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SEASONAL VARIATIONS IN EGG QUALITY TRAITS IN BELGRADE SUPERMARKETS

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Abstract: The aim of this study was to determine the quality of eggs available in Belgrade supermarkets during different seasons (winter, spring, summer), for various housing systems (cage, floor, and free-range), and to assess the representation of eggs from cage and non-cage systems in the year when Serbian egg producers have been granted an extended transitional period to comply with animal welfare legislation banning conventional cage systems. The research covered nine Belgrade supermarkets. All egg producers representing the three housing systems were recorded, and eggs up to 15 days old were tested for external and internal quality traits. The results show that cage-system producers remain dominant on the market, with a share ranging from 45.5% in winter to 50% in spring and summer. The share of floor (non-cage) eggs was 36.6% in winter and 30% in spring and summer, while free-range eggs had the lowest representation during all three seasons (around 20%). The findings indicate variability in egg quality traits influenced by both season and housing system as the second studied factor. Haugh Unit (HU) values, which represent an aggregate indicator of egg quality, were highest in winter, averaging 76.29 for the cage system, 76.31 for the floor system, and 77.28 for the free-range system. In spring and summer, lower HU values were recorded for all three systems, with a more pronounced decline in the non-cage systems. It can be concluded that there is a growing trend in the supply of eggs from non-cage systems in Belgrade supermarkets, which is more favorable in terms of animal welfare. The development of these systems could be further supported through education of producers and consumers, as well as through research and producer incentives. Although the study focuses on egg quality at the market level, and thus reflects the quality of the product reaching consumers, it also indicates potential weaknesses in the “from producer to consumer” chain. Therefore, it can be a starting point for future research on the entire system of egg production and distribution.

Key words: egg quality, season, housing systems, retail – supermarkets

Introduction

Table eggs are an important component of human diets worldwide due to their affordable price and high nutritional value, which makes them an ideal food for the daily diet of people of all age groups (Tolimir et al., 2017; Rafed et al., 2024). However, when analyzing data on egg consumption in Serbia, which amounted to 217 eggs per capita in 2023 (Statistical Office of the Republic of Serbia, Household Budget Survey, 2023), it can be seen that this figure is significantly lower compared to countries such as Mexico (368), Japan (337), China (255), Spain (273), and Denmark (248) (World Egg Organisation, 2018). One of the reasons for the lower egg consumption may be consumers’ concerns related to “cholesterophobia”, and therefore, education of consumers is essential. In this context, studies focusing on the nutritional value of eggs with an emphasis on the health aspect are particularly important, as they point out that cholesterophobia-the fear of consuming eggs due to potential health risks, most commonly cardiovascular diseases-is ungrounded. The health aspect has been the subject of numerous studies that generally summarize the key nutritional properties of eggs within a balanced diet and highlight their benefits for human health (Réhault-Godbert et al., 2019; Pal and Molnar, 2021; Virtanen and Larsson, 2024). According to Myers and Ruxton (2023), in European countries, an increased egg consumption would contribute to health benefits of the population.

In addition to the chemical composition and nutritional value of eggs, an important area of research is egg quality, especially from the perspective of food safety, different production systems, and consumer protection. The quality traits of eggs (external and internal) are influenced by factors prior to laying - such as genetics, hen age, nutrition, and housing system - as well as by factors after laying, including egg handling, i.e. packaging technology, transport, and storage conditions. Research in this field has been extensive and often involves the simultaneous examination of multiple factors (Feddern et al., 2017; Kopacz and Drażbo, 2018; Tavares et al., 2018; Polat Yurtseven et al., 2021; Rakonjac et al., 2021; Škrbić et al., 2021; Kim et al., 2022). From the consumer perspective, the most important aspect is the quality of eggs on the retail market, which serves as an indicator of the efficiency of the entire production and distribution chain. Pavlovski et al. (2007) emphasize that eggs produced on the farm may have good initial quality, which can be compromised by improper handling and storage conditions both on the farm and throughout the marketing channels. Therefore, studies on egg quality in retail (Jones and Musgrove, 2005; Khan et al., 2013) are particularly important, as their goal is to determine the external and internal quality traits of eggs under the influence of different storage conditions and egg handling. Apart from physical traits, egg quality assessments on the market include the monitoring of chemical (Petrovska et al., 2018) and microbiological changes in eggs (Omkarappa et al., 2019), as well as the assessment of variations in the nutritional quality of eggs in retail, depending on the genotype, housing system, and season (Akyurek and Okur, 2009; Feddern et al., 2017; Alshaikhi et al., 2021; Chatzidimitriou et al., 2024).

