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ECONOMIC ASPECTS OF VALUE-ADDED EGG PRODUCTION
EKONOMSKI ASPEKT PROIZVODNJE JAJA SA DODATOM VREDNOŠĆU

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ABSTRACT

In order to determine the profitability of value-added egg production, an economic analysis of the production costs incurred therein was performed. The cost of feed mixture for laying hens can be calculated as the sum of the raw material costs and the total mixture production and processing costs. The results obtained indicate that the production cost of value-added eggs (with increased contents of omega fatty acids and the use of natural pigments) was higher by RSD 3-9 than that of control eggs. The cost of currently available S class omega eggs approximates to 23 RSD/pc. Accordingly, the current cost of omega eggs in the Serbian market is higher by 4-9 RSD/pc than that of standard commercial eggs of the same class. Therefore, it can be concluded that the value-added egg production achieved in our experiment is extremely cost-effective and fully justified economically.

Key words: *flaxseed, camelina seed, natural pigments, table eggs, omega-3 eggs.*

REZIME

Da bi se utvrdila isplativost proizvodnje konzumnih jaja sa dodatom vrednošću urađena je ekonomska analiza troškova proizvodnje ovakvih jaja. Cena smeše za ishranu kokoši nosilja može se izračunati kao suma cena sirovina i troškova proizvodnje i prerade kompletne mešavine. Cena kontrolne smeše sa dodatim sintetičkim pigmentima (K1) i prirodnim pigmentima (K2) iznosila je 42,79 din/kg, odnosno 44,42 din/kg. Cena eksperimentalnih smeša zavisi od izvora ω-3 masnih kiselina i iznosi od 63,83 din/kg za smeše gde su kokoši nosilje hranjene lanom do 108,46 din/kg za smeše gde su kokoši nosilje hranjene lanikom. Cena komercijalne kompletne smeše za kokoši nosilje iznosi oko 40 din/kg. Na osnovu analize dobijenih rezultata dolazi se do cene jajeta sa dodatom vrednošću (povećan sadržaj omega masnih kiselina i upotreba prirodnih izvora pigmenata umesto sintetičkih pigmenata) koja bi morala da bude veća za 3-9 dinara od komercijalno proizvedenog jajeta. Cena komercijalno proizvedenih jaja S klase (mase od 65g do 70g) kreće se od 14 do 19 din/kom, u zavisnosti od proizvođača. Cena trenutno dostupnih omega-jaja S klase na tržištu, za koje je deklarisan samo povećan sadržaj omega masnih kiselina (bez upotrebe prirodnih pigmenata), iznosi oko 23 din/kom, dok cena domaćih jaja hranjenih na slobodnom ispustu iznosi oko 22 din/kom. Dakle, trenutna cena omega-jaja na tržištu je veća za 4-9 din/kom od standardnih komercijalnih jaja iste klase. Stoga se može zaključiti da je proizvodnja jaja sa dodatom vrednošću, prikazana u našem ogledu, višestruko isplativa i ekonomski u potpunosti opravdana.

Ključne reči: *lan, lanik, konoplja, prirodni pigmenti, komercijalna jaja, omega-3 jaja.*

INTRODUCTION

Eggs are one of the most complete foods in human nutrition. They are characterized by a very well-balanced content of proteins, fats, carbohydrates, vitamins and minerals (*Milošević and Perić, 2011*). However, with the increasing consumer awareness and their demand for "healthy" food, concerns about the use of eggs in everyday nutrition are mounting. Yolk colour has traditionally been considered a significant feature of egg quality (*Rakita et al., 2016*). However, consumers' concerns about the use of synthetic pigments for egg yolk colouration in the industrial production have been gaining increased attention due to their detrimental effects on human health (*Grashorn and Steinberg, 2002; EFSA, 2014*). Nowadays, eggs used in human nutrition are rich in n-6 polyunsaturated fatty acids (mainly linoleic acid) and have very low contents of n-3 fatty acids such as ALA (α-linolenic), DHA (docosahexaenoic acid) and EPA (eicosapentaenoic acid) (*Spasevski, 2018*).

