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The Egg Production Efficiency Index (EPEI) as an economic indicator for measuring poultry egg production

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Abstract

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The aim of the study was to introduce an up-to-date index for evaluation of economic efficiency of egg production in domestic fowl. The proposed egg production efficiency index (EPEI) was calculated using the following equation: EPEI = [(L × DEMP)/FCR)] × 100, where: L – Liveability (%); DEMP – Daily egg mass produced (kg); FCR – Feed conversion ratio (kg/kg egg mass). DEMP = (HDEP x AEW)/t, where HDEP – Hen-Day egg production (number); AEW – Average egg weight (kg); t – period (days). The ideal egg production efficiency index, calculated on the basis of a full production period, equals 310. For a production period of 52-81 weeks, EPEI of 230 may be estimated as a threshold for modern white and brown egg layer hybrids. EPEI may be also applied for monitoring of efficiency of egg production dynamics in a given group of stock layer hens. The index may be also used in other domestic fowl species.

Keywords: table eggs; production efficiency; egg production; FCR; egg weight

Introduction

Broiler and egg production are the two main branches of industrial poultry farming. Both are outlined with a substantial growth at a global scale, making poultry farming the most rapidly developing livestock husbandry sector (Mottet & Tempio, 2017). In 2020, about 133 million tonnes of poultry meat have been produced, with domestic chicken being the main fowl species (share of approximately 90%). For the same year, egg production was 93 million tonnes with 93.2% chicken eggs (FAOSTAT, 2022). Poultry meat and egg production are based on competitive relationships between producers of genetic material as well as the final produce. The production of quality and low-cost production is essential. The most commonly used parameter of feed transformation in poultry products (meat, eggs) is feed conversion ratio. This parameter is mainly of practical value and is determined on the basis of consumed feed and obtained produce (weight gain, 1 kg egg mass) for a specific period – the lower the FCR values, the more efficient the production (Yi et al., 2018; Lukanov, 2022). Another similar parameter important in poultry selection, is the residual feed intake (RFI), which is determined on the basis of observed feed intake and predicted feed intake, metabolic body weight and either the weight gain or egg mass for a specific production period, depending on the production type (Fathi et al., 2021). Unlike FCR, RFI may assume both positive and negative values; birds with negative RFI values are valuable for breeding programs (Zhang et al., 2017).

Broader indices, based on liveability and specific features related to production period duration also exist. Today, several indices are introduced and applied in broiler chicken farming to indicate the efficiency of production of a given broiler chicken hybrid. These are the European Production Efficiency Factor (EPEF) and the European Broiler Index (EBI), based on economically relevant traits as liveability, growth performance and feed conversion (Marcu et al., 2013). Apart in broiler chickens, these indices are applied also in fattening of quails (Lukanov, 2022), turkeys (Huff et al., 2013), ducks (Biesek et al., 2022), geese (Nemati et al., 2020), etc. In some literature sources, the more general term Productive Efficiency Index (PEI) is used instead of EPEF (Stringhini et al., 2006; Martins et al., 2016; Oliveira et al., 2018). Historically, several variants of the so-called Performance index have been proposed, which did not take into account the liveability (Bird, 1955). Schmidt (2008) has used the ratio of daily weight gain to feed conversion for PEI calculation.

Contrasting to meat-type poultry farming, the efficiency of stock or breeder eggs production is evaluated mainly through FCR. Narahari et al. (1983) have proposed the so-called Net feed efficiency index (NFEI) for determination of production efficiency of layer hens. The authors used several traits: difference between initial and final live weight of layers, the produced egg mass, and feed conversion for the production period. A disadvantage of NFEI is that it does not account for the influence of liveability and the number of produced eggs during the given period. The liveability is one of the main traits with direct effect on the economic efficiency of egg production (Zavala, 2021) and indicator of poultry health and welfare (Elson, 2015). The hen-day egg production is also an important trait with direct effect on economic efficiency of production of breeder and stock eggs, as they are usually marketed per number and not per kg. In stock egg production, the egg weight is relevant for its price, therefore eggs are graded by weight (EC, 2008). Morgan & Carlson (1968) have proposed the Performance efficiency index (PEI), with emphasis on egg-type poultry farming. It is based on the egg mass produced over a 30-day period related to live body weight, egg laying intensity and average daily feed consumption for the given period. Again, the liveability of the flock is not included, which may be pointed out as a disadvantage of the index. The latter may be avoided with use of egg production/egg laying intensity per hen housed. Kavtarashvili (2015) presents egg production efficiency indices used in Russia. One is identical to that proposed by Morgan & Carlson (1968), and the other is tied to production costs and expected income from the sale of eggs and poultry at the end of the productive period. The main disadvantages of this index are related to the impossibility of international and temporal comparability, even when using a unified currency, due to the different economic models and poultry farming practices. The same author also presents a European egg production efficiency coefficient based on egg mass and feed conversion obtained, having the weaknesses of NFEI.