There are relatively few data available in Serbia on the quality of eggs in supermarkets, and even less on how quality of these eggs varies depending on the season and housing system. Therefore, the aim of this study was to examine egg quality traits across three seasons (winter, spring, and summer), as well as to highlight potential differences among housing systems (cage, floor, and free-range) under specific market conditions. Additionally, the study aimed to assess how the process of complying with animal welfare regulations, including the ban on conventional cages for laying hens, affected the supply of eggs from alternative production systems in the Belgrade market.

Material and Methods

The study on the supply and quality of table eggs from three production systems-cage, floor, and free-range-across three different seasons (winter, spring, and summer 2025) was conducted in the territory of Belgrade, in nine retail outlets-supermarkets. The egg supply was determined by recording all producers represented in each supermarket, with the aim of identifying the seasonal dynamics in the supply of eggs from different systems. Egg quality assessment was performed on samples from all supermarkets, with 10 medium-sized (class M) eggs per producer, aged up to 15 days (the number of days from the packaging to the purchase did not exceed 15 days), to eliminate the effect of age on egg quality traits and to ensure conditions for a valid and mutually comparable assessment of egg quality. The sampling of all eggs was done in a single day, and quality parameters were evaluated the following day, during which the eggs were stored in a refrigerator. For each egg, the researchers analyzed external traits (egg weight, cleanliness and shell color, and egg shape index) and internal quality traits (albumen height, Haugh units, yolk color, and shell thickness). All analyses were carried out by using standard assessment methods: egg weight was determined by using an electronic scale with ±0.01 g accuracy; shell cleanliness and color were assessed visually, on a scale from 1 (dirtiest/lightest) to 5 (cleanest/darkest). Egg shape index was calculated as the ratio of width (mm) to length (mm) of the egg, measured by using a template for determining egg length and width. Albumen height was measured at the midpoint between the yolk edge and the thick albumen layer by using an AMES tripod micrometer with 0.1 mm precision. Yolk colour was assessed visually, comparing with the Roche Yolk Color fan (scale 1–15 for color intensity). Shell thickness was measured with a micrometer and expressed in µm. Haugh units (HU) were calculated using the following formula: $HU = 100 \cdot \log10 (H - 1.7 \cdot W^{0,37} + 7.6)$, where H is the albumen height (mm), and W is the egg weight (g). The recorded average monthly temperatures for Belgrade were 3.3°C in February, 16.8°C in May, and 25.4°C in July, as retrieved from monthly bulletins issued by the National Hydrometeorological Service of Serbia (RHMZ, 2025). The obtained results were processed with the statistical software package STATISTICA (Statistical), ANOVA procedure. The significance of the differences was assessed at the probability level of $p \leq 0.05$ by Tukey test.

Results and Discussion

Table 1 presents the results of the survey on the egg supply in Belgrade supermarkets in the winter, spring, and summer seasons of 2025 from different production systems-cage, floor, and free-range.

Table 1. Seasonal variations in egg supply in Belgrade supermarkets given by different housing systems

Housing system	**SM1**	**SM2**	**SM3**	**SM4**	**SM5**	**SM6**	**SM7**	**SM8**	**SM9**	**Total supply 1**
					Winter 2025					
Cage	P2	P3	P4	P3	P5	P3	-	P6	P3	5
Floor	P1, P2	P3	P4	P3	-	-	P3	-	-	4
Free range	P2	-	-	P3	-	-	P3	-	P2	2
Total supply 2	2	1	1	1	1	1	1	1	2	
					Spring 2025					
Cage	P7	P3	P4	-	-	P8	0	P6	-	5
Floor	P1, P2	P3	0	-	-	-	0	-	P2	3
Free range	P2	P3	P2	-	-	-	P3	-	P2	2
Total supply 2	3	1	2			1	1	1	1	
					Summer 2025					
Cage	P1	P3	P1, P4	P3	P8	-	-	P8	P6	5
Floor	P1, P2	P1	P3	P3	-	P3	P3	-	P2	3
Free range	P2	P3	-	P3	P2	-	P3	-	P2	2
Total supply 2	2	2	3	1	2	1	1	1	2	

SM – abbreviation for supermarket; P – abbreviation for the producer
Total supply 1 - number of producers by housing system
Total supply 2 - number of producers by supermarket

