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Are egg classes enough, or do we need an egg quality index?

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A b s t r a c t: This research on eggs from one of the largest producers on the Serbian market shows variations in the most important internal and external quality characteristics in relation to freshness (expressed in Haugh Units (HUs)) and weight class (S, M, L, XL). In parallel, sensory evaluation was conducted (for the two most common culinary methods of preparation) in order to determine whether consumers notice differences in quality when consuming scrambled eggs and how panellists perceive boiled eggs. Knowing that HUs are a scientific-based quality dimension, as opposed to weight classes that are consumer-based and associated with size of eggs, the authors have introduced a new total quality index elevating the perspective of HUs.

Keywords: *egg quality, total quality index, egg classes.*

Introduction

The perception of quality through the table egg supply chain has changed along with the rapid growth of production and has followed modern trends in the development of this industry. Research by the European Consumers' Association indicates that table eggs are increasingly recognized as a quality product, highlighting the most important parameter as safety, followed by eggs' freshness, nutritional value and sensory characteristics. Shell quality, albumen consistency and egg yolk colour are the most frequently evaluated attributes from the consumer's point of view (*Hernandez*, 2004).

From the market aspect, the most important characteristics are egg freshness, egg weight (size) and functional quality of the shell. Consumer preferences according to the colour of the shell and the size of the eggs differ according to the type of market. Research conducted in the last ten years indicates that most Europeans prefer a larger egg size, brown shell colour and dark orange yolk colour (*Bertechini*, 2017). This is partly related to the lack of understanding of quality assessment, due to consumer belief that a bigger egg is also of better quality (*Jacob et al.*, 2011).

In order to respond to market demands and ensure that consumers buy high quality eggs, criteria have been established for quality identification, evaluation and classification. Standardization of products according to physical and qualitative characteristics of economic importance for placing eggs on the European market is defined by Council Regulation (EC) No. 1308/2013 (*EC*, 2013) and Commission Regulation (EC) no. 589/2008 (*EC*, 2008). These provisions are also applied in Serbia, and include two egg quality classes: fresh class A eggs, with egg weight sub-categories (S, M, L, XL), and class B eggs (which are used for further industrial processing) (*Serbian Regulation*, 2019).

The mechanical characteristics of eggs are important from the transportation point of view and handling along the entire supply chain, while the geometric characteristics are important for the manner and type of packaging. Also, the quality of the shell is in direct correlation with the size, i.e., the weight of the eggs (S, M, L, XL), which significantly reflects on the sales revenue. It is well known that the colour and thickness of the shell decrease during the production cycle, while at the same time the egg gains weight (*Duman et al.*, 2016). Natural variations in the colour of the shell of eggs produced from the same line hybrid are associated with the age of the laying hen and the change in egg size (*Samiullah et al.*, 2015).

For consumers, the quality of the egg shell is primarily related to its structure, colour and appearance (*Koelkebeck*, 2010). Consumers prefer a dark shell color because of the belief that such eggs have

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a better texture, internal appearance and taste (*Berkhoff et al*., 2020). However, although the dark brown colour of the shell has a direct impact on the external quality perception of eggs, it does not correlate with the internal quality in terms of nutritional value, taste and cooking characteristics (*Jacob et al*., 2011).

Of the internal characteristics of the overall quality, the most important is the freshness of the eggs, i.e., the quality of the yolk and egg white. A good quality egg has a round, firm yolk, and has a smaller diameter when spilled due to its dense viscous egg white that covers a small area (*Zaheer,* 2015). Variability in egg freshness leads to complex changes in protein structure, which are primarily reflected in changes in pH, vitelline membrane, fatty acid composition and oxidative processes (*Hisasaga et al*., 2020). The consequences are changes in the diameter of the yolk, which takes on a flat appearance due to the absorption of water from proteins and results in diluted egg whites that cover a large area when spilled (*Tamiru et al.,* 2019). Freshness can be measured by various methods, but it is most often estimated (as a standard measure of quality) in Haugh units (HU) by the ratio of the thickness of the thick egg white to the weight of the egg (*Liu et al.,* 2016). In addition to the above, oxidative processes can also affect changes in the sensory characteristics of quality, primarily in the taste and smell of egg yolks (*Hisasaga et al*., 2020).