The absence of a modern and generally applicable index for assessment of production efficiency of eggs from domestic fowl species on the basis of main traits involved in determination of production costs is at the background of the present study's conception. Thus, the aim of the study was to introduce an up-to-date index for evaluation of economic efficiency of egg production in domestic fowl.

Material and Methods

Data used for the study purposes were supplied by two of global leaders in layer hen production. The egg layer hybrids were grouped as followed: white egg layer hybrids, brown egg layer hybrids, silver egg layer hybrids, black egg layer hybrids and all-purpose egg layer hybrids. One popular layer hen hybrid was selected for comparison from each of these groups. Data from a 52-week production period in free-range production systems were included. The following traits were analysed: liveability (%), egg production (number), average egg weight (kg) and feed conversion (kg/kg egg mass), calculated as ratio of total feed consumption (kg) to produced egg mass (kg) for the period.

For comparison of egg production efficiency between the two most popular production systems: cage and free-range, data from the technological documentation of popular white, brown and silver egg layer hybrids for a 52-week production period were used.

The dynamics of changes in the proposed egg production efficiency index and associated traits was monitored on the basis of data from the technological documentation of one of the most popular brown egg layer hybrids reared in free-range systems. An important prerequisite of such analysis on egg production was to use cumulative data of studied traits. A production period of 81 weeks was followed.

The proposed egg production efficiency index (EPEI) is calculated using the equation:

$$EPEI = [(L \times DEMP)/FCR)] \times 100$$
$$DEMP = (HDEP \times AEW)/t$$

where: L – Liveability (%); DEMP – Daily egg mass produced (kg); FCR – Feed conversion ratio (kg/kg egg mass); HDEP – Hen-Day egg production (number); AEW – Average egg weight (kg); t – period (days).

The EPEI results were compared to NFEI and PEI, calculated as followed:

$NFEI = [(EM + BW) \times 100]/FC$, where EM – egg mass produced per bird (g); BW – difference between initial and final live body weight (g); FC – feed consumption per bird (g) (Narahari et al., 1983)

$PEI = [(30 \times EW/BW) \times EW \times P] / F$, where EW – average egg weight (g); BW – average hen body weight (g); P – egg laying intensity (%); F – average daily feed consumption (g) (Morgan & Carlson, 1968).

Statistical processing of results and their presentation were carried out by means of Excel 16.0 software (2018, for Windows).