Based on the data in Table 1, it can be seen that the supply of eggs from different production systems (cage, floor, and free-range) in the winter, spring, and summer periods was relatively stable, ranging from 10 different brands in the spring and summer seasons to 11 in the winter, considering all supermarkets and production systems together. When comparing the cage system with the floor and free-range systems, it was found that the supply of eggs from cage systems was predominant throughout all three seasons. However, when comparing the cage system with non-cage systems (floor and free-range combined), it can be concluded that the cage system was slightly dominant only during the winter, with 55% of the total supply, while in spring and summer this ratio equalized (50:50). This may indicate a market transition influenced by legislative changes. Analyzing the supply from the producers' perspective, it can be concluded that only two producers (P2 and P3) were represented with eggs from multiple production systems across several seasons, suggesting that only a small number of producers have the flexibility and capacity to adapt to the increasingly demanding market through diversification of production. Most producers remain focused on more economical forms of production, while the availability of more ethically acceptable options floor and free-range eggs remains limited. The obtained results confirm that the transition toward more sustainable production systems has been progressing slowly, with a slight upward trend, which has also been confirmed in similar previous studies (Tolimir et al., 2020; 2024). Sinclair et al. (2022) pointed out that consumer attitudes and knowledge regarding eggs outside EU countries were not entirely understood. They conducted a survey in 14 non-EU countries, showing that consumers' understanding of egg production systems varied greatly, often with lack of knowledge, and regional differences both in the level of awareness and attention paid to animal welfare. Analyzing the situation globally, the authors stated that conventional cages were first banned in Europe in 2012, after which that the process of phasing out conventional caged egg production started in Canada, Australia, and New Zealand. However, they emphasized that the majority of eggs worldwide were still produced in cage systems, despite significant public awareness campaigns on animal welfare conducted in some countries. Rahmani et al. (2019) and Doyon et al. (2023) highlighted the importance of consumer awareness and their preferences toward eggs from different housing systems, considering animal welfare and environmental impact. Zinca et al. (2024) emphasized the effects of various housing systems on egg quality and pointed out that these systems remained a controversial topic among consumers, producers, researchers, and environmentalists, particularly regarding hen health, behavior, and egg quality. In Serbia, the transition from conventional cage systems to permitted (alternative) systems is directly influenced by legal regulations, according to which the final deadline has been re-extended (Rulebook on Conditions for Animal Welfare, 2024). Radulović et al. (2025) analysed the egg production sector and identified insufficient compliance with welfare standards as one of its weaknesses.

Considering that consumer attitudes can also influence a shift toward non-cage systems, education and better public awareness about production systems and egg quality would be of great importance in Serbia.

Table 2 presents data on the quality of eggs from different production systems - cage, floor, and free-range, in three seasons - winter, spring, and summer – in Belgrade supermarkets. According to the results, the season has a significant impact on both internal and external egg quality traits. Haugh units (HU), as the overall and most important indicator of egg freshness, showed the smallest seasonal variations in the cage system throughout all three seasons, indicating greater stability of the egg quality compared to the floor and free-range systems. However, although the results suggest that the cage production system is characterized by the smallest seasonal fluctuations in Haugh units, it should be considered that the research was conducted on eggs obtained from supermarkets. This leads to the question whether the observed stability in egg quality in the cage system is a result of the production system itself or of differences in handling, storage, and transportation of eggs to the retail location.

Also, based on the obtained results, it can be observed that Haugh unit (HU) values were the highest during winter for all three systems, while in warmer seasons, a decline in values occurred, which was more pronounced in eggs from floor and free-range systems. The finding that a decrease in certain egg quality parameters was recorded for all three systems indicates that none of the systems is completely immune to seasonal stress. The fact that retail eggs had higher HU values during winter was also confirmed by the study of Alshaikhi et al. (2021). The obtained results can be linked to higher temperatures during spring and summer, when several factors combine - accelerated biochemical changes due to higher temperatures, more difficult and slower cooling of eggs immediately after laying, as well as a potentially less efficient cold chain during storage and transportation to retail outlets in spring and summer. The negative effect of prolonged storage time and temperature on HU was also confirmed by Akyrek and Okur (2009) and Škrbić et al. (2021).

