor (EPEF) and the European broiler index (EBI) values for each fattening phase as well as for the whole fattening. The results obtained indicate that, in the later stages of fattening, the use of CLA during the whole fattening period is economically more justified than the non-CLA diets used for control broilers. With the use of CLA throughout the whole fattening, the EPEF and EBI values are consistent with these values calculated for the Cobb 500 standard. In addition to economic justification, the use of CLA also has human nutritional significance, since the broiler meat is enriched with CLA and has a more favourable n-6/n-3 fatty acid ratio.

1. Introduction

World poultry meat production, after decades of the primacy of pork production, equalized three years ago with pork production, and in 2020, it will be higher than the pork production. In total world meat production for the five-year average (2016-2020) of 323.25 million tons (mt), the amount of poultry meat was 122.82 (37.99%) mt. In Serbia, the total meat production for the five years (2015-2019) was 501.6 thousand tons, of which 97.8 thousand tons (19.59%) was poultry meat production [1, 2, 3]. In the last sixty years, poultry meat production has intensified in both developed and developing countries. In underdeveloped countries, poultry breeding has an extensive character, but it has great importance because it provides the poorest part of the population with meat and eggs as high-value foods, employs mostly female labour and enables the human population viability in unfavourable climatic conditions with underdeveloped agricultural production, e.g. with a small amount of water. In such circumstances, it is not possible to raise other types of domestic animals, except perhaps sheep and goats.

There has been progress in intensive poultry breeding, thanks primarily to genetic selection, reduction in fattening duration, and good feed conversion (below 1.77 kg of feed per kg of meat). Among meat species, poultry meat production is the most economically viable. In addition, poultry meat is a highly valuable food, especially breast meat (low in fat, high in protein). It has no religious restrictions, is easy to prepare, all parts of the carcass are usable, and it is the most common type of meat on the market.

One of the advantages of poultry meat is the ability to increase its nutritional value by choosing nutrients and supplements for live birds. This means that poultry meat can also be a functional food (it was first mentioned a little over 40 years ago in Japan and means food that, in addition to its usual ingredients, also contains ingredients that support certain human body functions). To date, there are several definitions of functional food, and from all definitions, we can conclude that functional food has additional nutritional value and serves to preserve human health via human nutrition. When we talk about poultry meat as a functional food, we primarily mean the possibility of increasing the content of n-3 fatty acids in meat (eggs), a more favourable n-6/n-3 fatty acid ratio, and enriching poultry meat and eggs with conjugated linoleic acid (CLA) [4, 5]. The fatty acid composition of poultry meat (eggs) is directly dependent on the fatty acid composition of broiler/laying hen diets. Thus, increasing n-3 fatty acids in poultry feed (with preparations of flax, green algae) improves the n-6/n-3 fatty acid ratio. Non-ruminant animals do not have the ability to synthesize CLA, so its occurrence in meat (eggs) is conditioned by its addition to animal diets. There are data that CLA can be found in meat (eggs) and poultry in whose diet CLA has not been added. However, these are insignificant amounts that are sometimes even below the detection threshold [6].

Of the numerous CLA isomers in poultry nutrition, two isomers are used: *cis*-9,*trans*-11 and *trans*-10,*cis*-12, which are in approximately the same ratio in commercial preparations. The isomer *cis*-9,*trans*-11 is most often stated to have an anti-carcinogenic effect in the human diet (cancer of the skin, breast, intestines, and liver), to reduce the occurrence or alleviate symptoms of diabetes, mitigate bone density loss and atherosclerosis, and to have a positive effect on reduction of chronic cardiovascular diseases [7, 8]. Isomer *trans*-10,*cis*-12 is considered to contribute to the reduction of obesity and to be of primary importance [7, 8]. In addition to meeting market needs, meat production (primary production) is especially interested in the economic viability of broiler fattening. In recent years, the economic viability of broiler fattening is most often expressed through the European production efficiency factor (EPEF) and the European broiler index (EBI).

