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THE ENVIRONMENTAL EFFECTS ON THE QUALITY PARAMETERS AND CHEMICAL COMPOSITION OF OSTRICH EGGS

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Összefoglalás

A kutatás célja a tojóév hónap és a környezeti hőmérséklet (május: 20 ºC; július: 27 ºC) hatásának vizsgálata volt a strucctojás minőségi paramétereire és kémiai összetételére. A takarmány összetétele mindkét időszakban megegyezett. Az elemzésbe májusban öt, júliusban hat db tojást vontunk be, melyek ugyanazon telepről származtak. A vizsgált külső minőségi tulajdonságok közé tartozott a tojássúly (g), hossz (cm), szélesség (cm), alakindex (%), tojástérfogat (g/cm^3), fajsúly (g/cm^3), héjszín (L*, a*, b*), héjvastagság (mm), héjfelszín (cm^2) és héjsűrűség (g/cm^3). A belső minőségi tulajdonságok a héjsúlyt (g) és héjarányt (%), a fehérjesúlyt (g) és fehérjearányt (%), a sárgájasúlyt (g) és sárgájaarányt (%), a sárgájaátmérőt (cm), a sárgája színét (L*, a*, b*), valamint a fehérje és sárgája pH-ját foglalták magukba. A tojás összetételét a fehérje és sárgája kevert, homogenizált mintájából állapítottuk meg. Az összetevők kémiai elemzése a következőkre terjedt ki: szárazanyag-tartalom (%), nyersfehérje- (%) és nyerszsírtartalom (%), ásványianyag-összetétel (Ca, Mg, P, Zn, Cu, Fe, K, Na, S, Mn; mg/kg), telített (%), egyszeresen telítetlen (%) és többszörösen telítetlen zsírsav-tartalom (%), telített/telítetlen zsírsavarány és a héj ásványianyag összetétele. Az eredmények azt mutatták, hogy májusról júliusra, a havi átlaghőmérséklet 20 ˚C-ról 27 ˚C-ra emelkedésével a minőségi tulajdonságok közül a tojáshéjvastagság, a sárgája átmérő és a sárgája pH csökkent. A kémiai összetételt tekintve, a tojás nyersfehérje- és aminosav-tartalma csökkent. A telített zsírsav-tartalom, valamint telített/telítetlen zsírsavaránya nőtt, míg az egyszeresen és többszörösen telítetlen zsírsavak aránya csökkent. A tojás ásványianyag-tartalma csökkent vagy nem változott, Mg-tartalma nőtt. A tojáshéj Ca-, K-, Mg- és S-tartalma nőtt. A vizsgált tényezők hatása a héjvastagság, a sárgája átmérő és a sárgája pH-jának csökkenésében, de legfőképpen a tojás kémiai összetételének változásában nyilvánult meg.
Kulcsszavak: strucc, termelési hónap, hőmérséklet, tojásminőségi paraméterek, tojásösszetétel

Abstract

The study aimed to investigate the effects of laying month and environmental temperature (May: 20 ºC; July: 27 ºC) on ostrich egg quality and chemical composition. The diet components were the same in the examined period. In May, five eggs, in July, six eggs were involved in the study from the same farm. The outer egg quality parameters included egg weight (g), length (cm), width

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(cm), shape index (%), egg volume (g/cm^3), specific gravity (g/cm^3), shell colour (L*, a*, b*), shell thickness (mm), shell surface (cm^2) and shell density (g/cm^3). The inner quality characteristics were shell weight (g) and ratio (%), albumen weight (g) and ratio (%), yolk weight (g) and ratio (%), yolk diameter (cm), yolk colour (L*, a*, b*) and the pH of albumen and yolk. Egg composition was measured from a mixed and homogenised sample of albumen and yolk. The chemical composition comprehended dry matter (%), crude protein (%) and crude fat content (%), mineral composition (Ca, Mg, P, Zn, Cu, Fe, K, Na, S, Mn; mg/kg), the ratio of saturated (%), mono-unsaturated (%) and poly-unsaturated fatty acids (%) and saturated/unsaturated fatty acid ratio of egg and the mineral composition of eggshell. The results showed that shell thickness, yolk diameter and yolk pH were lower in July at 27 ºC than in May at 20 ºC. The crude protein and amino acid content of eggs were also lower in July compared to May. The egg saturated fatty acid content and saturated/unsaturated fatty acid ratio increased, while the content of mono-unsaturated and poly-unsaturated fatty acid content decreased in July. The mineral composition of the egg declined or remained unchanged, however the Mg content increased. The content of Ca, K, Mg and S of the eggshell increased in the examined period. The effect of the examined factors was the most obvious in the case of egg chemical composition but significant differences could be observed in egg quality parameters, as well.

