

The effect of a diet supplemented with sea-buckthorn pomace on the colour and viscosity of the egg yolk

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Abstract

Sea-buckthorn pomace is a very valuable product which contains not only important nutrients but also high-quality oils. The question addressed in the present study was to what extent the diet containing the sea-buckthorn pomace would affect the viscosity and colour of egg yolk measured in the CIELAB system. The feeding mixture for laying hens was supplemented with 20; 50 and 100 g·kg⁻¹ of sea-buckthorn pomace. As a result, colour indices of the egg yolk such as L*, a* and b* changed significantly ($\alpha = 0.01$). The greatest relative enhancement was observed for indicator a* for the red colour. Visually, this corresponds to the more intense orange colour of the egg yolk. The addition of sea-buckthorn pomace to the diet for laying hens resulted in a larger increase in indicator ΔE^* (CIE total colour difference) compared to the control group. Colour indicator h_{ab} is the only indicator whose value oscillated around that determined for the control group. The addition of sea-buckthorn pomace to the diet resulted in an increase in colour indices a*, b* and C*_{ab}. Indicator ΔE^* also increased significantly with an increasing amount of sea-buckthorn pomace in a diet. Egg yolks were darker, had more intense red and yellow colours, and showed lower viscosity which are all features preferred by the consumer.

CIELAB, addition feeding, food quality, biophysical indicators of food

Hippophae rhamnoides (common sea-buckthorn) is the most commonly used species to make sea-buckthorn oil. The plant is native to Finland and has 9 subspecies (Kallio et al. 2002). Sea buckthorn is valued for its antioxidant, cardioprotective, antiatherogenic, antidiabetic, hepatoprotective, anti-carcinogenic, immunomodulatory, antiviral, antibacterial, anti-inflammatory and vasorelaxant effects. Due to these and other positive effects, the plant is included in both human and animal nutrition, in the latter case to increase the biological value of animal products (Krejcarova et al. 2015). It is characterized by a high content of oil that is present in seeds and some soft parts of the plant (pulp and skin). The content of oil in seeds is usually around 100 g·kg⁻¹ but can reach up to 150–160 g·kg⁻¹ in some varieties. Unlike seeds, the content of oil in the plant's soft parts including whole berries varies depending on the origin and other factors. The content of oil in fresh berries may vary from 14 g·kg⁻¹ (in the subspecies *sinensis* that occurs in China) to 137 g·kg⁻¹ in the subspecies *turkestanica* that grows in the western Pamir Mountains. The content of oil in berries within one population correlates well with morphological characteristics such as the size and colour of berries, which can lead to a two-fold difference. The content of oil in berries depends on the period of harvesting (Yang and Kallio 2002a).

Oil made of sea-buckthorn seeds is rich in two essential fatty acids: linoleic acid (18:2, n-6) and alpha-linolenic acid (18:3, n-3) whose concentrations in oil can reach up to 300–400 g·kg⁻¹ and 200–350 g·kg⁻¹, respectively. Other major fatty acids contained in oil made of sea-buckthorn seeds are: oleic acid (18:1n-9) 130–300 g·kg⁻¹, palmitic acid (16:0) 150–200 g·kg⁻¹, stearic acid (18:2) 20–50 g·kg⁻¹, vaccenic acid (18:1, n-7) 20–40 g·kg⁻¹ (Yang and Kallio 2002a,b).

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The colour and viscosity of the egg yolk are among the important sensory, physicochemical and nutritional indicators to evaluate the quality of eggs.

Unlike the subjective perception of colour, colority is determined objectively using spectrophotometric instruments with defined parameters (Dvořák et al. 2009; Saláková 2012). Colority is defined in the International Colorimetric System CIELAB (CIE 1986, Commission Internationale de l'Éclairage). It is based on the differences of three elemental complementary colour pairs: red-green (indicator a^*), yellow-blue (indicator b^*) and black-white (indicator L^*). Specific lightness L^* as the third characteristic is a function of reflectance, i.e. of the ratio between the intensity of reflected light and the intensity of incident light from 0 (black) to 100 (white). Calculations can be used to define further indices. The distance between two points ΔE^* (CIE total colour difference). Chroma C^*_{ab} is the value by which a particular colority differs from grey. The specific angle of hue h_{ab} which is usually expressed by the name of colority in relation to the colour (red, yellow, etc.) (Dvořák et al. 2009, 2012).

