ORIGINAL SCIENTIFIC PAPER

Yolk colour of eggs from different housing systems

Jasna Bertoncelj[1], Anja Gašperlin[1], Mojca Korošec[1]

Abstract

Eggs are nutrient-dense food with high biological value. They are a good source of protein, essential fatty acids and amino acids, vitamins and minerals. The colour of egg yolks is one of the important factors used to evaluate eggs' quality and is affected by the composition of poultry feed, mostly the pigment content, laying hens housing system and also genetic effects. In this study the colour of egg yolks from eggs produced in different housing systems was evaluated. DSM colour fan, Minolta chromameter and the AOAC method for determination of total carotenoid content were used. The results showed that there are differences in egg yolks colour according to the type of housing system. The most noticeable differences were detected between organic and caged eggs. Organic egg yolks were the brightest and contained the least carotenoids, while cage egg yolks were the darkest, with the highest content of carotenoids. The colour of egg yolks was also evaluated with sensory analysis. The sensory panel consisted of young consumers – students, who ranked the samples according to the intensity and likeness of the yolk colour. The students gave preference to orange-yellow colour of egg yolk. Results of the short questionnaire about consumption and purchase of eggs showed that participating students do not consume eggs often. The most important criterion for the purchase is egg production system, where free-range or barn eggs with more intense colour are preferred.

Key words: egg yolks, colour, carotenoids, chromameter, sensory analysis

Introduction

Eggs are a rich source of nutrients needed for the growth and development of the organism. They contain high-quality proteins, essential amino acids and fatty acids as well as variety of vitamins and minerals. Eggs consist of egg shell, egg yolk and egg white. The egg yolk is located in the central part of the egg and represents 25-33 % of the whole egg weight.

For consumers the quality criteria for eggs are most often freshness, the appearance of the shell and the colour of egg yolk. The quality of eggs also includes microbiological, technological, sensory and hygienic quality (Dvořák et al., 2009; Terčič et al., 2012). In some parts of the world, yolk colour is one of the most important factors used to evaluate egg quality (Kljak et al., 2012; Tolimir et al., 2016). In Europe, consumers' studies could reveal that pale yolks are less appreciated. The colour of the egg yolk is influenced by many factors such as breeding, genetic factors and contents of fat, antioxidants, calcium, vitamin A and pigments in the feed, latter has the highest influence. Laying hens are not able to synthesise colour pigments, but have the ability to transport about 20-60 % of pigments to the yolk from ingested feed (Hernandez et al., 2005; Dvořák et al., 2010; Islam and Schweigert,

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2015). The colour of the yolk depends on the quantity and ratio of carotenoids, natural yellow to red pigments in plants that have different functions in man and animal. The yolk colour results from the combination of yellow and red carotenoids. There are three main yellow carotenoids (lutein, zeaxanthin and apo-ester) and three main red carotenoids (canthaxanthin, citranaxanthin and capsanthin/capsorubin) used for egg yolk pigmentation. The proportion of the dietary intake of carotenoids that are absorbed and deposited in the egg yolk determines its colour varying from pale yellow to dark orange (Beardsworth and Hernandez, 2004).

The colour of egg yolks depends also on the laying hen housing system. Enriched cages are the dominating housing system in European Union countries with a share of 55.6 %, followed by barn and free-range systems (25.7 and 14.1 %, respectively). The share of organic egg production is still very low with only 4.6 % (Windhorst, 2018). Results of different studies showed that egg yolk from organic farming is less intensively coloured than egg from other housing system, especially from caged eggs (Hidalgo et al., 2008; Terčič et al., 2012; Englmaierová et al., 2014; Bovšková et al., 2014).

The colour of the egg yolk can be evaluated in various ways. One of the simplest methods for assessment of egg yolk colour is a visual estimation with the yolk colour fan. Colour perception depends on chemical and physical properties of the yolk, the quality and intensity of lighting produced by a light source and on the particular observer. Although this method is most commonly used worldwide to measure the colour of an egg yolk, it only gives information on colour, not the content of the biologically important carotenoids that have health promoting effects. Therefore, different chemical methods have been developed to quantitatively determine either total carotenoids or individual carotenoids in egg (Dvořák et al., 2009; Bovšková et al., 2014). The simplest one is the spectroscopic determination of total carotenoids as ß-carotene equivalents with AOAC method or newer simple and fast iEx/iCheck method. To determine the concentration of individual carotenoids HPLC method must be used (Islam and Schweigert, 2015). The colour of the egg yolk is also measured instrumentally with chromameter. The system is based on the CIE (Commision Internationale I'Eclariage) L*a*b* system for colour determination.