Keywords: ostrich, laying month, environmental temperature, egg quality parameters, egg chemical composition

Introduction

Being aware of the outer and inner quality parameters and geometrical properties of ostrich eggs enables the characterisation of a population and also we can estimate egg hatchability, the quality of shell and the inner composition and the weight of chicks (*Nedomová et al.*, 2009; *Nedomová and Buchar*, 2013). The egg quality parameters and egg composition greatly impact the hatchability of eggs and the quality of chicks (*Narushin* and *Romanov*, 2002). The shell, albumen and yolk play a significant role in embryo development. The minerals are transported from the shell to the yolk sac ready to be absorbed by the embryo to enable its qualitative and quantitative development (*Schaafsma et al*., 2000). The eggshell is made of protein in 2 % and $CaCO_3$ in 98 % (*Romanoff and Romanoff*, 1949). The main minerals of the eggshell include Ca, P, Cu, Zn, Mn and Fe (*Romanoff and Romanoff*, 1949; *Richards*, 1997). *Hudson et al.* (2004) stated that higher Zn deposition in eggs results in higher hatchability rates. The albumen is rich in proteins, amino acids, minerals and vitamins. The yolk is an optimal source of essential and non-essential fatty acids, proteins and serves as an energy resource for the anabolic processes (*Deeming*, 2002; *Noble et al*. 1996). The fatty acid content also determines embryo survival (*Angel*, 1993). Feed composition is in a positive correlation with egg composition (*Naber et al*., 1978). Both egg production and hatchability are influenced by the quantity and quality of feed. As the breeding season proceeds, the nutritional reserves of birds are being depleted (Ankney and Macinnes, 1978). In ostrich, we can find differences in the quality and chemical composition of eggs as affected by the laying month (*Di Meo et al*., 2003). A certain ratio of feed consumed by the birds is absorbed and occur in the eggs. The evaluation of egg and feed composition provides information on the depletion rate of nutritives and minerals from the eggs and organism. In this respect, the feeding should follow the needs of the animals. Environmental temperature indirectly influences egg composition through the absorption intensity of nutrients (*Tumová et al*., 2014). It is reported that the higher than normal (28-32 ˚C) environmental temperature decreases the weight of the egg and egg contents, shell

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thickness and changes the mineral composition of the eggshell (*Tumová et al*., 2014; *Zhu et al*., 2015). Heat stress can affect the endocrine system of birds through the excessive water and moderated feed intake required by thermoregulation (*Ruuskanen et al., 2021*). Changes in the endocrine system and feed consumption of birds can lead to some alterations in the egg parameters, too. The shell weight, shell strength and shell Mg content are significantly influenced by hen age (*Tumová et al*., 2014).

The study aimed to assess the quality parameters and composition of ostrich eggs laid at two different dates of the laying season. In this respect, we examined a cooler (May) and a warmer (July) month with a 7 ˚C difference between the mean temperatures. Our objective was to investigate the effects of laying month and environmental temperature on the quality and chemical composition of ostrich eggs. However, hatchability results were not available to draw further conclusions.

Materials and methods

Experimental eggs and measurements

The mean monthly temperature in May was around 20 ˚C and in July showed around 27 ˚C according to the weather archive.

In the pre-laying period, six weeks before the onset of laying 50 dkg of layer concentrate with 2 kg of alfalfa hay were provided/bird/day from the end of January increasing the amount of layer concentrate by 18 dkg/week. The quantity and chemical composition of feed provided for the birds in the breeding season are shown in *Table 1*. The composition of feed was the same during the examined period. However, we do not have information on the individual feed consumption and utilisation which could influence egg characteristics and composition.