Egg viscosity is also one of the important indicators. It affects a number of functional and technological properties of eggs such as the whipping and emulsifying ability (Kemps et al. 2010). Viscosity as a physical indicator depends on the age of the egg, storage temperature, the pH value, specific weight, the water content, and the straining of the egg. The viscosity of the egg yolk is $\times 8$ higher than that of the egg white (Simeonovova et al. 2003).

This study describes variations in the colour and viscosity of the egg yolk with the amount of sea-buckthorn pomace added to a complete feeding mixture for laying hens at 20, 50, and 100 $\text{g}\cdot\text{kg}^{-1}$.

Materials and Methods

A total of 4 groups, each containing 20 Isa Brown hybrid combination laying hens (55 weeks old), were examined in this experiment. Laying hens were reared in cages (area of 7.5 m) in the accredited experimental enclosure of the Department of Animal Nutrition, University of Veterinary and Pharmaceutical Sciences Brno. Laying hens in the control group received a complete feeding mixture without sea-buckthorn. Experimental groups of hens were fed feeding mixtures supplemented with 20 $\text{g}\cdot\text{kg}^{-1}$ (marked as E2 in figures and tables), 50 $\text{g}\cdot\text{kg}^{-1}$ (E5), and 100 $\text{g}\cdot\text{kg}^{-1}$ (E10) of sea-buckthorn pomace. Sea-buckthorn pomace was obtained as a side product after pressing sea-buckthorn berries (Leicora variety) in order to obtain sea-buckthorn juice. Sea-buckthorn pomace contained 200.03 $\text{g}\cdot\text{kg}^{-1}$ of crude protein, 130.73 $\text{g}\cdot\text{kg}^{-1}$ of fat, 160.72 $\text{g}\cdot\text{kg}^{-1}$ of fibre, and 20.05 $\text{g}\cdot\text{kg}^{-1}$ of ash, at the dry matter content of 940.16 $\text{g}\cdot\text{kg}^{-1}$.

Nitrogen content was determined by the Kjeldahl method using a Buchi analyser (by Centec Automatika, spol. s.r.o., Prague, Czech Republic) and the content of nitrogenous substances was calculated by multiplying the nitrogen concentrations by a coefficient of 6.25. Fat content was determined by the apparatus ANKOMXT10 Fat Analyzer and the fibre content by ANKOM 220 Fiber Analyzer.

A total of 20 eggs were collected from each group after a 10-day experimental period to evaluate the properties of the egg yolk.

The viscosity of the egg yolk was determined using a Rheo-viscometer. Samples in a cuvette 100 were maintained at 20 °C. The sample was poured in a cuvette and then mixed $\times 10$ using an arm with a ball on its end. The measuring range for the determination of viscosity was 0.05–106 Pa·s (i.e. 0.5–107 cP - centipoise). Loss of precision in determination was precluded by using suitable weights to ensure that each monitored time of the corrected path (29.28 mm) would exceed 10 s. Due to the volume of the cuvette, two homogenized and tempered egg yolks had to be measured at the same time. A total of 10 samples from each group were examined. The viscosity of each sample of the egg yolk was measured three times. The arithmetic mean was calculated from the three measured values and used for further evaluation. Measurements were repeated with an interval of 40 s. The time (s) was recalculated to viscosity (Pa·s) using the formulae for the corrected path method.

The determination of egg yolk colour. The egg yolk was separated from the egg white prior to measurement, placed on a Petri dish with a diameter of 50 mm, and then covered with a thin food foil. Colour was determined in the CIELAB system using the portable spectrophotometer Colour-guide sphere spex (BYK Gardner) with the exclusion of gloss, with a $d/8^\circ$ spherical geometry, D_{65} light source, 10° standard observer angle, and an 8 mm aperture. The instrument was calibrated to the food foil used, prior to measurement. All measurements were performed three times. The mean value calculated from the three measurements was used as the resultant value (Dvořák et al. 2009).

Further indicators of the CIELAB system were calculated from mean values of L^* , a^* , b^* coordinates and compared.