The obtained results can be interpreted in relation to the study by Feddern et al. (2017), who identified ambient temperature and relative humidity as key factors that negatively affect egg quality traits. Al-Obaidi and Al-Shadeedi (2018) reported greater variation in certain egg quality characteristics during the summer compared to the winter period. The importance and influence of the post-laying period on egg quality were highlighted by Kim et al. (2022), who also pointed out the challenge of maintaining egg quality during storage and transportation due to changes in external factors such as temperature and humidity. They emphasized the need to develop models for estimating Haugh units based on data on weight loss under cold chain conditions.

Table 2. Seasonal variations of egg quality in Belgrade supermarkets, by housing systems

Season	Sistem		Egg weight	Shell cleanliness	Shell colour	Egg shape index	Yolk colour	HU	Shell thickness
Winter	Cage	X̄	59.29[c]	4.78[ab]	3.85[de]	82.43[ns]	12.34[a]	76.29[d]	38.97[abc]
		Sd	±2.57	±0.78	±0.63	±3.36	±0.60	±8.24	±2.75
Spring		X̄	58.63[bc]	4.73[ab]	3.69[cd]	83.80 [ns]	12.57[ab]	71.18[bcd]	39.94[c]
		Sd	±2.37	±0.61	±0.58	±3,02	±1.23	±13.27	±2.82
Summer		X̄	57.37[ab]	4.31[a]	3.34[abc]	81.67 [ns]	12.39[a]	71.94[cd]	37.91[a]
		Sd	±2.68	±1.28	±0.67	±8.44	±1.52	±8.14	±2.88
Winter	Floor	X̄	57.54[abc]	4.66[ab]	3.80[de]	83.06 [ns]	12.39[a]	76.31[d]	37.76[a]
		Sd	±2.53	±1.00	±0.62	±3.81	±0.67	±10.71	±2.67
Spring		X̄	59.36[c]	4.62[ab]	3.90[de]	82.73 [ns]	12.56[a]	65.68[ab]	39.15[abc]
		Sd	2.53	1.05	0.54	2.78	0.81	9.76	±1.59
Summer		X̄	56.88[a]	4.42[ab]	3.27[a]	81.82 [ns]	12.50[a]	67.94[abc]	37.94[a]
		Sd	±3.34	±1.25	±0.72	±2.56	±1.42	±11.65	±2.79
Winter	Free- range	X̄	59.45[c]	5.00[b]	4.22[e]	82.82 [ns]	12.28[a]	77.28[d]	39.61[bc]
		Sd	±2.83	±0.00	±0.63	±3.71	±0.66	±6.19	±2.48
Spring		X̄	58.73[bc]	4.28[a]	3.70[bcd]	82.80 [ns]	13.14[b]	64.80[ab]	39.14[abc]
		Sd	±1.89	±1.44	±0.68	±3.74	±0.74	±10.89	±2.29
Summer		X̄	57.27[ab]	4.42[ab]	3.24[a]	80.87 [ns]	12.16[a]	63.41[a]	38.18[ab]
		Sd	±2.53	±0.98	±0.59	±2.54	±0.83	±10.44	±2.31
p-value			0.000	0.014	0.000	0.120	0.001	0.000	0.000

[a-e] - Different letters indicate significant differences among the means in each column
[ns]- not statistically significant differences among the means in the column

In addition to analyzing the Haugh unit (HU) as an overall indicator of egg quality, other egg traits presented in Table 2 can be discussed. Eggshell thickness was the lowest during the summer in all three housing systems, which may be attributed to the seasonal influence on shell mineralization. Conversely, the highest shell thickness was observed in spring, which is consistent with the findings of Ikusika et al. (2025), who explained this result by the improved calcium metabolism due to lower thermal stress in spring compared with the winter period. The obtained results for HU and shell thickness indicate that special attention should be paid to eggs collected in the summer period because of the potentially higher risk of shell breakage and reduced quality preservation. Yolk colour remained relatively consistent across the three seasons, with the highest values observed in free-range eggs during spring, which can be linked to the more diverse diet of hens and their access to green pastures. This is in agreement with previous findings (Hammershøj and Johansen, 2016; Gumulka et al., 2017).

These observations confirm that, both season and the housing system significantly affect the nutritional and physical properties of eggs, which should be taken into account when assessing the market quality of eggs.

Figure 1 presents the egg quality in Belgrade supermarkets, expressed as HU, in different seasons, by producers and housing systems.