A total of eleven eggs deriving from the same farm were investigated for quality parameters and composition. In the northern hemisphere, the breeding season starts in March and finishes in September. May is in the first, July falls in the second half of the laying season. Five eggs from May and six eggs from July were used in the study laid by 5-10 years old females. The origin of eggs was not linked to birds since they were unmarked. The eggs were maximum of two days old at examination and stored at 16 ˚C in the storage room for one day and 4 ˚C in the fridge for another day before the measurements. The eggs with weights within the normal weight range were chosen, randomly. The outer quality parameters included weight (g), length (cm), width (cm), shape index (%), egg volume (g/cm^3), specific gravity (g/cm^3), shell colour (L*, a*, b*), shell thickness (mm), shell surface (cm^2) and shell density (g/cm^3).

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Table 1: The composition and nutrient content of daily feed ration provided for the breeders as TMR (per bird per day, in DM)

Components (1)	**Quantity (2)**
Chopped alfalfa (3)	2.00 kg
Maize silage (4)	1.00 kg
Ostrich layer concentrate (5)	0.75 kg
Limestone (6)	0.07 kg
Molasses (7)	0.01 kg
Nutrient (8)	**Concentration** (9)
Dry matter (%) (10)	36.00
Metabolizable energy (MJ/kg) (11)	8.19
Crude protein (%) (12)	24.39
Crude fat (%) (13)	1.90
Ca (g/kg)	39.58
Na (g/kg)	3.49
P (g/kg)	6.49
K (g/kg)	16.21
Mg (g/kg)	2.78
Cu (mg/kg)	54.72
Fe (mg/kg)	215.28
Mn (mg/kg)	223.61
S (mg/kg)	3791.67
Zn (mg/kg)	153.06
ASP (%)	2.64
THR (%)	1.06
SER (%)	1.25
GLU (%)	5.14
PRO (%)	1.36
GLY (%)	1.17
ALA (%)	1.44
CYS (%)	0.22
VAL (%)	1.22
MET (%)	0.28
ILE (%)	1.11
LEU (%)	1.86
TYR ((%)	0.72
PHE (%)	1.19
HIS (%)	0.50
LYS (%)	1.25
ARG (%)	1.03
Saturated fatty acids (%) (14)	21.65
Mono-unsaturated fatty acids (%) (15)	20.65
Poly-unsaturated fatty acids (%) (16)	57.71
Saturated/unsaturated fatty adids (17)	35.78

* values are given on dry matter basis
* szárazanyag-tartalomra vonatkoztatva

1. táblázat: *A tojótakarmány összetétele és táplálóanyag tartalma*

összetevők (1), mennyiség (2), szecskázott zöldlucerna (3), silókukorica szilázs (4), strucc tojókoncentrátum (5), grit (6), melasz (7), táplálóanyagok (8), koncentráció (9), szárazanyag-tartalom (%) (10), metabolizálható energiatartalom (MJ/kg) (11) nyersfehérje-tartalom (%) (12), nyerszsír-tartalom (%) (13), telített zsírsav-tartalom (%) (14), egyszeresen telítetlen zsírsav-tartalom (%) (15), többszörösen telítetlen zsírsav-tartalom (%) (16), telített/telítetlen zsírsav arány (17)

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Some of the examined indices were calculated according to the following formulas:

*Shape index= (width/length) * 100*

*Volume= π/6 * length * width*

*Surface area= π * width*^{2}

*Circumference= π * width*

*Shell density= 1.945 * shell weight* $^{0.014}$

The inner characteristics involved shell weight (g) and ratio (%), albumen weight (g) and ratio (%), yolk weight (g) and ratio (%), yolk diameter (cm), yolk colour (L*, a*, b*) and the pH of albumen and yolk. Weights were measured with a two-decimal accuracy balance. A two-decimal-accuracy calliper was used to measure egg length, width, shell thickness and yolk diameter. The pH was examined with the Testo AG Germany 205 pH value gauge on homogenised samples by merging the measuring head into the homogenised egg content (the albumen and yolk separately). Shell and yolk colour were determined with a calibrated Chroma Meter (Y = 93.7, x = 0.3144, y = 0.3204), in which the L*, a* and b* coordinates indicate the lightness and colour shade of the egg parts according to the CIELAB colour paths (*Hernández et al*., 2019). Both pH and colour were determined in three replicates. Values are given as the mean of the three measurements.