The aim of the present study was to investigate variations in colour of commercial egg yolks from different housing systems (organic, free-range, barn and cage) using different methods, namely the DSM Yolk Colour Fan, Minolta chromameter and AOAC method for carotenoid content. Additionally, sensory analysis was performed with young consumers - students, who ranked the egg yolk colour according to the intensity and likeness.

Materials and methods samples

The eggs of Slovenian origin from different laying hens housing systems were purchased from the market. The housing systems are indicated by numerical codes used in shell eggs marking (Regulation (EC) No 589/2008) as follows: 0 – organic production; 1 – free-range eggs; 2 – barn eggs; 3 – eggs from caged hens (hens kept in enriched cages). From each housing system, the eggs from three different producers were purchased and for the analyses, three eggs randomly selected from retail packaging were used (Figure 1).

Figure 1 Samples of eggs from enriched cages (a) and organic egg production (b)

(a) (b)

Methods

Evaluation of egg yolk colour

The egg yolk colour was first evaluated visually by means of DSM yolk colour fan (Figure 2), which has a range of colour intensity values from 1 (light yellow) to 15 (dark orange) points. The egg yolk was manually separated from the white prior to measurement and placed on a Petri dish. The evaluation was carried out against a non-reflective surface using indirect daylight.

Figure 2 DSM Yolk Colour Fan (https://www.dsm.com/anh/en/feedtalks/eggyolk-pigmentation-guidelines.html)

Colour characteristics of egg yolks were also determined instrumentally in the CIE L*a*b* space, where lightness L* and two colour coordinates, a* (redness) and b* (yellowness) were defined by means of a Minolta CR-400 Chromameter. White standard was used to calibrate the chromameter. All measurements were performed three times and the final value was calculated as the average of the three values measured.

The pigmentation of egg yolks was determined as total carotenoid content with AOAC 958.05 method (AOAC, 1997). To 1 g of well homogenized egg yolk from three eggs of each producer and the same housing system, acetone was added in two steps, first 1 ml to make a smooth paste and then 50 ml. The solution was mixed and filtered. After washing the filter with acetone, the recovered acetone was diluted to 100 ml. Yolk colour equivalent to µg ß-carotene/g yolk was measured on a spectrophotometer at 450 nm wavelength. The ß-carotene equivalents (µg ß-carotene/g of yolk) were calculated by comparison with a calibration curve prepared with ß-carotene acetone solutions in the concentration range from 0.4 to 6.0 µg/mL.

Sensory assessment off egg yolk colour

The colour of egg yolks was also evaluated with sensory analysis. The sensory panel consisted of 30 young consumers – students of BSc Food Science and Nutrition programme at Biotechnical Faculty, who ranked the samples according to the intensity and likeness of the yolk colour, from the least intense/liked to the most intense/liked colour (ISO 8587: 2011).

Questionnaire about consumption and purchase of eggs

Prior sensory assessment students were asked to complete a short questionnaire about consumption and purchase of eggs. We were interested in the frequency and amount of eggs eaten, where they purchase eggs and what are the criteria for purchasing, eggs from which housing method do they use, and which colour of egg yolks they prefer.

Data analysis

Data obtained from DSM colour fan and Minolta chromameter readings, respectively, and the determination of ß-carotene content were processed with ANOVA and Duncan post hoc test to establish the differences in measured parameters among different egg housing methods. Friedman test was employed to check whether rank orders for colour intensity and likeness of egg yolks from different housing methods differ. The level of statistical significance was set at $p \leq 0.05$. Pearson correlation coefficients (r) were calculated to measure the strength of the linear relationships between the pairs of studied parameters.

Results and discussion

Colour parameters and total carotenoid content

The results of egg yolk colour evaluation with a DSM colour fan and Minolta chromometer, and spectrophotometric determination of yolk pigmentation by the AOAC method are summarized in Table 1. Results are expressed as means for every of the three producers of each laying hens housing system.

Egg yolk colour is an important parameter of yolk quality and generally ranks third amongst egg quality parameters, after freshness and eggshell quality (Englmaierová et al., 2014). Egg yolk colour fan is a common and simple tool used to determine yolk colour. In our research, the colour values ranged from 10 to 14.7, with the lowest value in the sample 0-2 from organic production, and the highest value in the sample 3-3 (enriched cages). The biggest differences within the same housing method were in egg yolks from organic production, with the values ranging from 10-13.3 (Table 1).