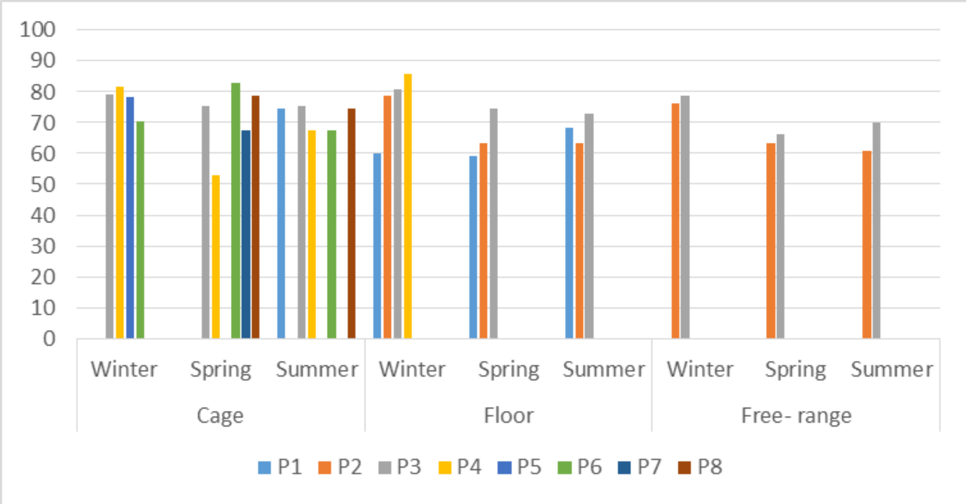

Figure 1. Egg quality in belgrade supermarkets, expressed in HU in different seasons by producers and housing systems

The results indicate that the quality of eggs available on the market shows pronounced variations in Haugh units depending on the season, with the highest quality recorded during the winter period, while a noticeable decline was observed in summer, particularly in eggs from free-range and floor systems. According to the study by Freitas et al. (2023), the variability of egg quality traits is greater in the summer than in the winter season, while the influence of both season and housing system on egg quality was also confirmed by Rakonjac et al. (2018). The question of whether the obtained retail egg quality is a result of the factors before laying - different genotypes, nutrition, housing conditions, hens' age and health or is a consequence of factors influencing egg quality after laying – temperature, relative humidity, presence of dust, foreign odors, and other effects during storage and transport - highlights the need for more extensive research covering the entire chain from the farm to retail, i.e., to the consumer. According to Roberts et al. (2004), a systematic improvement of egg quality would involve limiting the age of hens from which eggs are sourced, shortening the storage period before processing and distribution, enriching the hens' diet with the vitamin-mineral supplements and establishing higher grading standards. When observed by producer, HU values were the highest during the winter period for three producers (P2, P3, and P4) across all three housing systems. However, it can be noted that for certain producers (P1 and P6), the variation in HU could not be linked to seasonal trends, as no consistent pattern was observed. Due to the instability of supply and the lack of continuous seasonal availability, some producers (P5 and P7) could not be analyzed by season. It is important to emphasize that the study was conducted on samples collected from retail outlets; therefore, the differences observed among producers cannot be interpreted solely through the lens of production factors, but must also take into account transport conditions, storage duration, and storage regimes in supermarkets, which are particularly critical during warmer months. In this regard, the observed variations in egg quality reflect the complexity of the supply chain rather than production technology alone, highlighting the importance of maintaining quality control throughout the entire distribution pathway - from farm to consumer.

Conclusion

In line with the objective of this study, and based on the obtained results, several conclusions were drawn. The findings indicate a gradual transition toward non-cage systems, while eggs from cage systems remain dominant—both in terms of the number of producers represented in supermarkets and the range of products offered within each Belgrade supermarket. The further transition to non-cage systems in Serbia is directly influenced by legislative decisions regarding the definition or extension of deadlines for the ban on conventional cages. Additionally, this process could be affected by producer and consumer education, as well as by incentives for producers investing in permitted, alternative, and more humane housing systems. The results of the egg quality assessment in supermarkets indicate variability of traits under the influence of season, with more pronounced variations observed in eggs from alternative production systems (floor and free-range) compared with the cage system. Less favorable Haugh unit (HU) values, as an overall indicator of egg quality, during warmer seasons point to the need for special attention to preserving egg quality during these periods through the optimization of storage and transport conditions, as well as through the development of a systematic approach to monitoring quality under market conditions. Based on the obtained results, it is recommended to conduct further research encompassing the entire egg production chain-from farm to retail point-in order to identify the causes of variations in quality.