Regarding the evaluation of egg chemical composition, mixed, homogenised samples of albumen and yolk were assessed. The dry matter (%), crude protein (%) and crude fat content (%), mineral composition (Ca, Mg, P, Zn, Cu, Fe, K, Na, S, Mn; mg/kg), the ratio of saturated (%), mono-unsaturated (%) and poly-unsaturated fatty acids (%) and the saturated/unsaturated fatty acid ratio were examined. The mineral composition (Ca, Mg, P, Zn, Cu, Fe, K, Na, S, Mn; mg/kg) of eggshell was also measured on emptied, dried samples, individually. The determination of both feed and egg composition was carried out by the Central Laboratory of Agricultural and Food Products, University of Debrecen, according to the MSZ ISO and ISO standards.

Statistical analysis

The basic calculations and the preparation of tables for statistical analysis were conducted in the Microsoft Office Excel program. The descriptive statistics and the assessment of significant differences between parameters by month were evaluated by SPSS 23.0 using analysis of variance.

Results and Discussion

Regarding external egg characteristics (*Table 2*), we could not find any difference between laying months. The mean egg weight was 1419 g which is by the results of other authors (*Mushi et al.*, 2007; *Brand et al*., 2003; *Brassó* and *Komlósi*, 2021). However, *Di Meo et al*. (2003) found that ostrich eggs laid in the middle of the laying season (May and June) were about 40 to 50 grams heavier than eggs laid before (January) and after (July, August and September) that. The authors examined birds under the same climate conditions. The 30 ˚C environmental temperature resulted in a five-gram decrease in the weight of hen eggs compared to the 19 ˚C (*Carmon and Huston*, 1965). In our case, the 27 ˚C in July was not high enough to cause harm to the egg weight. The mean egg length and width showed 14.94 and 12.48 cm. The length is between 15 and 15.4 cm and the width ranges between 12 and 12.9 cm (*Koutinhouin et al*., 2014; *Mushi et al*., 2007; *Brassó* and *Komlósi*, 2021). The length of eggs showed an increasing tendency from January to September. However, egg width showed a curve revealing the lowest values in January and September (*Di Meo et al*., 2003). The mean shape index showed 83.60 %, the egg volume was 1204 cm^3, and the specific gravity revealed 1.16 cm^3. The shape index was between 82 and 84 % published by *Moreki et al*. (2016), *Benoît et al*. (2014) and *Selvan et al*. (2014). *Di Meo et al*. (2003) also stated a constant egg shape index during the breeding season. *Kim et al*. (2020) found that egg weight and egg shape index are not significantly influenced by the normal (22 ˚C) compared to the moderate (27 ˚C) environmental temperature. *Moreki et al*. (2016) declared that the egg volume is 1116 cm^3 being lower than the one we experienced. The authors found the same specific gravity being 1.16 g/cm^3.

Table 2: **The external ostrich egg characteristics in May and July**

Month and mean T˚ (1)	Weight (g) (2)	Length (cm) (3)	Width (cm) (4)	Shape index (%) (5)	Egg volume (cm^3) (6)	Specific gravity (g/cm^3) (7)
May (8)	1413.00±63.69	14.96±0.31	12.55±0.09	83.93±0.01	1219.67±51.92	1.16±0.01
July (9)	1424.17±53.82	14.91±0.29	12.41±0.08	83.36±0.01	1192.50±43.88	1.15±0.01
Mean (10)	1419.09±29.04	14.94±0.22	12.48±0.06	83.60±0.01	1204.85±33.99	1.16±0.01

