EFFICIENCY OF EGG PRODUCTION IN DIFFERENT ORGANIZATIONAL CONDITIONS

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ABSTRACT

In the past few decades, egg producers have faced numerous difficulties, including reduced egg consumption due to consumer concerns about egg cholesterol content, egg production's adverse environmental effects, a ban of conventional cages for rearing layers etc. Therefore, egg producers in Serbia need to constantly monitor their business efficiency indicators and strive to manage costs. In this study, four farm models were formulated to analyze their production costs and to establish and compare the values of economic efficiency indicators, before and after the transition to an enriched cage system, as well as with and without the possibility to produce and process part of feed components for complete mixtures for layers. According to obtained results, transition to an enriched cage system on the observed farms would cause an increase in total production costs between 5.1 and 5.3% and the purchase of complete mixtures on the market, between 2.3 and 5.8%. Also, anticipated organizational changes would have a negative effect on most economic efficiency indicators, reducing them by 5.2–49.5%, but would also lead to productivity improvement for the farm with the semi-automated production process.

Introduction

Until 2020, egg production in Serbia was organized so that the laying hens were mostly kept in a conventional cage system, implying keeping layers indoors during the entire period of flock production, in completely controlled conditions in terms of lighting,

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ventilation, nutrition, water distribution, manure removal and health care (available at: www.agroinfo). Although rearing layers in a conventional battery system requires significant investments, it also ensures a relatively quick refund and constant cash inflow during the production process which makes egg production profitable (Đoković, 2019). When it comes to facilities and equipment, modern technological solutions enable layers to reach their full production potential and allow the automation of the production process, with one employee rearing 15 to 50 thousand layers, resulting in the rationalization of labor usage (Milošević, Perić, 2011).

Nevertheless, the last few decades have brought more than one difficulty to egg producers. Initially, producers struggled with reduced egg consumption as a result of concerns by a large number of consumers regarding egg cholesterol content, which could potentially be harmful to their health. However, many research findings deny the connection between moderate egg intake and elevated blood cholesterol levels (Narahari, 2003; Nakamura et al., 2006; Jones, 2009; Virtanen et al., 2016; Abdollahi et al., 2019), and it will take much time until eggs take the place that they deserve in the human diet. This requires raising consumer's awareness of the importance of eggs in human nutrition, given that they are a source of useful proteins, fatty acids, vitamins and minerals (Applegate, 2000; Pavlovski et al., 2011; Miranda et al., 2015; Tolimir et al., 2016).

In the following years, this issue was accompanied by a number of problems related to environmental effects, especially ammonia emissions, followed by the health and safety of poultry workers and people living near poultry facilities regarding the potential transmission of zoonotic disease, as well as food safety, primarily potential for bacterial contamination in different housing systems (Mench et al., 2011).

However, focusing on hen welfare had the strongest impact on egg production. Images from poultry houses with a large number of layers reared in relatively small spaces, (usually cages), not being exposed to natural light for their entire life and not having freedom of movement, have contributed to the great expansion of alternative housing systems for layers in many countries (Rakonjac, 2017). Growing concerns about hen welfare led to the ban of conventional cages in the European Union from 2012 and transfer to enriched cages or some of the alternative housing systems. By 2016, in EU countries, 55.6% of the hens were housed in enriched cages, 25.7% in barn systems, 14.1% in free-range systems and only 4.6% in organic systems (Windhorst, 2017). Studies focusing on the implications of transfer to alternative housing systems have indicated a number of negative effects on egg production. The survey conducted in Belgium showed that a large number of Flemish egg farmers, almost 34%, terminated their business because of the ban on conventional cages and they experienced the time available to convert to a new housing system, as well as the communication from the government, as negative (Stadig et al., 2016). Also, as the main concerns arising from the transfer to alternative housing systems, Croatian farmers point out the increase in production costs, reduced competitiveness and unsatisfactory egg prices (Crnčan et al., 2014).

A similar study in Serbia showed that farmers were poorly informed about the transfer to alternative housing systems planned from 2020 and indicated the need for better awareness and understanding of hens welfare, banning the import of conventional batteries, providing support for investments in new equipment, developing an egg marking system and conducting consistent inspections (Rodić et al., 2014).