The values of L*, a* and b* parameters were

Table 1 Colour parameters and total carotenoid content of eggs from different production method

Sample (housing method-producer)	Colour parameter				Carotenoid content (μg/g yolk) (AOAC method)
	DSM[1] colour fan	Minolta (CIE Lab[2])			
		L*	a*	b*	
0-1	12.3	51.89	6.40	37.93	35.25
0-2	10.0	57.26	2.74	45.79	12.19
0-3	13.3	53.69	9.64	41.50	22.01
1-1	11.7	55.10	5.56	42.91	32.89
1-2	13.7	51.80	9.89	41.70	32.83
1-3	13.3	53.85	8.38	41.51	42.76
2-1	13.3	54.01	10.14	48.30	24.19
2-2	12.7	54.29	8.81	44.06	37.15
2-3	12.7	55.48	7.83	46.47	43.43
3-1	14.0	51.54	11.87	40.80	26.26
3-2	14.0	51.14	12.13	41.42	66.13
3-3	14.7	51.14	15.72	41.74	42.83

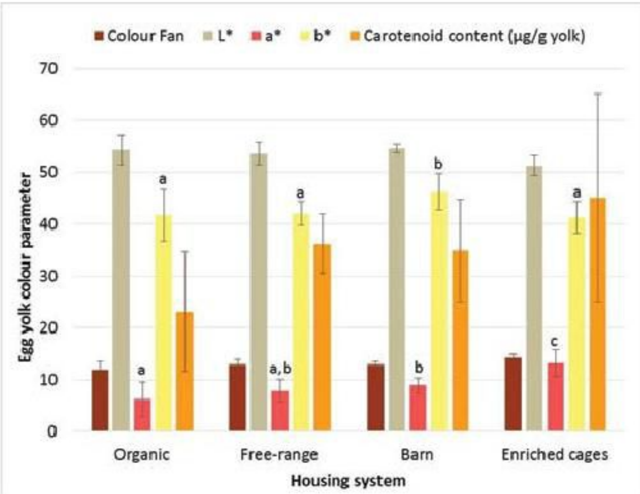
__0__: organic; __1__: free-range; __2__: barn; __3__: enriched cages
[1] DSM Yolk Colour Fan: 1 - light yellow; 15 - dark orange
[2] L: black (0) to white (100); a*: green (-) to red (+); b*: blue (-) to yellow (+)*

measured using the Minolta chromometer. The mean L* value ranged between 51.14 and 57.26 for egg yolks from different production method. The highest L* value, meaning the brightest colour, had sample 0-2 (egg yolk from organic farming), while the lowest (51.14) had the two samples from hens kept in enriched cages, which also had the highest values obtained with colour fan; these two egg yolks were the darkest. The average value of a* was between 2.74 and 15.72. The highest value of a*, which means more reddish colour, had a yolk sample of caged egg, and the lowest one of the samples from organic production. The parameter b* varied between 37.93 and 48.30. For 252 samples of egg yolks from hens kept in enriched cages Dvořák et al. (2009) reported L* values in much bigger range, from 43.42 to 68.51. Parameters a* and b* were more similar to our results, they ranged from 0.05 to 13.49 and from 22.38 to 48.18, respectively.

The carotenoid content expressed as ß-carotene measured by AOAC method varied between 12.19 in 66.13 μg/g yolk. From Table 1 it can be seen that the values varied among the different laying hens housing systems, as well as within the same system. The least total carotenoids contained sample 0-2 from organic housing system, while a particularly high content of carotenoids was determined in the yolk sample of egg from cage housing system (66.13 μg carotenoids/g yolk) whose colour value obtained with colour fan was also among the highest.

Figure 3 demonstrates the graphical presentation of averages values regarding the housing system.

Figure 3 The influence of housing system on the egg yolk colour and carotenoid content (mean ± SD). Different letters in bars of the same colour represent statistical differences (ANOVA, $p \leq 0.05$)



As it can be seen egg yolks from organic farming were among the brightest, with the average value L* of 54.28, and had the lowest redness (the lowest value of parameter a*). The latter was significantly different from a* values of egg yolks produced in barn and enriched cages. Egg yolks from organic farming contained the least total carotenoids and had the lowest colour value on the fan scale, however differences were not statistically significant. Eggs from barn and free-range systems showed similar results in all colour parameters determined, but in value b*. The egg yolks from hens kept in enriched cages were the darkest, with the average value L* of 51.27, with the highest colour value on the fan scale and the highest average content of total carotenoids. Their colour shade was significantly the reddest.