The aim of this study was to examine the effect of using CLA in broiler feed on the economic efficiency of fattening.

2. Materials and Methods

The study was conducted on 240 one-day-old chickens of both sexes and the same origin (Cobb 500) during a 42-day period. At the beginning of the study, broilers were randomly allocated to one of four dietary treatments. Each experimental group contained 60 animals housed in groups of 10 birds per pen in six repetitions (stocking density = 0.15 m^2/head). Conditions in the facility (ventilation, heating, lighting, and relative humidity) were according to the technological standards and recommendations for this hybrid [9]. Pens were bedded with straw and provided with fresh water and feed *ad libitum*. At the beginning of the study, the temperature of the room was 32°C, and then was gradually lowered to 22°C that was maintained until the end of the study. During the trial, relative humidity was 60-70%. A continuous period of six hours of darkness was provided during the night. From the start of the trial, each group of broilers was fed with one of four experimental diets which comprised the same basal diet, but differed only in the content of CLA. Basal diet was formulated according to the recommendations for the Cobb 500 strain [10] (Table 1).

Table 1. Ingredients of diets

Component	*Starter K*	*Starter O*	*Grower K*	*Grower O*	*Finisher K*	*Finisher O*

Maize	50.85	48.85	44.15	42.15	44.95	42.95
Wheat	-	-	10.00	10.00	15.00	15.00
Soybean semolina	15.00	15.00	17.00	17.00	20.00	20.00
Soybean meal	12.40	12.40	1.00	1.00	1.00	1.00
Soybean cake	17.00	17.00	23.30	23.30	14.70	14.70
Monocalcium phosphate	1.20	1.20	1.00	1.00	0.90	0.90
Limestone	1.60	1.60	1.60	1.60	1.60	1.60
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Premix	1.00	1.00	1.00	1.00	1.00	1.00
Lysine	0.20	0.20	0.20	0.20	0.10	0.10
Methionine	0.20	0.20	0.20	0.20	0.20	0.20
Adsorbent	0.20	0.20	0.20	0.20	0.20	0.20
CLA	-	2	-	2	-	2

Diets fed from days 1 to 42 were starter (days 1–10), grower (days 11–21) and finisher (days 22–42). The proximate composition of all feed mixtures was analysed according to [11] (Table 2).

Table 2. Chemical composition of diets.

Mixture	Diet	Proteins	Moisture	Fat	Ash	Cellulose
		$\overline{X} \pm$ SD				
Starter (0-10)	K	24.98±0.57	8.04±0.24	6.09±0.37	5.45±0.14	2.04±0.05
	O	24.97±0.47	8.06±0.27	6.96±0.35	5.50±0.15	2.04±0.04
Grower (11-21)	K	22.17±0.21	9.38±0.09	7.03±0.26	4.88±0.13	2.16±0.04
	O	22.11±0.47	9.38±0.10	7.09±0.29	4.92±0.12	2.16±0.05
Finisher (22-42)	K	20.91±0.87	9.98±0.07	5.44±0.11	4.76±0.21	2.38±0.26
	O	20.78±0.80	10.00±0.06	5.46±0.06	4.72±0.22	2.57±0.24

The control (K) group was without addition of CLA in the feed mixture, the O-I group received starter feed with 2% CLA from the beginning, the O-II group received feed with 2% CLA from day 11 of growing, and the O-III group received feed with 2% CLA from day 22 of finishing. The mixtures were balanced and fully met the needs of the animals at all stages of fattening.