The distance between two points ΔE^* (CIE total colour difference) was calculated according to the following formula:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

Chroma C^*_{ab} is the value by which the particular colority differs from grey according to the following formula:

$$C^*_{ab} = (a^{*2} + b^{*2})^{1/2}$$

The specific angle of hue h_{ab} is described by the name of a particular colour. Its value is calculated according to the following formula:

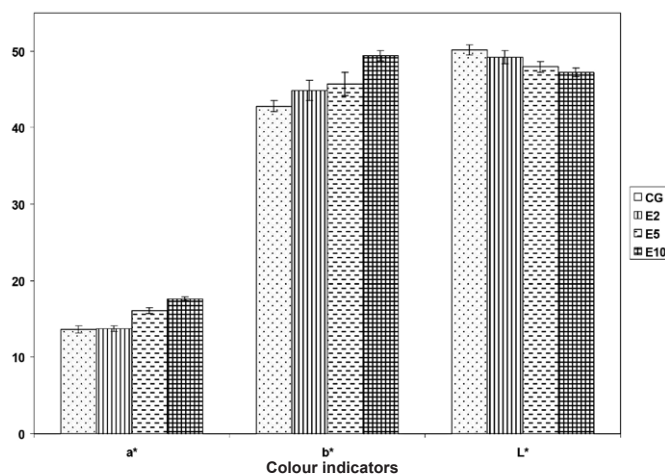
$$h_{ab} = \text{tg}^{-1} (b^*/a^*)$$

Data were processed statistically for each indicator (L^* , a^* , b^*) and viscosity (Figs 1 and 2). The effect of sea-buckthorn pomace added in the feeding dose on colour indicators and viscosity of the egg yolk was tested using one-factor ANOVA (MS EXCEL). Since large differences were assumed in the experiment, the null hypothesis was formed for the level of significance $\alpha = 0.01$.

Results

Figure 1 shows standard colority indicators of the egg yolk. Indicators a^* and b^* increased markedly (ANOVA) with the amount of added pomace. Indicator a^* increased in groups E5 and E10 in comparison with the control group. Variability documented by the standard error of the mean (SEM) was very low in all sets. Visually, egg yolks were of more intense orange colour. Indicator b , which was more variable than indicator a , correlated well with the amount of pomace in the feed. This was manifested by the saturation of the yellow colour. In contrast, indicator L decreased (ANOVA) with the amount of sea-buckthorn pomace in the feed. Variability characterized by SEM was very low. Egg yolks generally appeared to be darker.

Fig. 1. Variation in colour indicators of the egg yolk with the amount of sea-buckthorn pomace in the feed (Mean \pm SEM).



CG – Control group, E2 – the feed supplemented with 20 g·kg⁻¹ of sea-buckthorn pomace, E5 – the feed supplemented with 50 g·kg⁻¹ of sea-buckthorn pomace, E10 – the feed supplemented with 100 g·kg⁻¹ of sea-buckthorn pomace

It follows from the comparison with the control group that the addition of sea-buckthorn pomace in the feed resulted in a significant increase in indicators C^*_{ab} (chroma) and ΔE^* (CIE total colour difference) (Table 1). Both indicators increased with the amount of sea-buckthorn pomace in the feed. Hue h_{ab} was the only indicator whose value oscillated around that found in the control group (Table 1).

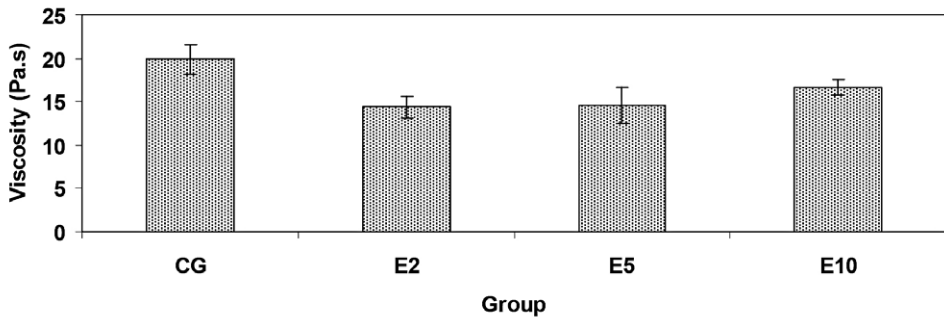
Table 1. Variations in calculated colour indicators of the egg yolk with the amount of sea-buckthorn pomace in the feed.

Group	C* _{ab}	h _{ab}	ΔE* compared to control
CG	44.943	80.420	0.000
E2	46.925	81.134	2.262
E5	48.445	78.449	4.392
E10	52.463	78.158	8.262

CG – Control group, E2 – the feed supplemented with 20 g·kg⁻¹ of sea-buckthorn pomace, E5 – the feed supplemented with 50 g·kg⁻¹ of sea-buckthorn pomace, E10 – the feed supplemented with 100 g·kg⁻¹ of sea-buckthorn pomace

Figure 2 provides an overview of the viscosity values for the egg yolk. It shows that viscosity decreased at the lowest amount of pomace added to the feed (20 g·kg⁻¹) but did not continue to change significantly (ANOVA) with the increasing amount of sea-buckthorn pomace in the feeding dose.