Other studies also reported that egg yolks colour depends on laying hen housing system. Hidalgo et al. (2008) reported that the intensity of egg yolk colour in eggs from Italian market was decreasing in the following order: cage > free-range > barn > organic housing system. Also in other studies (Đukić-Stojčić et al., 2009; Dvořák et al., 2010; Terčič et al., 2012; Englmaierová et al., 2014; Bovšková et al., 2014), egg yolks from cage housing system were found to be more intensely coloured than egg yolks from other housing systems.

The Pearson's correlation analysis (Table 2) among the analysed parameters shoved a strong correlation between colour fan value and sum of ranks for yolk colour likeness, intensity and redness (a* value), respectively. Sum of ranks for colour intensity is in strong relationship with lightness (L* value) and redness. Lightness of the egg yolk is in moderate negative correlation with redness and positive correlation with yellowness (b*).

Kljak et al. (2012) reported that colour determinations obtained by means of colour fan are highly subjective which makes them difficult to compare with determinations made in different conditions. In their study correlation analysis between the colour fan value and instrumentally measured a* values indicated a positive relationship (r=0.6274). Kljak et al. (2012) concluded that better and more objective insight in egg yolk colour could be achieved by measuring the CIE a* colour parameter. Similarly, Dvořák et al. (2009) found determination of colour in the CIE L*a*b* space much more exact and not distorted by subjective perception of colour. It provides much information about yolk colour, it is not very demanding in terms of time and space and is absolutely objective. The determination of colour value with yolk colour fan scale is influenced by light and subjective perception. Anyway, this method is widely spread in common practise as a simple method for the egg yolk quality assessment. The carotenoid content expressed as ß-carotene equivalents is not directly proportional to the DSM colour fan value (r=0.274). Bovšková et al. (2014) reported the same and explained that the colour depends not only on the carotenoid content but also on the composition of carotenoids, which can be diversified.

Sensory analysis

When evaluating egg yolks by intensity and likeness of the colour, students received all yolk samples at the same time and ranked them first by intensity and then by the likeness of the yolk colour from the least intense/liked to the most intense/liked colour. All students selected the same egg yolk sample from organic farming for the least intensively coloured, and similarly, the same sample of egg yolk from battery farming (enriched cages) for the most intensively coloured (Ftest=127.84; F=12.59). In evaluating the likeness of egg yolk colour, the students were not so uniform. Nevertheless, the majority of the students identified the colour of the yolk, which was regarded as the most pale yellow, for the least appealing. The colour of two samples of egg yolks from battery farming (enriched cages), tended to be most preferred, however the differences in sum of ranks were not significant (Ftest=-44.53; F=12.59).

Questionnaire results

With answers to survey questionnaire, the

Table 2 Correlation coefficients (r) from comparison of evaluated parameters

Parameter	L*	a*	b*	Carotenoid content	$R_{likeness}$	$R_{intensity}$
Colour fan value	-0.571**	0.776**	-0.198	0.274	0.914**	0.854**
L*	1	-0.646**	0.620**	-0.486	-0.721*	-0.905**
a*		1	-0.122	0.370	0.800*	0.931**
b*			1	-0.479	-0.207	-0.427
Carotenoid content				1	0.266	0.667
$R_{likeness}$					1	0.743*

$R_{likeness}$: sum of ranks for colour liking; $R_{intensity}$: sum of ranks for colour intensity;
**correlation is significant at p≤0.05; **correlation is significant at p≤0.01*

included students expressed their views about consumption and purchase of eggs, the criteria for purchasing and the significance of certain properties. The most important criteria for young consumers when purchasing eggs is laying hens housing system, following by the size of eggs end the price, while brand/manufacturer of eggs and colour of the shell are less important. According to the results of questionnaire, included students consume eggs 1 to 2-times a week, the amount of eggs consumed is not large, on average 2 to 3 eggs per week. Most students purchased eggs from relatives or buy them at the markets. The majority of the students buy and consume eggs from free-range and barn housing system and give preference to yolks that are more intense in colour, they prefer orange-yellow colour of the yolk.

The results of the study in Serbia (Tolimir et al., 2017), where 239 consumers were included, showed that 40% of consumers buy eggs in super/hypermarkets, 27 % get eggs elsewhere. When asked if the brand is important for their purchase, 30 % of consumers answered that the mark was not important, while for 15% of them the brand represents a criterion for the purchase. Serbian consumers preferred to buy larger eggs. The results of the survey, as in our study, showed that consumers prefer the orange-yellow colour of egg yolks, the colour is being an important parameter for the purchase of eggs.