We examined the production results (average final weight gain BWG at each fattening period, average daily gain ADG, feed conversion ratio FCR) and mortality (%), and then calculated the economic efficiency of broiler production using the European production efficiency factor (EPEF) [12] and the European broiler index (EBI) [13]. The following formulas were used to calculate these indicators:

BWG (grams on period) = BW (g) at the end period- BW (g) in first d;
ADG (g/chick/d) = BWG/ days number of growth period;
FCR (kg feed/kg gain) = cumulative feed intake (kg)/total weight gain (kg);
Viability (%) = chicks remaining at the end of period (%);
European Production Efficiency Factor (EPEF):

$$EPEF = \frac{viability\ (\%) x\ BW\ (kg)}{age\ (d)\ x\ FCR\ (kg\ feed/\ kg\ gain)}\ x\ 100$$

European Broiler Index:

$$EBI = \frac{viability\ (\%) x\ ADG\ (g/broiler/d)}{FCR\ (kg\ feed/\ kg\ gain) x\ 10}$$

Results were compared by statistical analysis using Microsoft Excel 2010 and GraphPad Prism software, version 8.00 for Windows (GraphPad Software, San Diego, California USA, www.graphpad.com). To determine the significance of the differences between the examined groups of compared parameters, we used analysis of variance (ANOVA), followed by Tukey's *post hoc* test. Testing the significance of the difference between the arithmetic means of the compared parameters and the standard value (prefixed according to the recommendations for this hybrid [9]) were conducted according to Petz et al. [14]. Differences were considered significant if the observed value was $p < 0.05$.

3. Results

Table 3 presents the production results and economic efficiency indicators of the Cobb 500 broiler fattening. There were no statistically significant differences between the average broiler weights ($p > 0.05$) on days 10, 21 and 42. There were no statistically significant differences between the average daily gain (from 31 to 32 g) on day 10. On day 21, the average daily gains were from 92.8 to 95.5 g and also did not differ statistically significantly. As there were no differences in the average broiler weights at the end of fattening, there were no statistically significant differences in the average daily gain on day 42. Compared to the standard values from the Cobb 500 Guide, the average broiler weights (Figure 1) on days 10, 21, and 42 were not statistically significantly different for control and experimental groups. Group O-I had a numerically higher average weight (2862 g) compared to the average standard Cobb 500 weight (2857 g). The statistical significance of the differences in feed conversion between our control and experimental groups and the Cobb 500 standard is present in Figure 2. On day 10, feed conversion values were from 1.46±0.12 (O-I) to 1.79±0.15 (O-III). Feed conversion values on day 21 were from 1.56±0.13 (O-I) to 0.169±0.14 (O-III). Feed conversion values of broilers that received CLA in feed were statistically significantly higher than the standard Cobb 500 feed conversion value on day 10 (1.05 kg) and day 21 (1.26 kg). At the end of fattening, the average feed conversion values were from 1.69±0.14 (O-I) to 1.87±0.14 (O-III). There was no statistically significant difference between the average feed conversion value of group O-I and the standard Cobb 500 feed conversion value or of the group O-II feed conversion value and the standard Cobb 500 feed conversion value, and these values were statistically significantly less than the feed conversions of the control (no CLA) and group O-III.

Table 3. Production results and parameters of economic efficiency of broiler fattening.

Fattening days	Parameters	K	O-I	O-II	O-III
1 to 10	BW (kg)	0.320	0.310	0.320	0.310
	ADG (g)	27.69	26.30	27.69	27.69
	FCR (kg feed/kg gain)	1.67	1.46	1.66	1.79
	Viability (%)	100	100	100	100
	EPEF	191.62	212.33	192.77	173.18
	EBI	165.81	180.14	166.89	154.69
1 to 21	BW (kg)	0.947	0.928	0.955	0.952
	ADG (g)	47.35	44.10	46.58	45.18
	FCR (kg feed/kg gain)	1.66	1.56	1.66	1.69
	Viability (%)	100	100	100	100
	EPEF	285.24	297.44	291.16	281.66

	EBI	272.11	282.69	278.54	267.34
1 to 42	BW (kg)	2.762	2.862	2.672	2.717
	ADG (g)	65.18	67.19	62.66	62.68
	FCR (kg feed/kg gain)	1.88	1.69	1.72	1.87
	Viability (%)	100	100	100	100
	EPEF	350.56	403.21	370.08	346.11
	EBI	346.17	397.53	364.30	336.26