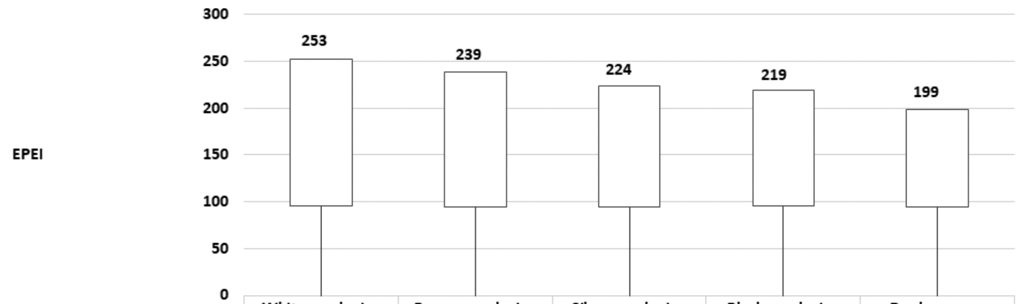
Results and Discussion

Fig. 1 illustrates the calculated egg production efficiency index for the four main groups of layer hens in comparison to that of an all-purpose hybrid. Expectedly, the white egg layer hybrids exhibited the highest EPEI values, whereas the all-purpose hybrid was outlined with most inefficient egg production: the difference between both was 22.4%. The EPEI in the second most common egg layer hybrids (brown) was by 5.3% lower than that of the white one. The least difference in EPEI values was calculated between silver and black hybrids (2.06%). The ideal value of the egg production efficiency index in domestic chickens may be calculated under the present selection levels on the basis of the following values: liveability − 100%; average daily egg weight – 0.062 kg and feed conversion ratio – 2.0. Thus, the ideal but practically unattainable in real production conditions EPEI would equal 310, a value that is by 18.5% higher than that obtained for the studied white egg layer hybrid and by 22.9% higher than EPEI of the brown egg layer hybrid. When data for egg production on hen housed basis were used, the effect of the liveability trait was enhanced, which resulted in lower values of the proposed index as compared to those calculated with egg production on hen day basis. On the other hand, the replacement of liveability with the hen-housed egg production resulted in rather low values and differences in numbers after the decimal point. This on turn leads to a more inconvenient comparison of studied genotypes.

On the basis of 98% liveability, 2.0 FCR and 63.2 g average daily egg weight, the ideal egg production efficiency index has a value of 310. Theoretically, higher values are also possible over a short time period at the end of the production cycle of a given flock. The idea behind EPEI is to include a full production cycle, with no considerable effect of its duration. Thus, an EPEI of 230 may be assumed as exemplary threshold value for modern white and brown egg laying hybrids.

The calculation of the NFEI, proposed by Narahari et al. (1983) resulted in the highest value for the white egg laying hybrid (48.84), followed by the all-purpose hybrid (47.15), the silver egg laying hybrid (46.96), the brown egg laying hybrid (46.86) and the black egg laying hybrid (45.17). This serious discrepancy is due to the significant effect of the difference between the initial and final body weight. Hybrids with great initial vs final live weight differences had also higher values of NFEI. This complicates the comparison not only of hybrids of different production types, but also that of egg laying hybrids with different selection goal – light vs classic. Apart the other shortcomings mentioned in the introduction, this index is characterized with rather close values of evaluated hybrids, often with differences in the numbers after the decimal point only.

The index developed by Morgan & Carlson (1968) − PEI, covers a large part of main criteria associated to egg production. The results about PEI in the selected hybrids showed values from 37.7 to 49.5 and ranking similar to that with EPEI. The differences between EPEI and PEI affected the all-purpose hybrid, whose PEI values were superior to that of the black hybrid. Despite the greater egg mass and higher egg laying intensity of the black egg laying hybrid, the higher average daily feed consumption had a serious negative impact on PEI values.



	White egg-laying hybrid	Brown egg-laying hybrid	Silver egg-laying hybrid	Black egg-laying hybrid	Dual-purpose hybrid
Liveability, %	95,5	94,5	94,5	95,5	94,5
Daily egg mass produced, kg	0,056	0,056	0,052	0,052	0,046
FCR kg/kg	2,1	2,2	2,2	2,27	2,2
EPEI	253	239	224	219	199

Fig. 1. EPEI values in different egg laying hybrids

EPEI may be also used to compare the egg production efficiency between different production systems. Fig. 2 presents the differences in EPEI values for three types of layer hens reared in cages and in free-range systems. The figure showed clearly that the production of eggs for consumption for the three studied hybrids was more efficient in the cage system. This may be attributed to the higher egg production intensity, higher egg weight and more efficient feed conversion in cage-reared compared to free-range layer hens. The difference in EPEI values was the greatest in the silver egg layer hybrid (7.65%), and the least – in the white egg layer hybrid (6.03%). The difference between EPEI of white and silver hybrids were greater in the free-range system (10.24%) than in the cage system (8.67%). The same trend was observed for the studied brown hybrid (3.26% vs 2.39%). The analysis of results showed that egg production by the white egg layer hybrid in a cage production system was the most efficient (EPEI=265), whereas the most inefficient egg production resulted from rearing silver egg layer hybrid in a free-range system (EPEI=224). The egg production from the brown layer hybrid was comparable yet more inefficient compared to the white hybrid with average differences in EPEI of 2.83% regardless of the production system.