1. táblázat: A strucctojás külső minőségi paramétereinek alakulása májusban és júliusban
hónap és átlaghőmérséklet (1), tojássúly (g) (2), hossz (cm) (3), szélesség (cm) (4), alakindex (%) (5), tojás térfogat (cm^3) (6), fajsúly (g/cm^3) (7), május (20 ˚C) (8), július (27 ˚C) (9), átlag (10)

Except for shell thickness, the physical parameters of the eggshell (*Table 3*) did not change by month. The mean shell colour showed 80.29 for L*, 2.25 for a* and 20.78 for b*. There was no literature available on ostrich eggshell colour. The eggshell showed an increasing thickness from the blunt end to the pointed end and it was thinner in July than in May. *Di Meo et al*. (2003) measured eggshell thickness being 2.21 mm, 2.20 mm and 2.24 mm from the blunt end to the shape end of the egg. Eggshell thickness was fluctuating during the breeding season showing significantly the lowest value on the 150th day of laying season. *Tumová et al.* (2014) declared that the higher environment temperature (28 ˚C) in contrast with the lower temperature (20 ˚C) has a negative effect on eggshell thickness. This fact can explain that the egg thickness was lower in the warm July compared to the cooler May. *Ebeid et al*. (2012) found that the high environment temperature (30-32 ˚C) results in 0.03 mm thinner eggshell in laying hens compared to a lower temperature (20-

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22 ˚C). However, *Kim et al*. (2020) revealed that there was not any difference in eggshell thickness between the optimal (22 ˚C) and moderate (27 ˚C) environmental temperatures. *Sales et al*. (1996) measured eggshell thickness between 1.82 and 1.84 mm which are much lower than the values we revealed. However, the authors did not have data on feeding and weather conditions. The authors did not find any difference between the thickness of each egg part. The mean egg surface was greater than the 464.97 cm^2 mentioned by *Nedomová* and *Buchar* (2013). The shell density was the same in both examined months.

***Table 3:* The physical parameters of the eggshell in May and July**

Month and mean T˚ (1)	Shell colour (L*) (2)	Shell colour (a*) (3)	Shell colour (b*) (4)	Shell thickness at the blunt end (cm) (6)	Shell thickness at the equator (cm) (5)	Shell thickness at the pointed end (cm) (7)	Shell surface (cm^2) (8)	Shell density (g/cm^3) (9)
May (8)	79.95±1.13^a	2.19±0.47^a	21.02±1.73^a	2.24±0.04^b	2.29±0.03^b	2.29±0.04^b	494.34±7.09^a	2.10±0.01^a
July (9)	80.62±1.03^a	2.31±0.43^a	20.54±1.58^a	2.12±0.04^a	2.09±0.03^a	2.14±0.04^a	483.31±6.47^a	2.10±0.01^a
Mean (10)	80.29±0.77	2.25±0.32	20.78±1.17	2.18±0.03	2.19±0.03	2.22±0.03	488.82±4.79	2.10±0.01

$^{a, b}$ Means in a column having a different superscript differ (P<0.05)

3. táblázat: A tojáshéj fizikai paramétereinek alakulása májusban és júliusban

hónap és átlaghőmérséklet (1), héjszín (L) (2), héjszín (a*) (3), héjszín (b*) (4), héjvastagság a tojás tompa végén (cm) (5), héjvastagság az egyenlítőnél (cm) (6), héjvastagság a tojás hegyes végén (cm) (7), héjfelszín (cm^2) (8), héjsűrűség (g/cm^3) (9), május (20 ˚C) (10), július (27 ˚C) (11), átlag (12)*

***Table 4*: The weight and ratio of egg components in May and July**

Month and mean T˚ (1)	Shell weight (g) (2)	Shell ratio (%) (3)	Albumen weight (g) (4)	Albumen ratio (%) (5)	Yolk weight (g) (6)	Yolk ratio (%) (7)
May (8)	275.72±7.26	19.54±0.35	793.23±37.23	56.14±0.01	344.06±15.90	24.33±1.31
July (9)	256.67±6.63	18.68±0.32	795.00±34.03	57.64±0.01	323.33±14.52	23.68±1.19
Mean (10)	266.19±4.92	19.11±0.24	794.11±25.24	56.96±0.01	333.69±10.77	24.01±0.89