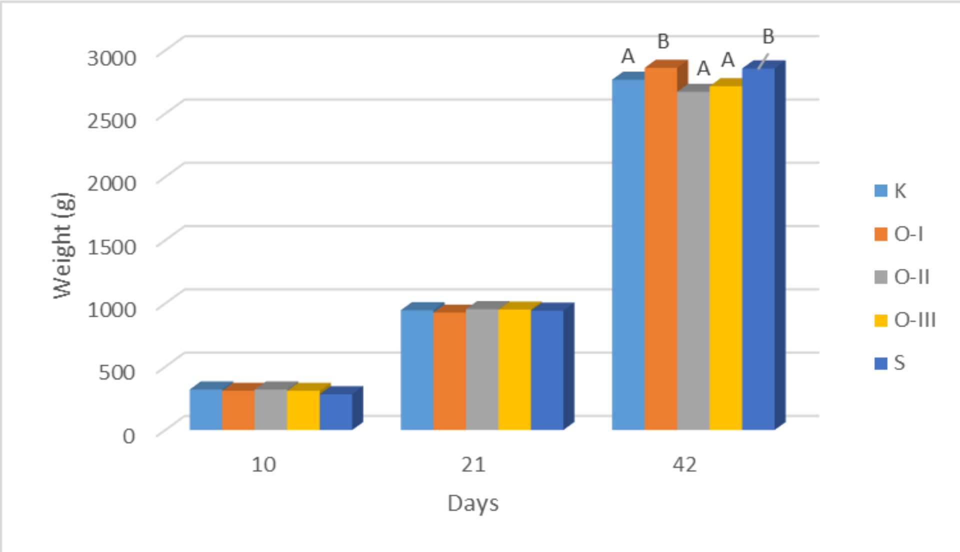

Figure 1. Average broiler weights and standard Cobb 500 weights during fattening.
Different letters A and B indicate different average broiler weight, p<0.05

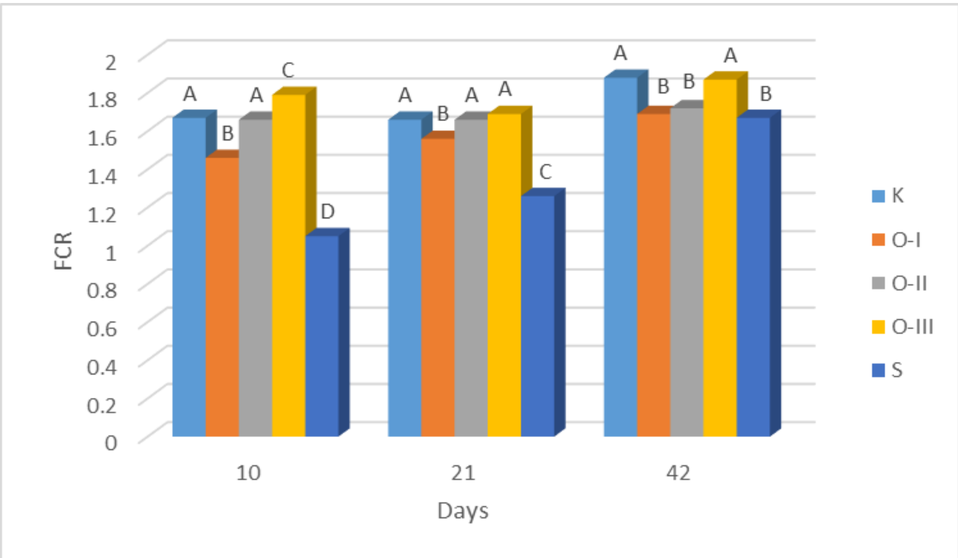

Figure 2. Average feed conversion values (kg) and standard Cobb 500 feed conversion values.
Different letters A, B, C and D indicate different feed conversion values, p<0.05