The used index (EPEI) is also appropriate for monitoring of changes in egg production efficiency in a specific group of layer hens. Fig. 3 illustrates the time course of average weekly values of EPEI in a popular brown egg layer hybrid in relation to changes of traits involved in its determination. The most serious increase in EPEI was observed from the 1st to the 6th production week (20-25 weeks of age), mainly due to the significant increase in egg laying intensity and egg weight, which influenced the DEMP trait. This tendency, although at slower and decreasing rate, was observed until the 13th-14th production week (32-33 weeks of age). Assuming the average EPEI value of 232 for the 81-week production period as optimal, this efficiency of egg production was attained during the 17th-18th production week (36-37 weeks of age). Reduction of EPEI below this value occurred as late as after the 76th production week (95 weeks of age). The last five weeks of the production period marked a dramatic reduction of EPEI that reached 223, mainly due to the low cumulative liveability, decreased egg laying intensity and worse feed conversion. If EPEI values of 250 are accepted as corresponding to very high production, such values were present during 42 weeks – from the 23rd production week (42 weeks of age) to the 64th production week (83 weeks of age). The peak EPEI value (266) was registered during the 42nd production week (61 weeks of age). EPEI over 260 was maintained over 26 weeks: from the 29th production week (48 weeks of age) to the 54th production week (73 weeks of age). This demonstrates convincingly that under appropriate rearing and feeding conditions, modern layer hens maintain high production parameters for a long time, which resulted in high EPEI values even at the end of the 81-week period of egg production.

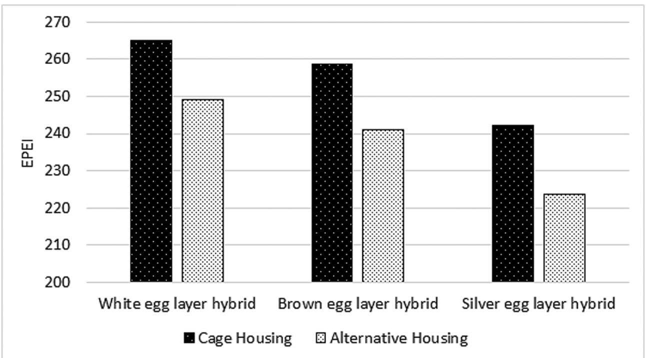


Fig. 2. EPEI in three types egg laying hybrids, reared in cage and free-range production systems

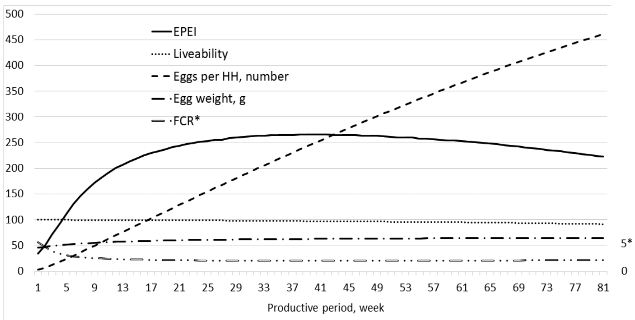


Fig. 3. Dynamics of changes in EPEI and associated traits in a brown egg laying hybrid

Conclusion

The proposed egg production efficiency index (EPEI) summarizes several of most important production traits of both stock and breeder eggs: liveability of birds, number of eggs produced per bird, produced egg mass an feed conversion ratio. Higher values of the index corresponded to more efficient egg production and vice versa. Depending on the production type and the specific period, EPEI in domestic chickens vary substantially attaining approximately 270, with desirable values for modern egg layer hybrids exceeding 230.

The proposed egg production efficiency index (EPEI) may be applied in other domestic fowl species, including for comparison of efficiency of breeder eggs' production.

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