The modernization and intensive rearing of animals fed cereals (corn, sunflower, soy, etc.) rich in unsaturated fatty acids (primarily linoleic acid) have led to a discrepancy in the ratio between n-6 and n-3 fatty acids in the meat of fattened animals (pigs, poultry and fish) and the eggs produced. This type of diet increased the ratio of n-6/n-3 from 1-2:1 to 15-20:1, which was reflected in an increase in typical modern age diseases (*Simopoulos, 2009*). The increased incidence of cardiovascular diseases, cancer, inflammatory and autoimmune diseases in the last two decades was attributed to the deficiencies of n-3 fatty acids in the diet (*Simopoulos 2001; 2002*) due to the competition between omega-6 and omega-3 fatty acids for enzymatic desaturation. Although both enzymes (Δ-5 and Δ-6 desaturasses) prefer omega-3 versus omega-6 fatty acids, this process is slow and disabled by a high linolic acid intake, which is typical for nutrition in developed countries (*Simopoulos, 2009*).

This knowledge has led consumers to become more interested in products enriched with omega-3 fatty acids. Although a great amount of these fatty acids is found in fish and seafood (*Laca et al., 2009*), the consumption of these foods is at a very low level in most countries, which is why it is necessary to search for other alternative sources. Eggs can be enriched by changing the diet of laying hens, what allows the production of eggs with increased contents of desirable functional ingredients (*Grčević et al., 2011*). The most straightforward method of producing eggs with an increased content of n-3 fatty acids is to incorporate oilseed seeds and oil (flaxseed, rapeseed, camelina seed, hempseed, etc.), as well as fish oil and algae, in the diet of laying hens (*Yannakopoulos et al., 2005; Sujatha and Narahari,* *2011; Gakhar et al., 2012; Cherian and Quezada, 2016; Kralik and Lovrekovic, 2018*). The amount and composition of n-3 fatty acids from such sources are very different. Therefore, the source of n-3 fatty acids, their composition and the amount to be incorporated into the diet for laying hens must be carefully planned (*Bhalerao et al., 2014*). The main goal is to increase the level of omega-3 fatty acids to satisfy the daily needs of people when consuming one egg (*Grashorn, 2005*). However, there are limits in the quantity of oilseeds added to the feed without affecting animal health and performance, as well as the final product acceptability. Therefore, the following considerations should be taken into account: the sensory properties of the product, the costs of incorporating oilseeds rich in omega-3 fatty acids into the diet of laying hens, and the expiry date of such products (*Lopez-Ferrer et al., 1999; Zuidhof et al., 2009*).

The increased amount of these healthy compounds in the egg yolk will simultaneously increase the price of functional eggs thus produced. Therefore, the purpose of this paper is to determine the economic cost-effectiveness of such type of egg production.

MATERIAL AND METHOD

Dietary treatment

A total of 240 Lohmann Brown layers were enrolled in the study and allocated to eight treatment groups (2 control and 6 experiment treatment groups). The control (K1 and K2) laying hens were fed a corn-soybean meal basal diet (Table 1), whereas the experimental (E1-E6) laying hens were fed a corn-soybean meal based diet with the addition of co-extrudate of linseed, camelina seed and hempseed (as presented in Table 2).

The control treatment K1 involved using synthetic pigments (0.055 g/kg), whereas the control treatment K2 and all the experimental treatments (E1-E6) involved the same amount of natural pigments (1% carrot and 0.5% paprika). All the hens were housed in individual wire cages with feed and water available *ad libitum*.

Sample collection and analysis

Laying hens were fed for four weeks, after which 10 eggs were randomly chosen and analysed. The fatty acid composition of eggs was determined using the Agilent 7890A system (Agilent Technologies, Santa Clara, CA, USA) gas chromatography, as described by *Spasevski et al.* (*2016*).