Figure 3 presents the EPEF values of the studied broilers and the EPEF value calculated for the standard Cobb 500. The EPEF value of group O-I on day 10 was statistically significantly higher (p

<0.05) than the EPEF values of K, O-II, and O-III groups. For the same period, the standard Cobb 500 EPEF value was statistically significantly higher compared to the control and experimental groups. On day 21, a statistically significantly higher EPEF value was calculated for the Cobb 500 standard in relation to the EPEF value of the control and experimental groups of broilers. On the same day, there were no statistically significant differences between the average EPEF values of the control and experimental groups. At the end of the fattening, EPEF values of O-I and the Cobb 500 standard did not differ statistically, but they were both statistically significantly higher compared to the control, O-II, and O-III groups.

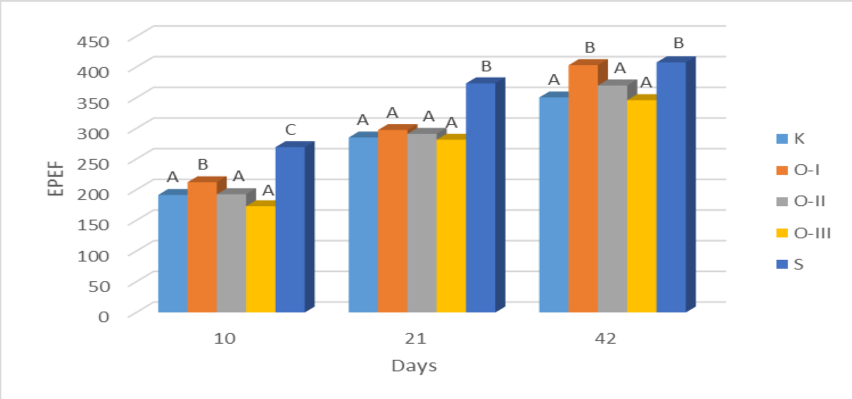

Figure 3. EPEF values of broilers and standard Cobb 500 EPEF values.
Different letters A, B and C indicate different EPEF values, $p<0.05$

On days 10 and 21, the EBI of the Cobb 500 standard was statistically significantly higher than the EBI values of the control and experimental groups (Figure 4). By the end of fattening, the EBI value of group O-I and the EBI value of the Cobb 500 standard did not differ significantly, and they were statistically significantly higher than the EBI values of groups K, O-II, and O-III.

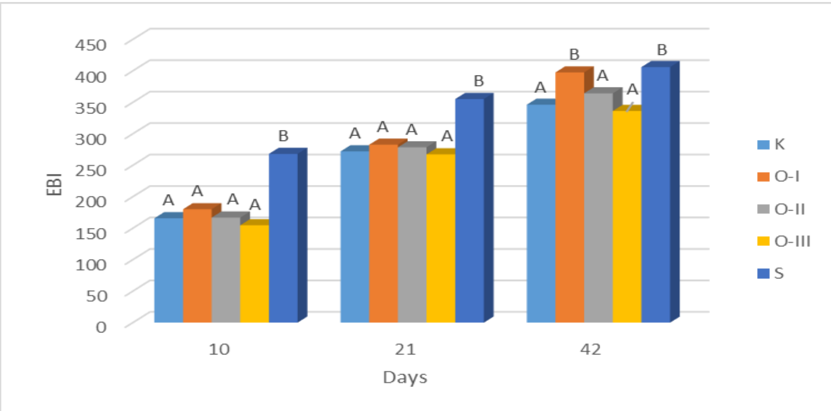

Figure 4. EBI values of broilers and standard Cobb 500 EBI values.
Different letters A and B indicate different EBI values, $p<0.05$