Sezonske varijacije u karakteristikama kvaliteta jaja u beogradskim supermarketima

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Rezime

Cilj rada bio je da se utvrdi kvalitet jaja u beogradskim supermarketima tokom različitih sezona (zima, proleće, leto), za različite sisteme gajenja (kavezni, podni i slobodni) i da se proceni zastupljenost jaja iz kaveznih i nekaveznih sistema u periodu ponovnog produženja roka za usklađivanje sa zakonskim propisima o dobrobiti životinja kojima se zabranjuju konvencionalni kavezni sistemi. Istraživanje je obuhvatilo devet beogradskih supermarketa. Svi proizvođači jaja iz sva tri sistema su evidentirani, a jaj a starosti do 15 dana su uzorkovana i testirana na spoljašnje i unutrašnje osobine kvaliteta. Rezultati pokazuju da su proizvođači iz kaveznih sistema dominantni na tržištu, sa udelom u rasponu od 45,5% zimi do 50% u proleće i leto. Udeo jaja iz podnog (nekaveznog) držanja bio je 36,6% zimi i 30% u proleće i leto, dok su jaja iz slobodnog uzgoja imala najmanju zastupljenost tokom sva tri sezone (oko 20%). Rezultati ukazuju na varijabilnost osobina kvaliteta jaja pod uticajem sezone i sistema gajenja, kao drugog proučavanog faktora. Vrednosti Haugovih jedinica (HJ), koje predstavljaju zbirni indikator kvaliteta jaja, bile su najviše zimi, u proseku 76,29 za kavezni sistem, 76,31 za podni sistem i 77,28 za sistem slobodnog gajenja. U proleće i leto zabeležene su niže vrednosti HJ za sva tri sistema, sa izraženijim padom u nekaveznim sistemima. Može se zaključiti da postoji rastući trend u ponudi jaja iz nekaveznih sistema u beogradskim supermarketima, što je povoljnije sa stanovišta dobrobiti životinja. Razvoj ovih sistema mogao bi se dodatno podržati kroz edukaciju proizvođača i potrošača, kao i kroz istraživanje i podsticaje proizvođačima. Iako se rad fokusira na kvalitet jaja na nivou tržišta i time odražava kvalitet proizvoda koji stiže do potrošača, on takođe ukazuje na potencijalne slabosti u lancu „od proizvođača do potrošača“. Stoga rad može biti polazna tačka za buduća istraživanja celog sistema proizvodnje i distribucije jaja.

Ključne reči: kvalitet jaja, sezona, sistemi gajenja, maloprodaja – supermarketi

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Conflict of interest

The authors declare no conflict of interest.

References

Akyurek H., Okur A.A. 2009. Effect of storage time, temperature and hen age on egg quality in free-range layer hens. *Journal of Animal and Veterinary Advances*, 8, 10, 1953-1958.

Al-Obaidi F.A., Al-Shadeedi S.M.J. 2018. Effect of summer and winter seasons on egg abnormalities of outdoor rearing some native chicken strains. *Journal of Biodiversity and Environmental Sciences (JBES)*, 12, 3, 220-225.

Alshaikhi A.M., Abdullatif A.A., Badwi M.A., Alsobayel A.A. 2021. Effects of storage period, marketing channels and season on internal and external quality of commercial table eggs marketed in Riyadh City (Saudi Arabia). *Brazilian Journal of Poultry Science*, 23, 1. https://doi.org/10.1590/1806-9061-2020-1334

Chatzidimitriou E., Davis H., Baranski M., Jakobsen J., Seal C., Leifert C., Butler G. 2024. Variation in nutritional quality in UK retail eggs. *Food Chemistry*, 454, 139783. https://doi.org/10.1016/j.foodchem.2024.139783

Doyon M., Bergeron S., Saulais L., Labonté M.È., Provencher V. 2023. Do consumers value welfare and environmental attributes in egg production similarly in fresh eggs and prepared meals? *Animals*, 13, 3, 324. https://doi.org/10.3390/ani13030324

Feddern V., De Prá M.C., Mores R., da Silveira Nicoloso R., Coldebella A., de Abreu P.G. 2017. Egg quality assessment at different storage conditions, seasons, and laying hen strains. *Ciência e Agrotecnologia*, 41, 322-333. https://doi.org/10.1590/1413-70542017413002317