Table 1. Composition of complete mixtures for laying hens

Ingredients (%)	Treatment	
	K1	K2
Corn	57.60	57.60
Soybean meal	20.00	20.00
Sunflower meal - 33% protein	8.50	8.50
Soybean oil	1.30	1.30
Yeast	2.00	2.00
Monocalcium phosphate	1.20	1.20
Sodium bicarbonate	0.10	0.10
Premix	1.00	1.00
Limestone	8.00	8.00
Salt	0.30	0.3
Paprika		0.50
Carrot		1.00
Synthetic pigment (g/kg)*	0.055	

Control treatment K2 contains: 0.04 g/kg carophyll red and 0.015 g/kg carophyll yellow

Table 2. Share of co-extrudate in the mixtures for laying hens

Treat.	Co-extrud. (mix. of oilseed and corn meal in the 1:1 ratio)	Share of co-extrud[%]	Share of fat from co-extrud. [%]
E1	linseed + corn meal	13.5	3
E2	linseed + corn meal	22.5	5
E3	camel. seed+corn meal	16.6	3
E4	camel. seed+corn meal	27.6	5
E5	hempseed + corn meal	18.4	3
E6	hempseed + corn meal	30.7	5

RESULTS AND DISCUSSION

With a special mixture design, it is possible to increase the content of some functional ingredients in table eggs such as omega-3 fatty acids, selenium, vitamins (vitamins E and A) and carotenoids (*Aziza et al., 2013; Skřivan et al., 2015; Spasevski et al., 2016; Kralik and Lovrekovic, 2018*). The main issue regarding the consumption of such eggs is their cost, which is somewhat higher than the cost of table eggs. However, with a specially designed mixture, an increase in omega-3 fatty acids can be achieved with a minimal increase in the price of eggs.

Table 3 shows the cost of mixtures and the egg production costs (according to the consumption of the mixture needed for the production of one egg). Upon comparing the costs of control and experimental eggs, it was established that the costs of buying laying hens, their breeding, labour costs and distribution costs are the same in all the cases studied. Therefore, differences in the costs of eggs can be attributed to the differences in the cost of feed for laying hens. The cost of complete mixture can be calculated as the sum of the cost of raw materials and the cost of the mixture production and processing, which approximates 15% of the total raw material price. The costs of control mixture with added synthetic pigments (K1) and with natural pigments (K2) were 42.79 RSD/kg and 44.42 RSD/kg, respectively. It can be noted that the production costs of eggs containing natural pigments (K2) were very similar to the production costs of eggs with synthetic pigments (K1), which indicates that, from the economic perspective, there is no reason to use synthetic pigments instead of natural ones. According to the *Regulation on Animal Feed Quality (2010),* it is allowed to use synthetic pigments in the industrial egg production in Serbia in quantities up to 80 mg/kg individually or in combination with carotenoids (although they can be harmful to human health). Apart from free range eggs available in the Serbian market, there are no table eggs which contain natural sources of pigments.

Table 3.Cost of mixtures for feeding laying hens and the cost of table eggs and omega-3 eggs

Treatments	Cost of mixtures (RSD/kg)	Cost of egg production (RSD/pc)
K1	42.79	5.6
K2	44.42	5.8
E1	63.83	8.3
E2	68.62	8.9
E3	108.46	14.1
E4	142.72	18.6
E5	80.56	10.5
E6	98.39	12.8