Fig. 2. Variation in the viscosity of the egg yolk with the amount of sea-buckthorn pomace in the feed (Mean ± SEM).



CG – Control group, E2 – the feed supplemented with 20 g·kg⁻¹ of sea-buckthorn pomace, E5 – the feed supplemented with 50 g·kg⁻¹ of sea-buckthorn pomace, E10 – the feed supplemented with 100 g·kg⁻¹ of sea-buckthorn pomace

Discussion

Although the colour of the egg yolk improved with the amount of pomace, the differences were not as significant as when natural pigments were added into the feed (Dvořák et al. 2012). This particularly applies to indicator ΔE* (Table 1) whose maximum value in our study was 8.262 whereas in the above-mentioned study it varied within the range of 17.917– 24.265. Values reported in this paper are very similar to those determined for pastured laying hens as the calculated indicator ΔE* (total colour difference) is 13.257 (Dvořák et al. 2012), in comparison with the control group.

Dried tomato pulp can also be used in laying hens as an alternative feed. The supplementation of a diet with up to 100 g·kg⁻¹ of the pulp has no negative effect on the quality of eggs (Nobakht and Safamehr 2007). Other authors reported a more intense egg yolk colour when the feeding dose for laying hens contained 100 g·kg⁻¹ of dried tomato pulp to substitute wheat and maize (Mansoori et al. 2008).

Supplementation of the feed with 50% palm kernel pomace enriched with palm oil had no negative effect on the performance of local Nigerian hens and on the quality of their eggs. The colour of the egg yolk increased significantly ($P < 0.05$) (Afolabi et al. 2012). Chong et al. (2008) described the significantly lighter colour of the yolk when extracted palm kernel pomace was added in the feed for laying hens at an amount of 250 g·kg⁻¹.

Supplementation of the feeding dose with 10–100 g·kg⁻¹ linseed cake increased the level of thiocyanate in blood serum. However, no significant differences in indicators of egg quality between experimental and control groups were found. The composition of particular acids in lipids in the egg yolk changed. For example, the level of linolenic acid in the egg yolk increased (Richter et al. 1998). The feeding paste containing 30, 60 or 90 g·kg⁻¹ of rape pomace had no significant effect on the weight and quality of eggs, except for a slight discoloration of the egg yolk (Obadalek et al. 1997).

The egg yolk viscosity decreases with the storage duration and due to thermal effects (Lucisano et al. 1996; Adamiec et al. 2002). The ovomucin-lysozyme complex plays a major role, contributing to changes in the viscosity of both the egg yolk and the egg white (Chang and Chen 2000). No correlation was shown between the viscosity and emulsifying ability of the egg yolk (Waimaleongora et al. 2009).

Variation in the egg yolk viscosity with the storage duration and temperature was studied by Severa et al. (2010). Yolks were stored for a period of 8 weeks at temperatures varying in the range of 4–16 °C. The analysis of yolks revealed the signs of shear thinning behaviour and the existence of yield stress (Ma et al. 1990). These effects were prevented by storing the yolks only for 3 days. However, viscosity decreased upon the addition of sea-buckthorn pomace to the feed. This is probably associated with a small portion of sea-buckthorn oil contained in the pomace. The addition of a small amount of sea-buckthorn pomace to the feed led to a 25% decrease in viscosity. Increasing the portion of sea-buckthorn pomace in the feed did not result in a further decrease in viscosity (Fig. 2).

When eggs were irradiated with gamma-radiation at a dose up to 3 kGy, the viscosity of the fluid egg white decreased. This led to increased emulsifying ability, whipping performance and greater stability of foam made of the egg white. In contrast, the viscosity of the egg yolk increased upon irradiation (Ma et al. 1990).

The addition of sea-buckthorn pomace in the feed increases the values of colour indicators a*, b* and C*_{ab}. Indicator ΔE* significantly increases, depending on the amount of pomace added to the feed. Yolks are darker and of a more intense red and yellow colour. A significant 25% decrease in viscosity was detected for the lowest amount of sea-buckthorn pomace added to the feed.

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