4. táblázat: A tojásalkotók súlyának és arányának alakulása májusban és júliusban

hónap és átlaghőmérséklet (1), héjsúly (g) (2), héjarány (%) (3), fehérjesúly (%) (4), fehérjearány (%) (5), sárgája súly (g) (6), sárgája arány (%) (7), május (20 ˚C) (8), július (27 ˚C) (9), átlag (10)

The weight and ratio of egg components did not change during the breeding season (*Table 4*). The albumen (794.11 g) was the greatest part of the egg, followed by the weight of yolk (333.69 g) and the shell weight (266.19 g). The shell made up about one-fifth (19.11 %) of the egg weight, the albumen was more than half (56.96 %) and the yolk ratio was one-fourth (24.01 %) of that. We did not reveal any difference in the weight and ratio of egg components. *Kim et al*. (2020) found that the weight of shell, albumen and yolk did not differ on optimal (22 ˚C) and moderate (27 ˚C) environmental temperatures. However, *Carmon and Huston* (1965) declared that the 30 ˚C environmental temperature in hen eggs decreased the weight of eggshell by one gram, the weights of the yolk and albumen by 2.2 and 1.6 grams compared to the 19 ˚C. Our results were closer to the 19.6 %, 57.1-59.4 % and 21-23.3 % (dry and rainy seasons) shell, albumen and yolk ratios declared by *Koutinhouin et al*. (2014) but higher than the 13.36 % for shell and lower than the 60.5 % and 26.04 % for albumen and yolk reported by *Moreki et al*. (2016). In the study of *Di Meo et al.* (2003), the yolk ratio decreased from 23.2 to 21.6 % and the ratio of albumen increased from

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57.8 to 59.5 % from the onset to the end of laying season. The shell ratio remained unchanged. The authors explained the differences as being genetic effects or the effect of the laying month.

***Table 5*: Yolk characteristics in May and July**

Month and mean T° (1)	**Yolk diameter (cm) (2)**	Yolk colour (L*) (3)	**Yolk colour (a*) (4)**	**Yolk colour (b*) (5)**	**Yolk colour by yolk fan (6)**	**Albumen pH (7)**	**Yolk pH (8)**
May (8)	13.66±0.38^{b}	62.26±1.26^{a}	7.25±0.73^{a}	56.45±1.88^{a}	10.40±0.27^{a}	8.16±0.15^{a}	6.21±0.03^{b}
July (9)	12.53±0.35^{a}	61.36±1.15^{a}	7.87±0.67^{a}	54.76±1.72^{a}	12.00±0.24^{a}	7.93±0.14^{a}	6.08±0.03^{a}
Mean (10)	13.09±0.26	61.81±0.85	7.56±0.49	55.61±1.28	11.20±0.81	8.04±0.10	6.15±0.02

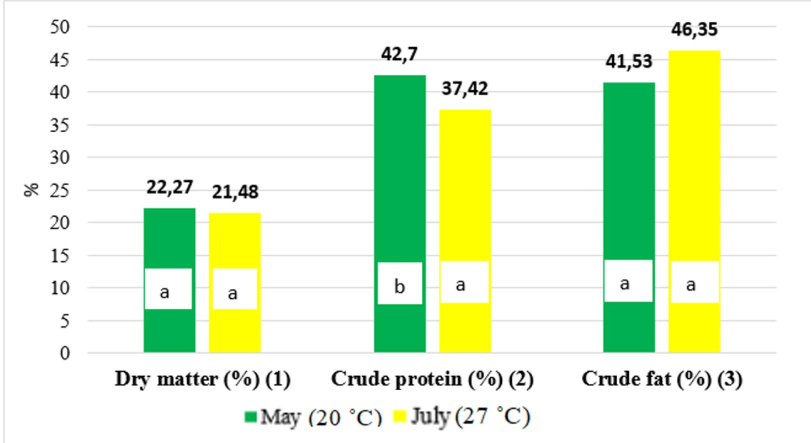
$^{a, b}$ Means in a column having a different superscript differ (P<0.05)