4. Discussion

The cost-effectiveness of broiler fattening is one of the particularly important factors that has contributed to the increase in broiler meat production in the past few decades. It depends on the total value of fattening and the cost of fattening. As the value of fattening increases and the cost of fattening decreases, the economy of fattening increases. In recent years, two indices have been used to calculate the cost-effectiveness of fattening: EPEF and EBI. To calculate the EPEF, we used a formula that includes the viability of broilers, their weight, and also the feed conversion for each fattening stage and for the whole fattening. The EBI value is calculated from a formula that includes viability, average daily gain, and feed conversion for each stage of fattening [12, 13, 16, 17]. Higher EPEF or EBI values indicate a better fattening economy [12, 18]. The key factor in both these economic efficiency indices is the feed conversion ratio, because feed accounts for about 70% of the costs in today's large broiler fattening systems. The other 30% of costs are fixed costs (depreciation, one-day-old chicks, energy costs, labour, broiler health care) [15]. The feed conversion value in broilers has been reduced thanks primarily to genetic selection, while diet was far less important for feed conversion reductions [18, 19].

Our results indicate that the feed conversion values (Figure 2) had the greatest impact on the EPEF and EBI values. On days 10 and 21, broiler weight did not affect the EPEF values, and on day 42, it had an impact but far less so than the feed conversion values. The standard Cobb 500 feed conversion values were significantly lower on days 10 and 21 than feed conversion values for the control and experimental groups of broilers, which resulted in higher values of EPEF and EBI. ADG (g) did not have a significant effect on the EBI values, since the values of this parameter on day 10 were between 26.30 g and 27.069 g, on day 21 were between 44.10 g and 47.35 g, and on day 42 were between 62.66 and 67.19 g (Table 3). However, on day 42, the feed conversion values for groups O-I and O-II were at the level of that of the Cobb 500 standard, so an impact on the EPEF and EBI values was seen at the end of fattening. The high viability of the broilers can be explained by optimal breeding conditions, primarily by the small number of broilers in the groups and good initial performance of the one-day-old chicks (vitality, uniform weights).

There are numerous data in the literature on the effect of adding CLA to the broiler diets on production results in fattening, and they are often contradictory [20, 21, 22, 23]. However, the use of CLA in non-ruminant diets should not be seen only in terms of production results (final weight, weight gain, conversion) but also from the standpoint of the nutritional value of meat. In non-ruminants, the use of CLA in the diet is important because it provides meat with added value, since the meat contains CLA in an amount that depends on the amount of CLA added to the diet. The animal fattening duration also plays a role. This added value is not only the CLA content but is also the improved n-6/n-3 fatty acid ratio in the meat, as has been seen in pork with CLA addition. The importance of CLA and the n-6/n-3 fatty acid ratio is well known in human nutrition. Meat with added value can be labelled as a functional food, so it would understandably fetch a higher price, which should be reflected in the economic profitability of fattening [24, 25, 26, 27]. Poultry meat enriched with CLA is of special importance given the fact that the total production and consumption of poultry meat in the world have increased to 39% of total meat production and to 15 kg per capita per year, respectively [1]. The use of meat with high CLA content in human nutrition could gradually result in lower mortality from chronic non-communicable diseases and contribute to a lower number of people suffering from these diseases.

5. Conclusion

The results in this paper support the use of CLA in broiler nutrition, since this is economically justified given the good production results (broiler weight at the end of fattening, feed conversion, growth) and the resultant broiler meat has added value and can be defined as a functional food. To calculate the economic justification of fattening, the use of EPEF or EBI values are justified since these indices are based on broilers' production results. These indices can be applied in different conditions, such as comparison of the cost-effectiveness of fattening different broiler hybrids, different feed compositions, different lengths of fattening period, the influence of different climatic conditions on production results, etc.