Conclusions

The results of our study showed that there are differences in the egg yolk colour according to the laying hens housing method, probably because of the different feed. Egg yolks from organic farming were among the brightest and had the least red shade of colour. They contained the smallest amount of carotenoids and had the lowest colour value on the colour fan scale. Eggs from barn and free-range systems showed similar results in all methods used. The egg yolks from enriched cages hens were the darkest, with the reddest colour shade and the highest colour value on the fan scale. The carotenoid content in egg yolks from this type of housing method was the highest. The sensory analysis and questionnaire revealed that the majority of participating students preferred egg yolks with a more intense colour.

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Boja žumanjka jaja iz različitih sustava proizvodnje

Sažetak

Jaja su nutritivna hrana visoke biološke vrijednosti. Dobar su izvor proteina, esencijalnih masnih kiselina i aminokiselina, vitamina i minerala. Boja žumanjka je jedan od najvažnijih čimbenika koji se koristi za ocjenu kvalitete jaja, a na njega utječe sastav hrane za perad, uglavnom sadržaj pigmenta, sustav uzgoja kokoši nesilica i genetski učinci. U ovom istraživanju ocijenjena je boja žumanjka iz jaja proizvedenih različitim metodama uzgoja kokoši nesilica. Korišteni su DSM lepeza s paletom boja, Minolta kromametar i AOAC metoda za određivanje sadržaja ukupnih karotenoida. Rezultati su pokazali da postoje razlike u boji žumanjka jaja prema metodi uzgoja kokoši. Najočitije razlike utvrđene su između jaja iz ekološkog uzgoja i jaja iz kaveznog uzgoja. Žumanjci jaja ekološkog uzgoja bili su najsvjetliji i sadržavali su najmanje karotenoida, dok su žumanjci jaja iz kaveznog uzgoja bili najtamniji, s najvećim sadržajem karotenoida. Boja žumanjka jaja također je ocijenjena senzorskom analizom. Senzorni panel činili su mladi potrošači - studenti koji su uzorke svrstali prema intenzitetu i sviđanju boje žumanjka. Studenti su dali prednost narančasto-žutoj boji žumanjaka. Rezultati kratkog upitnika o potrošnji i kupnji jaja pokazali su da uključeni studenti jaja ne konzumiraju često. Najvažniji kriterij za kupnju su sustav proizvodnje jaja, preferiraju se jaja iz slobodnog ili podnog uzgoja s intenzivnijom bojom.

Ključne riječi: žumanjci, boja, karotenoidi, kromametar, senzorska analiza

Farbe des Eigelbs aus verschiedenen Produktionssystemen

Zusammenfassung

Eier sind nahrhafte Lebensmittel von hohem biologischem Wert. Sie sind eine gute Quelle von Eiweiß, essentiellen Fettsäuren und Aminosäuren, Vitaminen und Mineralstoffen. Die Eigelbfarbe ist einer der wichtigsten Faktoren für die Beurteilung der Qualität von Eiern und wird von der Zusammensetzung der Geflügelfuttermittel, hauptsächlich dem Gehalt an Pigmenten, dem Zuchtsystem von Legehennen und den genetischen Auswirkungen beeinflusst. In dieser Studie wurde die Farbe des Eigelbs untersucht, das mit verschiedenen Hühnerzuchtmethoden hergestellt wurde. Zur Bestimmung des Gesamtcarotingehalts wurden der Farbfächer der Firma DSM, das Minolta-Farbmessgerät und die AOAC-Methode verwendet. Die Ergebnisse zeigten, dass es Unterschiede in der Farbe des Eigelbs in Abhängigkeit von der Methode der Hühnerzucht gibt. Die offensichtlichsten Unterschiede wurden zwischen Eiern aus dem ökologischem Anbau und Eiern aus der Käfigaufzucht festgestellt. Das Eigelb aus dem ökologischen Anbau war am hellsten und enthielt den geringsten Anteil an Carotinen, während das Eigelb aus der Käfigzucht am dunkelsten war und den höchsten Gehalt an Carotinen aufwies. Die Eigelbfarbe wurde darüber hinaus durch eine sensorische Analyse bewertet. Das Team für die sensorische Bewertung bestand aus jungen Verbrauchern - Studenten, die die Proben nach Intensität und Ähnlichkeit der Dotterfarbe klassifizierten. Die Studenten bevorzugten die orange-gelben Eidotter. Die Ergebnisse eines kurzen Fragebogens zum Verzehr und zum Kauf von Eiern haben gezeigt, dass die betroffenen Studenten Eier nicht häufig konsumieren. Das wichtigste Kriterium für den Kauf ist das Eiproduktionssystem, bevorzugt werden Eier aus der Freiland- oder Bodenzucht mit einer intensiveren Farbe.