Freitas L.C.D.S.R., Tinôco I.D.F.F., Gates R.S., Santos T.C.D., Andrade R.R., Barbari M., Bambi G. 2023. Spatial Variability of External Egg Quality in Vertical Naturally Ventilated Caged Aviaries. *Animals*, 13, 4, 750. https://doi:10.3390/ani13040750

Gumułka M., Krawczyk J., Otwinowska-Mindur A. 2017. Effect of production cycle and season on quality and fatty acid profile of organic eggs from local Polish Greenleg Partridge hens. *European Poultry Science*, 81. https://10.1399/eps.2017.188

Hammershøj M., Johansen N.F. 2016. Review: The effect of grass and herbs in organic egg production on egg fatty acid composition, egg yolk colour and sensory properties. *Livestock Science*, 194, 37-43.

Ikusika O.O., Dwakasa H., Luphuzi S., Akinmoladun O.F., Mpendulo C.T. 2025. Assessment of egg quality across seasons, storage durations, and temperatures in commercial laying hens. *Applied Sciences*, 15, 19, 10344. https://doi.org/10.3390/app151910344

Jones D.R., Musgrove M.T. 2005. Effects of extended storage on egg quality factors. *Poultry Science*, 84, 11, 1774-1777. https://doi.org/10.1093/ps/84.11.1774

Khan M.J.A., Khan S.H., Bukhsh A., Abbass M.I., Javed, M. 2013. Effect of different storage period on egg weight, internal egg quality and hatchability characteristics of Fayumi eggs. *Italian Journal of Animal Science*, 12, 2. https://doi.org/10.4081/ijas.2013.e51

Kim T.H., Kim J.H., Kim J.Y., Oh S.E. 2022. Egg freshness prediction model using real-time cold chain storage condition based on transfer learning. *Foods*, 11, 19, 3082. https://doi.org/10.3390/foods11193082

Kopacz M., Drażbo A. 2018. Changes in the quality of table eggs depending on storage method and time. *Scientific Annals of Polish Society of Animal Production*, 14, 3, 37-45. https://doi:10.5604/01.3001.0013.5084

Myers M., Ruxton C.H.S. 2023. Eggs: healthy or risky? A review of evidence from high quality studies on hen's eggs. *Nutrients*, 15, 12, 2657. https://doi:10.3390/nu15122657

Omkarappa V.C, Fairoze M.N, Benakabhat M.C, Bhave K., Karabasanavar N. (2019). Study of retail egg supply chain for quality in relation to level of sanitization andfarm of origin. *Turkish Journal of Veterinary & Animal Sciences*, 43, 6, 800-807. https://doi.org/10.3906/vet-1903-2

Pal M., Molnár J. 2021. The role of eggs as an important source of nutrition in human health. *International Journal of Food Science and Agriculture*, 5, 1, 180-182. https://doi:10.26855/ijfsa.2021.03.023

Pavlovski Z., Škrbić Z., Cmiljanić R., Lukić M. 2007. Sistem garantovanog kvaliteta jaja u odnosu na propise EU i zahteve potrošača. *Savremena poljoprivreda*, 56, 1-2, 75-82.

Petrovska K., Joshevska E., Kalevska T., Kitanovski V., Kitanovski D. 2018. Chemical changes in eggs in different storage conditions. *Scientific Works of University of Food Technologies*, 65, 1, 48-54.

Polat Yurtseven E., Şekeroğlu A., Tainika B., Duman M., Emre Şentürk Y. 2021. Effect of production system and age on egg quality parameters: a case of Niğde Province Çamardı District, Turkey. *Turkish Journal of Agriculture - Food Science and Technology*, 9, 8, 1407–1412. https://doi.org/10.24925/turjaf.v9i8.1407-1412.4241

Radulović S., Jokić Ž., Šefer D., Marković R., Perić D., Stevanović J., Mihailović N. 2025. Viwes on problems in poultry production and directions of future development (in Serbian). *Živinarstvo*, 8/9.

Rafed R., Abedi M.H., Mushfiq S.R. 2024. Nutritional value of eggs in human diet. *Journal for Research in Applied Sciences and Biotechnology*, 3, 1, 172-176. https://doi.org/10.55544/jrasb.3.1.28

Rahmani D., Kallas Z., Pappa M., Gil J.M. 2019. Are Consumers' egg preferences influenced by animal-welfare conditions and environmental impacts? *Sustainability*, 11, 22, 6218. https://doi.org/10.3390/su11226218

Rakonjac S., Petrović M.D., Bogosavljević-Bošković S., Škrbić Z., Perić L., Dosković V. 2018: Effect of age and season on production performance and egg quality of laying hens from different rearing systems. *The Journal of Animal and Plant Science*, 28, 6, 1602-1608.