The cost of the commercial complete mixture for laying hens approximates to 40 RSD/kg. The cost of experimental mixtures depends on the source of ω-3 fatty acids and share of co-extrudates in the mixtures (share of fat from co-extrudates). The cost of mixtures with a 3 % share of fat ranged from 63.83 RSD/pc, when hens were fed a linseed based diet, to 108.46 RSD/pc, when hens were fed a camelina seed based diet. With the addition of co-extruded linseed, camelina seed and hempseed in the amount of 13.5% (E1), 16.6% (E3) and 18.4% (E5) into the diet of laying hens, the production costs of omega-3 eggs have increased in comparison to the production costs of table eggs (Table 3). Based on the analysis, the cost of added-value egg production (increased contents of omega fatty acids and the use of natural pigments) should be higher by RSD 3-9 than commercially produced table eggs. In Serbia, the cost of commercially produced eggs of the S class (weights from 65g to 70g) ranges from 14 to 19 RSD/pc, depending on the manufacturer. The cost of currently available omega-eggs of the S class, with the increased content of omega-fatty acids and without the use of natural pigments, is approximately 23 RSD/pc. However, the cost of free range eggs is about 22 RSD/pc. Therefore, the current cost of omega-eggs on the market is higher by 4-9 RSD/pc than standard commercial eggs of the same class. Moreover, the ratio of n-6/n-3 fatty acids in egg yolks when hens were fed the E1, E3 and E5 diets was 1.41, 1.74 and 5.09, respectively (*Fig. 1*). According to *Simopoulos (2000)* and *Kralik (2008)*, the ratio of omega-6/omega-3 fatty acids in egg yolk lipids less than 4:1 is considered to be beneficial to human health. Accordingly, it can be concluded that the value-added egg production achieved in our experiment is extremely cost-effective and fully justified economically. When hens were fed mixtures with higher share of co-extrudates (5% of fat), the costs of mixtures and egg production were higher and ranged from 68.62 to 142.72 RSD/kg and from 8.9 to 18.6 RSD/pc, respectively. The addition of larger s of linseed, camelina seed and hempseed based co-extrudates into the diet of hens resulted in a better ratio between omega-6 and omega-3 fatty acids (*Fig. 1*). However, this wasn't economically sustainable because the desirable ratio of omega-6/omega-3 fatty acids was even achieved with a lower share of co-extrudates (linseed and camelina seed based co-extrudates). The addition of co-extruded hemp seed with shares of 18.4 % and 30.7 % (E5 and E6) to the diet of hens caused a significant decrease in the n-6/n-3 ratio in comparison to control eggs, but this ratio was still higher than 4:1.

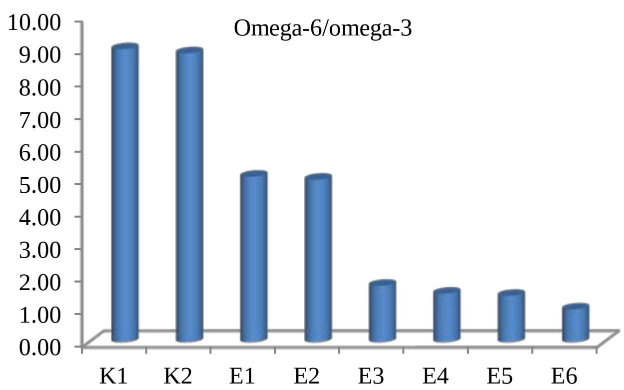

Fig. 1. Ratio of omega-6/omega-3 fatty acids in egg yolks

One way in which consumers can reduce the risk of cardiovascular and other degenerative diseases is the consumption of ω-3 fatty acids that have been shown to have a positive effect on human health. The insufficient consumer education about the usefulness of these fatty acids, low standard of people in Serbia and higher prices of omega-3 eggs than those of table eggs contributed to low popularity of such eggs in the domestic market. However, omega-3 eggs are already popular in many parts of the world and consumed by health-aware consumers who are willing to pay extra for these eggs *(Bhalerao et al., 2014)*.

CONCLUSION

In the Serbian market, there are no table eggs (except free range eggs) which contain natural sources of pigments (as opposed to synthetic pigments). On the basis of the results obtained, we can conclude that the production costs of eggs containing natural pigments were very similar to the production costs of eggs with synthetic pigments. The addition of linseed, camelina seed and hempseed based co-extrudates (fat share of 3%) to the diet of laying hens resulted in achieving the desirable ratio of omega-6/omega-3 fatty acids in egg yolks. The production cost of eggs enriched with omega-3 fatty acids and natural pigments (carrot and paprika) should be higher by RSD 3-9 than commercially produced table eggs. Therefore, the production of these eggs with added value is extremely profitable and fully justified economically. Conversely, the addition of larger amounts of oilseed based co-extrudates (fat share of 5%) to the diet of hens proved economically unsustainable even though the desirable ratio of omega-6/omega-3 fatty acids was achieved.

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