Schlüsselwörter: Eigelb, Farbe, Carotine, Farbmessgerät, sensorische Analyse

El color de la yema de los huevos de diferentes tipos de producción

Resumen

Los huevos son un alimento con el valor biológico muy alto. Son un fuente de proteínas, de los ácidos grasos esenciales y de los aminoácidos, de las vitaminas y de los minerales. El color de la yema es uno de los factores más importantes para la evaluación de la calidad de los huevos y le afecta el alimento de los aves, en su mayoría el contenido del pigmento, el tipo de la cría de las gallinas ponedoras y los efectos genéticos. En este trabajo fueron evaluados los colores de las yemas de los huevos de diferentes tipos de cría de la gallinas ponedoras. Fue usada la guía de DSM con el abanico de color de yema, el medidor de croma Minolta y el método AOAC para determinar la deposición total de los carotenoides. Los resultados mostraron que existen las diferencias en el color de la yema de los huevos en relación con el método de la cría de las gallinas. Las diferencias más evidentes fueron determinadas entre los huevos de la cría ecológica y de la cría en jaula. Las yemas de los huevos de la cría ecológica fueron las menos saturadas y depositaron la menor cantidad de carotenoides, mientras las yemas de los huevos de la cría en jaula fueron las más saturadas, con el depósito de carotenoides más alto. El color de la yema de los huevos también fue analizado por la evaluación sensorial. El panel sensorial fueron los consumidores jóvenes - los estudiantes que clasificaron las muestras según la intensidad y según su gusto del color de la yema del huevo. Los estudiantes dieron la prioridad al color naranja-amarillo de la yema. Los resultados del cuestionario corto sobre el consumo y la compra de los huevos mostraron que los estudiantes participantes no consumen los huevos a menudo. El criterio más importante para la compra son el sistema de producción de los huevos y son preferidos los huevos de la cría libre o de la cría en suelo con el color más saturado.

Palabras claves: yemas, color, carotenoides, medidor de croma, evaluación sensorial

Il colore del tuorlo dell'uovo in base alle differenti tecniche d'allevamento

Riassunto

Le uova sono un alimento nutriente dall'alto valore biologico. Sono una buona fonte di proteine, acidi grassi essenziali e amminoacidi, vitamine e minerali. Il colore del tuorlo dell'uovo è uno dei fattori più importanti nella valutazione della qualità dell'uovo stesso. Esso è influenzato sia dalla composizione del mangime per pollame (in particolare dal contenuto di pigmenti), dalla tecnica d'allevamento delle galline ovaiole e da affetti genetici. In questo studio è stato valutato il colore del tuorlo di uova provenienti da galline ovaiole allevate secondo differenti metodi. Per condurre questo studio ci si è serviti della mazzetta di colori DSM, del colorimetro Minolta e del metodo AOAC atto a stabilire il contenuto dei carotenoidi totali. I risultati hanno dimostrato che esistono differenze nel colore del tuorlo in base al metodo d'allevamento delle galline. Le maggiori differenze sono state accertate tra le uova di galline allevate secondo il metodo biologico e le uova di galline allevate in gabbia. I tuorli delle uova provenienti da allevamento biologico sono risultati più chiari e meno ricchi di carotenoidi, mentre i tuorli delle uova di galline allevate in gabbia sono risultati più scuri e col maggiore contenuto di carotenoidi. Il colore del tuorlo è stato sottoposto anche ad analisi sensoriale. Per l'occasione è stato creato un panel test formato da giovani consumatori – studenti che hanno classificato i campioni in base all'intensità e al gradimento del colore del tuorlo. Gli studenti hanno preferito i tuorli dal colore giallo-aranciato. I risultati del breve questionario sulla consumazione e l'acquisto di uova hanno dimostrato che gli studenti coinvolti non sono frequenti consumatori di uova e che il principale criterio per l'acquisto è il metodo d'allevamento delle galline ovaiole. Sono preferite, infatti, le uova dal colore più intenso provenienti da allevamenti all'aperto o a terra.

Parole chiave: tuorli, colore, carotenoidi, colorimetro, analisi sensoriale