Many Serbian egg producers were burdened by a possible decrease in production cost-effectiveness and profitability due to the transition to an enriched cage system or one of the alternative housing systems, which required more comprehensive analyses of the economic efficiency of egg production in different housing systems (Đoković, 2019). This is why it was beneficial not only to examine and compare main business success indicators in different housing conditions but also in different organizational conditions.

Materials and methods

To achieve the research goals, several data sources were used. The most important data source was the financial and operational records of the observed farms for the production of table eggs. The data were collected and summarized in 2019, right before the mandatory transition to alternative housing systems. Data on natural and economic indicators of realized costs and business results, applied housing system for layers, mechanization and labor supply, organization of the production process, etc. were obtained by field research. It required direct observation, participant observation, qualitative interviews, using relevant documents and categorizing and analyzing collected data. Four farms, of different capacities, operating in different organizational conditions, were visited, in order to formulate a model for each one of them. Data were gathered on the observed farms by interacting with farm owners and their employees. Accordingly, the basis for further data processing was created through observations made on the farms and by studying and analyzing available production capacities, calculations and production plans, accounting records and financial plans, work standards and employee records.

Also, national and international statistical publications and databases of importance for the subject of research, such as the Food and Agricultural Organization (FAO), International Trade Center (ITC), the Statistical Office of the Republic of Serbia etc. were employed to gather data concerning production, prices of table eggs, reproductive materials and other inputs.

The main goal of the research was to establish and fully comprehend some of the factors (applied housing system, way to provide feed for layers and the level of automation of the production process) that contribute to achieving different levels of economic efficiency of farms for the production of table eggs and their quantification.

Consequently, the following assumptions have been made:

• The transition from a conventional to an enriched cage system affects the achieved economic efficiency of farms for the production of table eggs by reducing it, and

• Different organization of the production process, in terms of providing feed for layers and the automation of the production process, affects the level of production costs, and thus the level of achieved economic results on the observed farms.

Any comparison of absolute values of indicators implies the existence of identical production conditions for each observed organizational unit, which can certainly be provided in experimental conditions, but is almost impossible to find in production practice.

Accordingly, conducting this research first required the application of modeling method in order to ensure comparability of the obtained performance indicators and to neutralize the influence of subjective factors that affect business results. Therefore, the formulation of the model implied that all observed farms use the same layer hybrid and apply the recommended production technology, have the same flock production period. Similarly, calculations should be made with the same, average prices of all inputs and outputs, and under the same commercial and financial conditions.

Four models of egg production farms were formulated to enable description, prognoses and analyses of characteristics and achieved results, before and after changes caused by the ban of conventional cages and other organizational conditions, hereinafter – farms I, II, III and IV.

Models formulated based on observed farms for the production of table eggs involve maintenance of the same hybrid Lohmann brown-classic, the application of technology within standards recommended for this hybrid and the observation period of 57 weeks, from 18 weeks of age when laying hens were included until the 74th week of age when they were excluded from the production process.

HOUSING SYSTEM on the observed farms included rearing layers in conventional and enriched (furnished) cages.

The total capacity of farm I was 122,688 layers, which were equally distributed in six poultry houses. From a total of 3,456 enriched cages on farm I, 3,312 cages were categorized as large (for groups of 36 layers), and 144 cages as medium (for groups of 24 layers).

Farm II had 8,520 conventional cages designed for groups of 10 layers, amounting to a total of 85,200 layers. The cages were arranged in three larger poultry houses with a total capacity of 7,200 cages and a smaller one containing 1,320 cages.

Farm III had one poultry house with 1,200 enriched cages containing a total of 34,800 layers. Out of the total number of cages, 1,080 were designed for groups of 30 layers and categorized as large, while 120 were designed for groups of 20 layers, classifying them as medium.

Farm IV had organized production in three poultry houses with 6,528 conventional cages designed for groups of 5 layers. The total capacity of farm IV is 32,640 layers, distributed in two larger poultry houses containing 12,240 layers each and a smaller one containing 8,160 layers.