A recent survey of quality perceptions along the entire table egg supply chain in Serbia highlighted the shape and size of eggs (i.e., weight groups/weight classifications) as very important characteristics for all stakeholders (*Mitrović et al.,* 2021). In addition to the above, sellers and consumers singled out the age of eggs (i.e., their freshness) and shell characteristics as very important quality parameters (*Mitrović et al.,* 2021). For these reasons, this study aimed to examine the variation of selected internal quality characteristics (height and colour of egg whites, yolk colour and yolk proportion in the spilled surface) in relation to freshness (expressed in HU) from one of the largest manufacturers on the market. Also, as pointed out by consumers and in relation to the established classification, the most important external characteristics of the shell (colour, thickness and deformation) and geometric characteristics of eggs (shape index) were studied. Sensory evaluation was also conducted in order to determine whether consumers notice the stated differences in quality when consuming boiled and scrambled eggs.

Materials and Methods

Instrumental analysis of egg quality

The mass of 100 eggs was measured on an analytical balance, OHAUS Adventurer Model AR2140, USA. Shell deformation was tested with a Brookfield CT3 Texture Analyser, with the following parameters: peak load (N), shell deformation (mm), final load (N). Shell thickness (mm) was determined using digital Vernier calliper INSIZE 1113 (0–150mm/0–6). Egg albumen (mm) was measured with a micrometre B C Ames Co, Waltham, Massachusetts, USA. Eggs were analysed on the tenth day from the day of laying.

Haugh units

After determining the external characteristics of the shell and the mass, the eggs (100) were broken on flat plastic surfaces and the height of the egg white was determined. The Haugh unit (HU) was calculated based on the established equation (*Hisasaga et al*., 2020):

$$HU = 100 \log (H + 7.57 - 1.7 \times M^{0.37}) \quad (1)$$

HU – Haugh Unit; H – height of the albumen (mm); M – egg mass (g);

After measurement, the eggs were classified into three groups by freshness as follows: group C (HU = 20–40), group B (HU = 40–60), group A (HU = 60–80).

Computer Visual System (CVS)

Determining the colour of the shell, egg white, yolk, the proportion of yolk in the spilled surface and determining the egg shape index was performed by computer visual method according to *Tomasević et al*. (2019). Color was measured in three-dimensional (CIELAB) space, as the distance of the coordinates of two colors (Δ). The difference in lightness (L*), red (a*) and yellow (b*) were calculated and presented as total color differences (ΔE). Color parameters (L*a*b*) are expressed as an average of seven random measurements for each sample (100 eggs) (*Tomasević et al*., 2019).

The total colour differences between the identified groups of eggs (in relation to the quality determined by HU for albumen and egg yolk and in relation to the defined weight groups S, M, L and XL for egg shell) were calculated using the following equation (*Milovanović et al*., 2021):

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (2)$$

$$\Delta L^* = L_1 - L_0 \quad (3)$$

$$\Delta a^* = a_1 - a_0 \quad (4)$$

$$\Delta b^* = b_1 - b_0 \quad (5)$$

The criterion for determining colour differences was defined as follows: ΔE = 0–0.5 not perceptible differences, ΔE = 0.5–1.5 slightly perceptible differences, ΔE = 1.5–3 perceptible differences, ΔE = 3–6 very perceptible differences (*Milovanović et al*., 2021). Recent research shows that untrained evaluators, i.e. consumers, can detect color differences (ΔE) of approximately 1 (*Altmann et al.,* 2022).