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References
[1] https://www.statista.com/statistics/237632/production-of-meat-worldwide-since-1990/
[2] Statistički godišnjak Republike Srbije 2020:222
[3] Statistički godišnjak Republike Srbije 2017:250
[4] Markovic R, Ciric J, Strcevic M, Sefer D and Baltic M Z 2018 *Poult. Sci.* **97** 166–76
[5] Baltic M Z, Dokmanovic Starcevic M, Basic M, Zenunovic A, Ivanovic J, Markovic R, Janjic J and Mahmutovic H 2015 *Anim. Feed Sci. Technol.* **210** 225–33
[6] Kumari S, Meng J G and Ebrahimi M 2017 *Int. J. Food Prop.* **20** 491–506
[7] Yuan G, Chen X and Li D 2015 *J. Agr. Food Chem.* **63** 1883–95
[8] Kim J H, Kim Y, Kim Y J and Park Y 2016 *Annu. Rev. Food Sci. Technol.* 7 221–44
[9] Cobb-Vantress, 2018a, Cobb 500. Broiler Performance and Nutrition Supplement. https://www.cobb-vantress.com/products/cobb500. (accessed on 8 August 2020)
[10] Cobb-Vantress, 2018б, Broiler Management Guide. https://www.cobbvantress.com/resource/management-guides. (accessed on 15 April 2019)
[11] A.O.A.C. Official Method of Analysis 1995 16th ed., AOAC. Washington, DC
[12] Marcu A, Vacaru-Opris I, Dumitrescu G, Petculescu Chiochina L, Marcu A, Nicula M, Pet I, Dronca D, Kelciov B and Maris C 2013 *J. Anim. Sci. Biotechnol.* **46** 339–46
[13] Van I 2003 *Growth and Broilers Industrialization* ed Ceres (Bucharest) 235–6
[14] Petz B, Kolesarić, V and Ivanec, D 2012 *Petzova statistika: Osnovne statističke metode za nematematičare* (Jastrebarsko: Naklada Slap)
[15] Tesic M and Nedic D 2015 *Ekonomika veterinarstva* (Fakultet veterinarske medicine Beograd)
[16] Aviagen, 2019, Ross 308 / Ross 308 FF Broiler Performance Objectives. https://en.aviagen.com/brands/ross/products/ross-308 (accessed on 8 August 2020)
[17] Susim M R, Achintya B and Ganesh B 2020 *Int. J. Poult. Sci.* **19** 338–45
[18] Lukić M, Petričević V, Škrbić Z, Delić N, Tolimir N, Dosković V and Rakonjac S 2020 *Biotechnol. Anim. Husb.* **36** 447–62
[19] Havenstein G B, Ferket P R and Qureshi M A 2003 *Poult. Sci.* **82** 1500–8
[20] Jiang W, Nie S, Qu Z, Bi C and Shan A 2014 *Poult. Sci.* **93** 1202–10
[21] Halle I, Jahreis G, Henning M, Köhler P and Dänicke S 2012 *Journal für Verbaucherschutz und Lebensmittelsichetheit* **7** 3–9
[22] Cardinal K M, Moraes M L, Borille R, Lovato G D, Ceron M S, Vilella L M and Ribeiro A M L 2017 *J. Agric. Sci.* **9** 208–16
[23] Moraes M, Ribeiro A M L, Santin E and Klasing K 2016 *Poult. Sci.* **95** 237–46
[24] Baltic Z M, Markovic R and Djordjevic V 2011 *Meat Technol.* **52** 154–9
[25] Djordjevic J, Pantic S, Boskovic M, Markovic R, Dokamovic-Starcevic M, Baltic T, Laudanovic M and Baltic M Z 2015 *Meat Technol.* **56** 109–19
[26] Boskovic M, Baltic M Z, Ivanovic J, Djuric J, Dokmanovi M, Markovic R, Sarcevic D and Baltic T 2015 *Meat Technol.* **56** 8–15
[27] Pantic S, Ivanovic J, Glamočlija N, Janjic J, Markovic R, Nesic K and Baltic M Z 2016 *Meat Technol.* **57** 102–9