In accordance with modern achievements in the field of the automation of the egg production process, most of the work on farms I, II and III was automated when it came to food and water distribution, temperature and humidity regulation, manure removal, collecting, classing and packing eggs, as well as monitoring and control both at the level of individual poultry houses and the entire farm. On Farm IV, unlike other observed farms, some operations within the production process had to be performed manually, namely operations concerning monitoring and control, collecting and packing eggs, feed delivery from feed mixer to poultry houses, measuring feed quantity and managing the time of its distribution.

PRODUCTION VALUE was calculated based on the average price of eggs in the period of the production cycle provided by the Statistical Office of the Republic of Serbia and the prices for cracked eggs and hens excluded from production were calculated as the average of the prices that could be achieved by the leading processors of eggs and poultry meat and slaughterhouses on the domestic market during the production cycle. Farms sporadically generated revenues from the sale of poultry manure which were not included in the production value calculation since they were generally equal to or slightly below the costs incurred by manure removal.

EGG PRODUCTION COST DATA In accordance with the most commonly used methods of cost classification and methods of keeping records on the observed farms, the following cost classification was formulated and applied:

1. Production costs, which included the following categories.

a) Pullet cost – All observed farms used pullets from a commercial hatchery. The price of 18-week-old layers was calculated as the average price of the leading breeders on the domestic market in the observed period.

b) Feed cost -– Feeding mixtures used on the observed farms comply with the recommended nutritional composition standards for Lohmann Brown-Classic layers and were adapted to the needs of reared hybrid according to their age. Therefore, mixtures differed in composition (nutrient ratio), while dietary phases differed in duration: the first mixture for layers was used in the period from 18 to 45 weeks of age (for 28 weeks), the second from 45 to 65 weeks of age (for 20 weeks) and the third mixture was used from the 65th week until the end of the production cycle (in the last 9 weeks).

Farms I and IV had their own feed mixers, while farms II and III purchased complete mixtures on the market. Farm IV provided the necessary components exclusively on the market, while farm I produced some components. Only a small part of corn and soybean production on farm I was organized on its own land, while most of it was organized on rented, state-owned agricultural land by exercising preemptive lease rights due to egg production. Prices of purchased individual components or complete mixtures used in layers diet were obtained using the average annual purchase prices of agricultural products and the average prices of leading fodder factories on the domestic market for the observed period. The lease price of land in the observed period was calculated as the average lease price per hectare of state-owned agricultural land in the district where farm I, which organized crop production in order to provide part of the feed for layers, was located. The prices of feed components produced by farm I were calculated on the basis of applied production technology and realized variable costs. The corresponding part of fixed costs in crop production was included in the egg production costs since the complete volume of corn and soybean production was used as feed for layers. Input prices in crop production (seeds, fertilizers, pesticides etc.) were calculated as the average realized in the observed period using specialized government databases.

c) Other costs – This group of costs was calculated based on each farm documentation in the observed period and it consisted of costs concerning energy, water, printing and labeling materials, control of layers health and egg quality, medications, nutritional and medical supplements, disinfection, disinsection and deratization, etc.

d) Labor cost – Within the calculation of labor costs, the minimum gross wages were used when it came to employees with lower educational levels, and the average gross wages for this type of agricultural production when it came to employees with higher educational levels, all based on official government publications and databases.

e) Housing cost – This category of costs included depreciation costs, interest costs and maintenance costs for poultry houses, other facilities and installed equipment and was calculated using farm documentation for the period of flock production.

f) General costs – The group of general costs was also calculated relying on farm records for the observed period, and it consisted of insurance costs, costs of uniforms and protective equipment, costs of bookkeeping services (if realized externally), business audit costs, costs of professional training for workers (symposia, seminars, etc.), costs of computer equipment and software maintenance, etc.

2. Sale costs include two cost categories.

a) Packaging costs – The calculation of packaging costs included only the transport packaging costs, and was obtained by multiplying the number of transport boxes and other packaging materials with their average market prices. The retail packaging costs are charged within the price of eggs, and were reimbursed when sold to customers, while packaging costs related to printing and labeling materials were already calculated within the category of other costs.

b) Distribution costs – Egg distribution costs were calculated based on farm records for the flock production period. The distribution included order processing, product handling from the farm's storage to the place of delivery and transport costs, mainly fuel, oil, tolls, registration, insurance etc.