The egg shape index (SI) was determined using the following equation (*Nedomová and Buchar*, 2014):

$$SI = \frac{B}{L} \quad (6)$$

B = egg width (mm)

L = egg length (mm)

The criteria for determining the characteristics of the egg shape were defined as follows: SI <72 sharp shape, SI = 72–76 standard shape, SI > 76 round shape.

Knowing the dimensions of the egg provides an opportunity to determine the following geometric characteristics (*Nedomová and Buchar*, 2014):

Geometric diameter $D_g = (LB^2)^{1/3}$ (mm) (7)

Sphericity $\Phi = \frac{Dg}{L}$ (8)

Egg volume $V = (0.6057 - 0.0018B)LB^2$ (mm^3) (9)

Egg surface $S = (3.155 - 0.013L + 0.0115B)LB$ (mm^2) (10)

Sensory testing of egg quality

The sensory panel consisted of 12 experienced and trained evaluators of food of animal origin. The panelists were trained in two sessions of two hours, in order to check the detection of target sensory characteristics and knowledge of the methodology (*Đekic et al*., 2021).

Descriptive method

Evaluation of hard-boiled eggs — 48 eggs (laid on the same day from the same producer) were boiled for 8 minutes in boiling water. After cooking, the eggs were cooled to 40°C and prepared for testing without the addition of salt. The eggs were peeled, cut in half and placed on white cardboard trays previously marked with three-digit codes (*Parpinello et al*., 2006).

Sensory evaluation of hard-boiled eggs was performed by a descriptive method by 12 trained panellists, in two sessions in two repetitions. The examination was performed during two days in the laboratory space for sensory analysis at the Faculty of Agriculture, University of Belgrade. Panellists evaluated the intensity of the following attributes using a linear scale of 15 cm with two anchors at each side: 1) visual appearance (shape of boiled egg; 0 = irregular ovoid shape to 15 = ideally ovoid shape), 2) smell (smell of whole egg, 0 = no smell to 15 = intense smell), 3) taste (characteristic taste of whole egg; 0 = no taste of egg to 15 = intense taste of egg), 4) hardness of egg yolk (0 = soft to 15 = hard) 5) hardness of egg white (0 = soft to 15 = hard) 6) stickiness of egg yolk (gum stickiness intensity; 0 to 15) (*Hayat et al*., 2010; *Sasaki et al*., 2019).

Discriminatory test

Evaluation of scrambled eggs — 48 eggs laid on the same day from the same producer were homogenized with a blender. After homogenization, eggs were cooked in a heated Teflon pan for 2 minutes with constant stirring, without the addition of salt or oil. Then, 30 g of prepared scrambled eggs were placed on white cardboard trays previously marked with three-digit codes (*Parpinello et al*., 2006).

Sensory evaluation of scrambled eggs was performed by testing the differences in the triangle in accordance with the procedures of ISO 4120 (*ISO*, 2021) and ISO 16820 (*ISO*, 2019). The panellists performed sensory evaluation in two consecutive sessions in two repetitions. Sensory evaluation was conducted in a dedicated laboratory space for sensory testing, with breaks between sessions of 10 minutes.

Panellists were presented with two different types of scrambled eggs to determine the existence of perceptible differences between the eggs with different HUs. For that purpose, 32 triads of eggs were used, using a sequential method of applying the triangle test (*Ilić et al*, 2021)

Quality Index Method (Quality Index)

Having in mind that egg classes distinguish eggs based on size while HUs differentiate them based on size and albumen, we employed a total quality index technique to see how the selected quality characteristics correlated with HUs using additional quality characteristics.

In order to calculate a unique quality index comprising different quality characteristics, the egg quality results were evaluated in line with research by *Režek Jambrak et al*. (2018), *Đekic et al*. (2018) and *Đekic et al*. (2017), using the rule "the lower the value, the better the quality", for two additional criteria — total colour difference for egg yolk colour and egg white colour, equation 11:

$$QI = \frac{X_i}{X_{max}} \quad (11)$$

QI – quality index of a selected quality characteristic; x_i – measured value in the subset of values; x_{max} – maximal value in the subset of values.