Rakonjac S., Dosković V., Bogosavljević-Bošković S., Škrbić Z., Lukić M. Petričević V., Petrović M.D. 2021. Production performance and egg quality of laying hens as influenced by genotype and rearing system. *Brazilian Journal of Poultry Science*, 23, 02, 001-008. https://doi.org/10.1590/1806-9061-2019-1045

Réhault-Godbert S., Guyot N., Nys Y. 2019. The golden egg: nutritional value, bioactivities, and emerging benefits for human health. *Nutrients*, 11, 3, 684.

RHMZ. 2025. National Hydrometeorological Service of Serbia. https://www.hidmet.gov.rs , Accessed 10.10.2025

Roberts J.R. 2004. Factors affecting egg internal quality and egg shell quality in laying hens. *Journal of Poultry Science*. 41, 3, 161-177.

Rulebook 2025. Rulebook on conditions for animal welfare in terms of animal housing, rooms and equipment in facilities where animals for production purposes are kept, reared and placed on the market, the manner of keeping, breeding and trade of certain species and categories of animals, as well as the content and management of animal records' keeping. *Official Gazette of the RS*, 6/10, 57/14, 152/20, 115/23.

Sinclair M., Lee N.Y.P., Hötzel M.J., de Luna M.C.T., Sharma A., Idris M., Islam M.A., Iyasere O.S., Navarro G., Ahmed A.A., Curry M., Burns G.L., Marchant J.N. 2022. Consumer attitudes towards egg production systems and hen welfare across the world. *Frontiers in Animal Science*, 3, 995430. https://doi.org/10.3389/fanim.2022.995430

Statistical Office of the Republic of Serbia. 2023. Household Budget Survey. Statistical Office of the Republic of Serbia, Belgrade, https://publikacije.stat.gov.rs/G2024/PdfE/G20245710.pdf. Accessed 10.10.2025

Škrbić Z., Lukić M., Petričević V., Bogosavljević Bošković S., Rakonjac S., Dosković V., Tolimir N. 2021. Egg quality of Banat naked neck hens during storage. *Biotechnology in Animal Husbandry*, 37, 2, 87-97. https://doi.org/10.2298/BAH2102087S

Tavares B.O., Pereira D.F., Salgado D.D., Mac-Lean P.A.B. 2018. Mortality, production and quality of eggs of different rearing systems. *Engenharia Agrícola*, 38, 4, 478–485. https://doi.org/10.1590/1809-4430-eng.agric.v38n4p478-485/2018

Tolimir N., Maslovarić M., Škrbić Z., Lukić M., Budimović N., Milić D., Radišić R. 2020. Attitudes of Serbian producers and consumers of table eggs on the ban on conventional batteries and the transition to enriched cages and alternative production systems. *Biotechnology in Animal Husbandry*, 36, 4, 463-476. https://doi.org/10.2298/BAH2004463T

Tolimir N., Maslovarić M., Škrbić Z., Lukić M., Milić D., Trailović Nedeljković J. 2024. Situation on the market of eggs from non-cage production systems. *Biotechnology in Animal Husbandry*, 40, 1, 29-40. https://doi.org/10.2298/BAH2401029T

Tolimir N., Maslovarić M., Škrbić Z., Lukić M., Rajković B., Radišić R. 2017. Consumer criteria for purchasing eggs and the quality of eggs in the markets of the city of Belgrade. *Biotechnology in Animal Husbandry*, 33, 4, 425-437. https://doi.org/10.2298/BAH1704425T

Virtanen J.K., Larsson S.C. 2024. Eggs - a scoping review for Nordic nutrition recommendations 2023. *Food & Nutrition Research*. 68. https://doi.org/10.29219/fnr.v68.10507.

World Egg Organisation 2018. Global egg production continues to grow, retrieved from https://www.internationalegg.com/resource/global-egg-production-continuesto-grow/, accessed 15.09.2025.

Zinca A.I., Lungu V.D., Moise A.E., Drăgotoiu D. 2024. The influence of laying hen rearing systems and maintenance technologies on egg quality parameters: a review. *Scientific Papers: Animal Science and Biotechnologies*, 57, 1, 260-265.

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