After formulating the models, an economic analysis of farm business was performed. In order to establish the success of the observed farms, the value of production and total costs were determined. The gross financial result was calculated as the difference between the previous two.

The indicators of business success in the different housing systems and organizational conditions were established before and after mandatory transition to alternative housing systems and other organizational changes.

Finally, a comparative analysis was used to establish and interpret the difference in the indicators of business efficiency of the observed farm models, both realized before and after mandatory transition and anticipated, changed conditions. In addition, the comparison of the achieved results was performed to provide alternatives concerning decision making and possible directions in the future development of the production of table eggs.

Results and discussion

Production value, costs and financial result analysis

The amount, share and occurrence of certain cost categories were determined by numerous, mainly organizational factors, which indicated the need to analyze the structure of total costs on the observed farms (Table 1).

Table 1. The structure of total costs in the period of flock production on the observed farms

Cost category	Farm I		Farm II		Farm III		Farm IV	
	000 RSD	%	000 RSD	%	000 RSD	%	000 RSD	%
I Production costs	237,210.5	87.2	175,788.2	84.0	72,383.9	85.3	65,168.8	89.1
- Pullet cost	56,927.2	20.9	39,532.8	18.9	16,147.2	19.0	14,875.8	20.3
- Feed cost	106,779.6	39.3	93,915.1	44.9	39,317.6	46.3	36,482.4	49.9
- Other costs	23,185.1	8.5	10,284.1	4.9	2,982.4	3.5	2,119.5	2.9
- Labor cost	13,816.8	5.1	10,984.5	5.2	4,035.0	4.8	4,639.8	6.3
- Housing cost	24,909.4	9.1	14,031.4	6.7	8,312.9	9.8	5,689.4	7.8
- General costs	11,592.4	4.3	7,040.3	3.4	1,588.8	1.9	1,361.9	1.9
II Sale costs	34,770.3	12.8	33,364.4	16.0	12,522.4	14.7	7,971.5	10.9
- Packaging costs	12,900.4	4.8	9,199.3	4.4	3,652.2	4.3	3,147.8	4.3
- Distribution costs	21,869.9	8.0	24,165.1	11.6	8,870.2	10.4	4,823.7	6.6
III Total cost (I+II)	271,980.8	100.0	209,152.6	100.0	84,906.3	100.0	73,140.3	100.0

*Source: A*uthors' calculations

At the beginning of each production cycle, pullet costs must appear in the production of table eggs. Judging by their share in the total costs, they usually come in the second place, right after the feed costs. According to Van Horne (2014), the average share of pullet costs in total production costs was 19.2% in the EU in 2013. Based on the results obtained on the observed farms in Serbia, the share of pullet costs in the total costs does not vary significantly from the EU average and ranges from 18.9% to 20.9%.

Within the total costs of egg production, feed costs take the largest share. Feed costs realized during the production cycle on the observed farms were in line with the farm capacity, i.e. they were the highest on farm I, with the largest number of layers, and the lowest on farm IV, with the smallest number of layers. However, observed per capacity unit, the situation is significantly different. Farm I had the lowest feed costs per housed hen, amounting to 852.2 RSD, while the amount of these costs on farms II, III and IV was 1,102.3 RSD, 1,129.8 RSD and 1,117.7 RSD, respectively.

The main advantage of farm I, in terms of realized feed costs, comes not only from a fully automated feeding process, but also from the fact that it organizes crop production to ensure part of the components for layers diet. The decision to produce only corn and soybeans on the total cultivated areas on farm I was based on the fact that corn and soybean semolina participate with about 75% in each of the three mixtures used as a feed for layers. The processing of soybeans into soybean semolina was performed within the farm's feed mixer. By extruding 100 kilograms of soybeans, an average of 98 kilograms of soybean semolina could be obtained, and losses of 2% in the extrusion process increased the cost price of soybean by 0.4 RSD per kilogram. During the period of flock production, 48.2% of the total required quantities of corn and 51.5% of the total required quantities of soybean semolina were provided by farm I, through its own production, while achieving savings in total feed costs compared to other observed farms.