The total quality index (TQI) was calculated as recommend by *Finotti et al*. (2007):

$$TQI = \sqrt{\sum_{j=1}^{N} (QI_j)^2} \quad (12)$$

For understanding the TQI, rule of the thumb is 'the lower the TQI value, the better the quality'.

Statistical data processing

Statistical processing of the obtained data was performed in SPSS Statistics 20.0 using ANOVA one-factor analysis of variance. Differences between groups were found at the level of statistical significance of 0.05.

Statistical processing of sensory test data for the triangle test was performed in accordance with the requirements of ISO 16820 (*ISO*, 2019), setting criteria as follow: $p_d = 0.25$, $\alpha = \beta = 0.05$.

Results and Discussion

Egg quality characteristics

The results of colour characterization tests in relation to egg freshness expressed by HUs are presented in Table 1. The average determined differences in yolk and egg white colours between the identified quality groups were in ranges that were not statistically significant (p>0.05), even though consumers were able to observe those differences in egg shell and yolk hues (ΔE) in eggs from different freshness categories (*Altmann et al.*, 2022). Similar effects were found for the determined differences in shell, in relation to different egg classes (S, M, L, XL), which are shown in Table 2.

All shell quality measurements varied in relation to egg weight. Shell thickness increased with egg weight from S to L class, while shells of class

Table 1. Characterization of colour: egg yolks and egg whites in relation to egg freshness quality groups (Haugh Units (HU))

Parameter CVS (n=7)	Egg yolk colour (n=100)			Egg white colour (n=100)		
	C (HU=20–40) (n=36)	B (HU=40–60) (n=33)	A (HU=60–80) (n=31)	C (HU=20–40) (n=36)	B (HU=40–60) (n=33)	A (HU=60–80) (n=31)
L*	69.73 ± 2.30	70.23 ± 0.22	71.10 ± 0.20	91.62 ± 0.19	91.03 ± 0.10	91.27 ± 0.11
	49.63 ± 0.22	47.08 ± 0.17	46.44 ± 0.48	−0.33 ± 0.13	−0.35 ± 0.09	−0.35 ± 0.14
	78.38 ± 0.53	78.60 ± 0.65	77.72 ± 0.51	8.22 ± 0.20	9.97 ± 0.30	10.25 ± 0.29
Colour						
P	P > 0.05			P > 0.05		

Parameter	Egg yolk colour		Egg white colour	
ΔE	C-A comparison	B-A comparison	C-A comparison	B-A comparison
	5.06 ± 0.39	1.03 ± 0.67	2.06 ± 0.12	0.37 ± 0.05
Evaluation	Very perceptible	Perceptible	Perceptible	Not perceptible

Table 2. Characterization of colour: eggshells in relation to egg weight classes (S, M, L, XL)

Parameter CVS (n=7)	**Egg shell colour (n=100)**			
	S (n=25)	**M (n=25)**	**L (n=25)**	**XL (n=25)**
L*	59.69 ± 1.39	60.90 ± 2.21	60.29 ± 1.99	62.11 ± 2.01
	33.54 ± 0.29	32.45 ± 0.33	33.03 ± 0.20	32.74 ± 0.58
	37.17 ± 0.44	35.93 ± 0.66	36.91 ± 0.60	36.66 ± 0.97
Colour				
P	P > 0.05			

Parameter	**Egg shell colour**			
ΔE	**S-M**	**M-L**	**L-XL**	**S-XL**
	4.17 ± 2.04	1.67 ± 1.29	3.47 ± 1.86	6.76 ± 2.60
Evaluation	Very perceptible	Perceptible	Very perceptible	Very perceptible

XL eggs were no thicker than those of class L eggs (Table 3). The results for shell deformation to the breaking point differed only for class S eggs, while for classes M, L and XL, they were relatively constant.

The comparisons of egg weight in relation to egg white height and HU value coincided with the research of other authors (*Kralik et al., 2017*). Dense egg white height and HU value were negatively correlated with egg weight, which can be seen in Table 4.

Table 3. Characterization of egg shell in relation to egg weight classes (S, M, L, XL)

Egg class (n=100)	**Shell thickness (mm)**	**Peak Load (N)**	**Shell deformation (mm)**	**Final Load (N)**
S	0.47 ± 0.11	49.32 ± 11.87	0.37 ± 0.12	13.63 ± 5.00
M	0.53 ± 0.07	51.00 ± 8.45	0.30 ± 0.06	13.24 ± 4.61
L	0.57 ± 0.12	44.63 ± 15.87	0.34 ± 0.14	14.30 ± 5.75
XL	0.55 ± 0.11	46.05 ± 9.17	0.32 ± 0.12	11.54 ± 4.05
P	P > 0.05			

Table 4. Characterization of shape and basic parameters of egg quality in in relation to egg freshness quality groups (Haugh Units (HU))

Quality groups in relation to HU (n=100)	**Egg mass (g)**	**Egg albumen (mm)**	**Egg yolk in the spilled surface (%)**	**L (mm)**	**B (mm)**	**SI (%)**	**D_g (mm)**	**Φ (%)**	**S (mm²)**	**V (mm³)**
I (HU=20–40)	67.74 ± 6.29	2.48 ± 0.40	22.53 ± 6.10	61.34 ± 4.32	47.82 ± 1.91	78.21 ± 4.51	51.94 ± 2.32	84.86 ± 3.26	8532.95 ± 731.79	73166.38 ± 8839.63
II (HU=40–60)	47.60 ± 3.24	2.50 ± 0.33	22.59 ± 2.06	53.81 ± 1.97	42.81 ± 1.23	79.67 ± 4.01	46.19 ± 1.01	85.92 ± 2.85	6790.16 ± 283.92	52168.64 ± 3214.19
III (HU=60–80)	62.06 ± 8.31	4.70 ± 0.61	23.26 ± 5.11	57.76 ± 3.41	46.33 ± 2.75	80.27 ± 3.66	49.85 ± 2.77	86.35 ± 2.62	7874.03 ± 827.54	65171.91 ± 1024.83
P	P > 0.05									

Sensory evaluation

The triangle test did not reveal significant sensory differences in smell and taste that could be observed between eggs with an HU value up to 70 and those with an HU value over 70 (Figure 1). The HU is considered a standard measure of internal quality and indicates oxidative processes during egg storage, which further affect sensory characteristics (*Hisasaga,* 2020). Regardless of the above, the panellists did not find differences (p>0.05) in the sensory properties of scrambled egg made from eggs of different freshness.

Comparisons of descriptive sensory characteristics of boiled eggs from different classes (XL-L/S-M) are shown in Figure 2. The average score for the intensity of smell and taste of eggs from group I (XL-L) tended to be higher (i.e., better) compared to eggs