When it comes to layers' nutrition, in addition to the composition of feed mixtures and the prices of components, according to Matthews and Sumner (2015), the total feed costs oscillate due to variations in the amount of feed per bird and the average egg production per bird over the life of a flock, as in the feed waste in different housing systems. The conversion ratio has slowly improved over the past few decades, largely as a result of the efforts of poultry breeders, which comprise a separate industry from the table egg industry, and individual producers can improve the conversion ratio through management techniques, but for the most part, they cannot influence it significantly in the short-run (Sumner et al., 2008). On the other hand, feed waste belongs more to the scope of egg producers, since it primarily results from the feeding process organization and automation level. Accordingly, even though Farm IV had made savings by making mixtures in its own feed mixer, the way the feeding process was organized had contributed to the farm being ranked second in terms of realized feed costs per housed hen.

The amount of other costs on the observed farms depends on many factors such as farm capacity, water supply (wells or city water supply), number of poultry houses and other facilities, leased and owned agricultural land, etc. During the production cycle, the highest amount of other costs was noted on farm I, primarily due to land lease costs. Their share in other costs was quite significant, about 46%, given that only this farm organizes crop production to provide part of the feed for layers and that it is organized mostly on leased land.

There are numerous factors affecting labor costs, but the most influential factors determining the required number of employees are farm capacity, the organization of the production process and the level of automation. On the other hand, in addition to the required number of employees, the amount of labor costs is determined by employee's qualifications and price per working hour.

According to Caspari et al. (2010), in the EU, the average share of labor costs in total costs for 2008 was 4.7%. Results obtained on the observed farms in Serbia showed that labor costs ranged between 4.8% and 6.3% and did not decrease proportionally to farm capacity, mainly due to employee qualification structure and the degree of automation of the production process. Consequently, the labor costs on farm IV, which has a lower capacity, but engages more manual work, were higher compared to farm III.

Housing costs are affected by the value of fixed assets at the beginning and end of their use, length of the period of use, applied depreciation rates, the share of own and borrowed funds in total funds, interest rates, the frequency of equipment failures, and the price of spare parts, etc. Therefore, farms I and III, with enriched cages and newer equipment and facilities, had significantly higher housing costs per housed hen (203.0 and 238.9 RSD) compared to farms II and IV, with conventional cages (164.7 and 174.3 RSD).

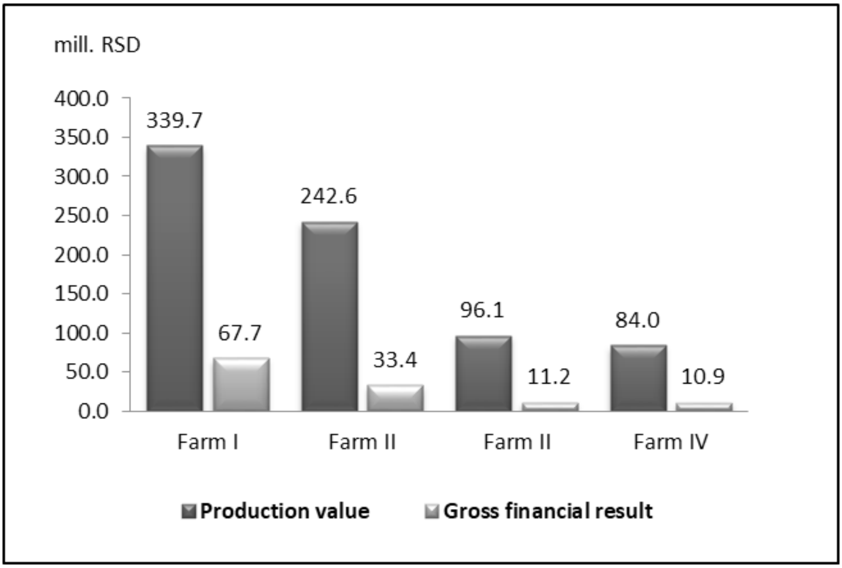
The share of general costs in total costs on the observed farms ranged from 1.9% on smaller capacity farms to 4.3% on the farm with the largest capacity. The amount of this cost category was mostly determined by insurance costs, as well as auditing costs that occur on farms that are legally obliged to perform annual audits.