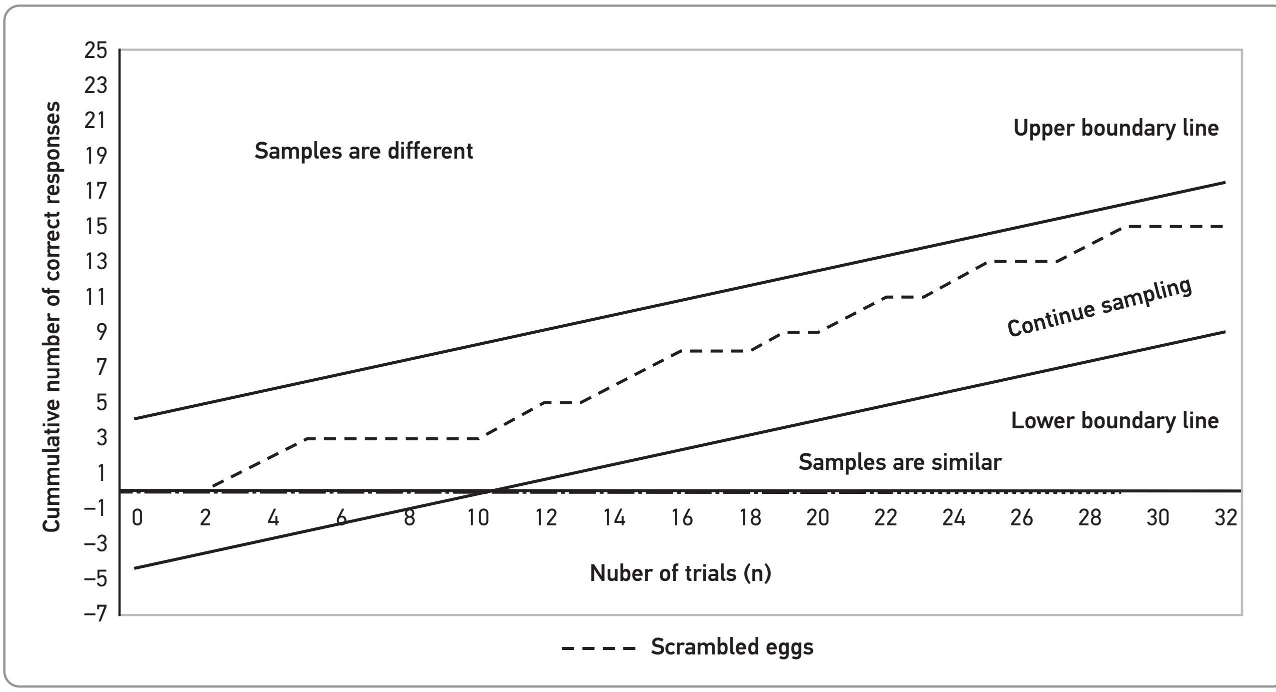

Figure 1. Discriminant triangle test — Differences between scrambled egg groups divided by Haugh Units

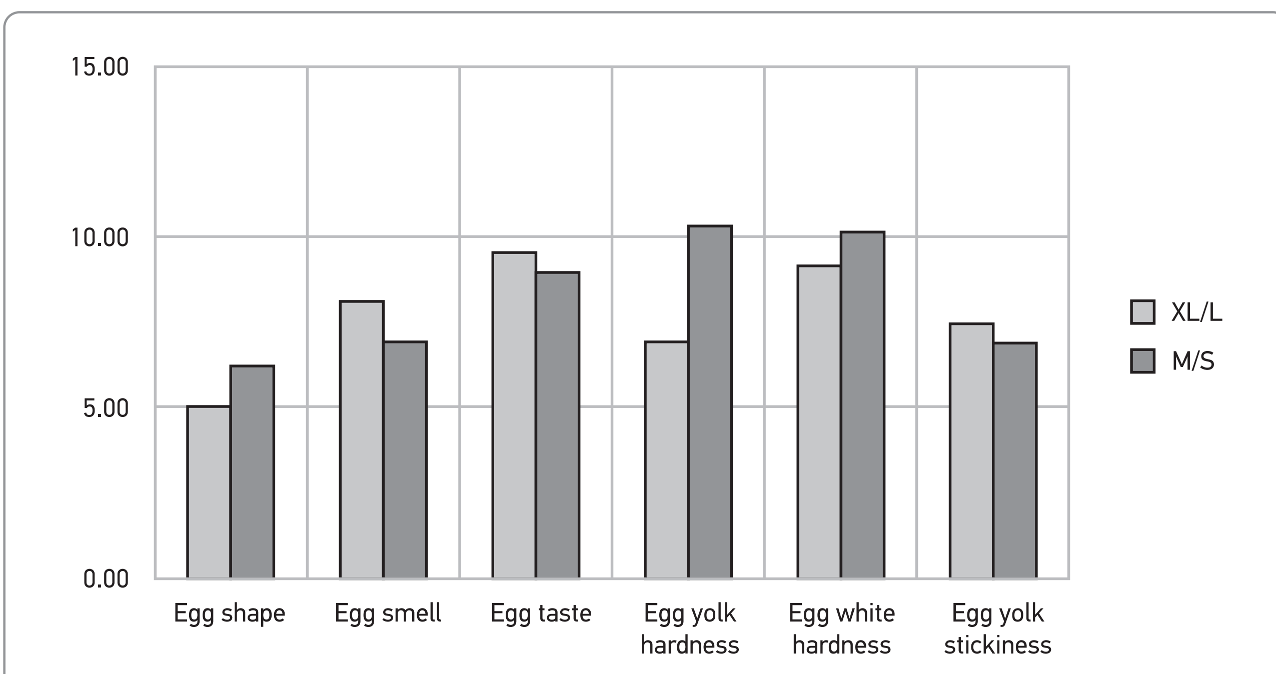

Figure 2. Descriptive characteristics between boiled eggs of different quality classes

from group II. However, the eggs from the second group received a better grade for the visual appearance of the cross-section, and for the hardness of the egg white and yolk. Also, the stickiness of the yolk to the palate was lower in group II eggs (M-S). The results showed there were no statistically significant differences ($p>0.05$) between the compared sensory characteristics in terms of cross-sectional appearance, smell, taste, egg white hardness, or hardness and stickiness of the yolk within the selected egg groups.

Total quality index

Bearing in mind that the higher the HU, the better the quality, authors compared two classes of eggs (HU 20–40; HU 40–60) with the eggs scoring HU above 60, using total quality index where the rule of thumb is "the lower the overall score, the better the overall quality". The introduction of two additional parameters — ΔE egg yolk and ΔE egg white — within the formula shows that TQI of HU 20–40 scored worst (1.732), followed by TQI of eggs with HU 40–60 (0.469). As expected, best score of TQI was for eggs of highest HU value (TQI = 0.111).

Conclusion

As expected, external quality characteristics associated with weight classes do not show any quality pattern as these classes are only perceived by consumers (the bigger the egg the better the quality) with no scientific background.

Opposed to this, the research results indicate that there are differences in colour (egg yolk and egg white) between eggs of different freshness (HU) that the consumers were able to observe. In parallel, the calculation of the total quality index shows that the combination of selected characteristics can give a new dimension in the assessment of egg quality. Opposed to this, the sensory panel did not detect any perceivable differences between these quality groups. Future research should focus on deploying the total quality index using HU and instrumental quality characteristics as a baseline for developing a new quality perspective.

Da li su klase jaja dovoljne, ili nam je potreban indeks kvaliteta jaja?

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A p s t a r k t: Ovo istraživanje ukazuje na varijacije u najvažnijim unutrašnjim i spoljašnjim karakteristikama kvaliteta jaja jednog od najvećih proizvođača na srpskom tržištu u odnosu na svežinu (izraženu Hogovim jedinicama (HJ)) i težinske klase (S, M, L, XL). Paralelno, sprovedena je i senzorna evaluacija (za dva najčešća kulinarska načina pripreme) kako bi se utvrdilo da li potrošači primećuju razlike u kvalitetu prilikom konzumiranja kajgane i kako panelisti percipiraju kuvana jaja. S obzirom da je HJ naučno zasnovana dimenzija kvaliteta, za razliku od težinskih klasa koje su zasnovane na potrošnji povezanoj sa veličinom jaja, autori su uveli novi indeks ukupnog kvaliteta koji daje novu perspektivu HJ.

Ključne reči: *kvalitet jaja, indeks ukupnog kvaliteta, klase jaja.*

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