Results obtained on the observed farms showed that realized sale costs range from about 8 million RSD on the farm with the lowest capacity up to 34.8 million RSD on the farm with the largest capacity. However, observed per capacity unit, the burden of sale costs was the highest on farm II, reaching 391.6 RSD, followed by farm III, I and IV with 359.8, 283.4, and 244.2 RSD per housed hen, respectively.

Significantly higher sale costs on farms II and III were realized due to high distribution costs since these farms have a large distribution network that extends throughout the entire territory of Serbia. In addition, delivery made by these farms was done, for the most part, directly to retail stores, even to large retail chains. On the other hand, regarding distribution costs on farm I, some savings were made, given that eggs were delivered to larger customers to central warehouses, while the lowest amount of these costs was realized on farm IV as a result of a relatively modest distribution network, extended mainly on the local market.

As previously mentioned, production value was calculated as the total volume of produced eggs and hens excluded from production sold at average market prices, and on the observed farms it ranged between 84.0 and 339.7 million RSD (Figure 1).

Figure 1. Realized production value and gross financial result in the period of flock production on the observed farms



*Source: A*uthors' calculations

Observed per capacity unit, the highest gross financial result (gross profit) was achieved on farm I in the amount of 551.7 RSD, while farms II, III and IV realized 392.8, 321.7 and 333.8 RSD per housed hen, respectively. Based on achieved results, farm I was significantly ahead of other observed farms, as it was the only farm that organized crop production in order to provide part of the feed for layers and accomplished considerable savings in feed costs.

Economic efficiency indicators

To establish the business success of the observed farms for the production of table eggs, the basic indicators of economic efficiency were calculated and presented in Table 2, namely cost-effectiveness (production value/total costs), profitability (gross profit/ production value) and productivity (gross profit/labor cost).

Table 2. Economic efficiency indicators on the observed farms

Indicator	Farm			
	I	II	III	IV
Cost-effectiveness	1.25	1.16	1.13	1.15
Profitability	19.93	13.79	11.65	12.96
Productivity	24.58	22.09	23.82	18.11

*Source: A*uthors' calculations

The calculated indicators of economic efficiency on all observed farms showed that egg production was cost-effective and profitable with a satisfactory productivity level. Judging by all the economic efficiency indicators, the best results were achieved on farm I. The slightly lower value of these indicators was realized on farms with lower capacity due to considerable investments in new equipment on farm III and semi-automation of the production process on farm IV.

Since the law in Serbia forbids rearing layers in conventional cages since 2020, the calculation of costs incurred by transferring to an enriched cage system has been performed on farms II and IV.

The increase in total production costs given in Table 3 represents the difference between newly incurred liabilities, based on credit funds raised for new equipment, and savings made in labor costs, based on full production process automation.

Table 3. An increase in total costs of the production cycle on farms II and IV due to the transition to an enriched cage system (000 RSD)

Category	Farm	
	II	IV
Newly incurred loan repayment costs	11,061.8	5276.4
Decrease in labor costs	-	1,558.0
Increase in total production costs	11,061.8	3,718.4

*Source: A*uthors' calculations

Farm II had a fully automated production process, even before the transition to an enriched cage system, so the savings in labor costs were calculated only for farm IV. Therefore, the transition to an enriched cage system caused an increase in total production costs between 5.1 and 5.3% on these farms.

Also, farmers face numerous difficulties related to the possibility of organizing their crop production to obtain part of the components for making complete mixtures, as well as the possibility of building their capacities for feed processing.

Possibilities of reducing production costs through organizing crop production are limited due to the availability of land resources, changes in legislation related to the right of the pre-emption of state-owned agricultural land and farm's ability to meet the application requirements, prospects for providing mechanization and other necessary resources for crop production, etc. Hence, if there were no opportunities for the production and processing of some mixture components, this would inevitably lead to an increase in feed costs on farms I and IV (Table 4).

Table 4. An increase in feed costs in the production cycle on farms I and IV due to the purchase of complete mixtures on the market (000 RSD)

Category	Farm	
	I	IV
Feed costs – own production of some components and/or processing	106,779.6	36,482.4
Feed costs – purchase on the market	133,208.5	38,160.6
Increase in feed costs	26,428.9	1,678.2

*Source: A*uthors' calculations

Based on the data from Table 4, it can be noted that there would be an increase in feed costs if there were no organizational conditions enabling the production and processing part of the components for layers' nutrition. Feed costs would be higher by 1.68 million RSD on farm IV and 26.43 million RSD on farm I, although an increase in total production costs on farm I would be 15.78 million because of the reduction in other costs by 10.65 million RSD, which is the amount that farm pays for the leased land. Therefore, an increase in feed costs would lead to an increase in total costs ranging between 2.3 and 5.8%.

The transition to an enriched cage system and the purchase of complete feed mixtures on the market would have a negative impact on most economic efficiency indictors of the observed egg farms (Table 5).

Table 5. Economic efficiency indicators on the observed farms after the transition to an enriched cage system and the purchase of complete mixtures on the market

Indicator	Farm			
	I	II	III	IV
Cost-effectiveness	1.18	1.10	1.13	1.07
Profitability	15.28	9.23	11.65	6.54
Productivity	24.58	22.09	23.82	27.27

*Source: A*uthors' calculations

The comparative analysis points to the fact that the only increase could be expected in productivity on farm IV due to reduced labor costs, while all other indicators would decrease or, at best, remain unchanged. Most of the calculated business performance indicators reached the highest values on farm I, even with a reduction ranging from 5.6 to 23.3%.

Farms II and IV, with conventional cages, would endure the strongest negative effects of anticipated changes. On farm II, the reduction of economic efficiency indicators would range from 5.2 to 33.1%, while the strongest impact would occur on farm IV whose profitability would be almost halved, reduced by 49.5%. On the other hand, farm IV would endure significant productivity elevation, by about 50%.

By comparing obtained results, it can be concluded that the producers' concern about the transition to an enriched housing system was completely justified. This transition represents a certain "de-intensification" of table egg production followed by increased costs due to the purchase and installation of new equipment, and in some cases, the reconstruction of existing or building new poultry houses. Also, the absence of organizational conditions to produce and process feed components on their farms would limit producers' alternatives for cost management.

Conclusions

Changes in organizational conditions have a considerable effect on egg production total costs and, consequently egg producers' business performances. Some of these changes are uncontrollable and lawfully mandatory, while others are within the producer's scope.

The results of the conducted study confirmed both assumptions made about the impact of the housing system, the way of providing feed for layers and the level of automation of the production process on the business efficiency of the observed farms.

When it comes to the ban on conventional cages, study results showed that the transition to enriched cages had the strongest impact on profitability, which endured a reduction almost by half on the farm with the semi-automated production process. The transition from semi-automation to full automation of the production process was twofold regarding costs. It caused an increase in costs due to the investments in new equipment, and a reduction in labor costs due to fewer employees. However, as full automation required a much larger investment than labor cost savings, such a change had an adverse effect on total production costs.

Therefore, it can be concluded that the transition to an enriched cage system inflected economic efficiency indicators negatively, which was most noticeable in the farm's profitability and accumulative capacity. Additionally, the economic motivation of a large part of producers who had old technical solutions within conventional cage systems was questioned by the reduction of financial results due to this mandatory transfer.

Obtained results also showed that the possibility to produce and process part of feed components for layers allowed farms to make some savings in feed costs. For egg producers, a lack of opportunities to organize crop production and/or build capacities for its processing would mean an increase in total costs between 2.3 and 5.8%, which would further lead to a deterioration of economic efficiency indicators.

That is why egg producers should consider options to improve business performance through organizing crop production and building their feed mixers whenever organizational conditions allow it. Also, obtained results may be used as a foundation for further research to measure and assess the economic efficiency of investments in land purchase to organize the production of main components for layer nutrition.

Conflict of interests

The authors declare no conflict of interest.

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