5. táblázat: A *sárgája tulajdonságainak alakulása májusban és júliusban*

hónap és átlaghőmérséklet (1), sárgája átmérő (cm) (2), sárgájaszín (L) (3), sárgájaszín (a*) (4), sárgájaszín (b*) (5), sárgájaszín színskála alapján (6), fehérje pH (7), sárgája pH (8), május (20 ˚C) (9), július (27 ˚C) (10), átlag (11)*

The yolk diameter and yolk pH decreased from May to July (*Table 5*). The mean yolk diameter showed 13.09 cm. However, *Elsayed* (2009) found a progressive increase in yolk diameter during the year but the egg weight also increased. The authors considered these changes as the effect of the month. However, *Islam et al.* (2001) reported that the season does not have a significant effect on yolk diameter. We did not have literature data on the effect of temperature on egg yolk diameter. *Kwang-Taek* and *Hong-Rock* (2002) determined 14.4 cm for yolk diameter. We did not find changes in yolk colour. Literature data on this parameter was not available. According to *Fernández-López et al*. (2006), the pH of albumen is 9.22 being far greater than the 8.04 we measured. Although *Kwang-Taek* and *Hong-Rock* (2002) measured 8.3 for albumen and 6.6 for yolk pH. The albumen pH is strongly alkaline compared to the yolk being acidic (6.15). Both pHs are effective against microorganisms. According to *Ayoola et al.* (2016), the higher environmental temperature increases egg pH. Storage period from 2 to 30 days and storage temperature (at 2 ˚C, 12 ˚C and 25 ˚C) increase albumen and yolk pH (*Lee et al*., 2016) but eggs in both examined months were fresh eggs, stored at 16 ˚C.

Figure 1: Ostrich egg chemical composition in May and July



[a, b] different letters indicate significant differences (P<0.05)
* values are given on dry matter basis
* szárazanyag-tartalomra vonatkoztatva

2. ábra: A strucctojás kémiai összetételének alakulása májusban és júliusban

szárazanyag (%) (1), nyersfehérje (%) (2), nyersszsír (%) (3), május (20 ˚C) (4), július (27 ˚C) (5),

The mean dry matter content of the evaluated eggs was 21.88 % (*Figure 1*). The crude protein content decreased by 5.28 % from May to July and the mean protein content of eggs was 40.06 %. The egg yolk is rich in fat, so the total fat content of eggs was high (44.16 %). Although great changes could be demonstrated between the fat content of the two examined months, differences were not significant (p= 0.051). *Sinanoglou et al.* (2011) found the fat content of ostrich egg yolk to be 37.14 % which is lower than our result. *El-Shawaf et al*. (2011) measured a higher crude protein (44.59 %) and a lower crude fat content (36.95 %) in whole ostrich egg. *Abu Salem* and *Abou-Arab* (2008) demonstrated the protein and fat content of ostrich eggs to be 47.09 and 45.10 %. The protein content found by the authors was much higher and the fat content was higher than in our study. Differences could stem from the different feed compositions, however, no literature data was published on it. *Di Meo et al*. (2003) found that the dry matter content of albumen was increasing from the onset of the laying period to the end of that (from 11.1 to 12 %). The dry matter content of yolk was fluctuating during the breeding season, being the lowest (47.5 %) on the 110th day. The crude protein content remained unchanged (47.7-48.2 %) during the laying season and the crude fat was fluctuating to a small extent (from 43.8 to 44.2 %).

***Table 6*: The mineral composition of ostrich egg content in May and July**

Minerals (mg/kg) (1)	May (20 ˚C) (2)	July (27 ˚C)(3)	Mean (4)
Ca	3843.74±107.46[a]	3952.51±98.10[a]	3898.13±72.75
Cu	8.59±0.21[a]	8.95±0.19[a]	8.77±0.14
Fe	85.87±6.56[a]	100.95±5.99[a]	93.41±4.44
K	5118.09±169.46[a]	4918.53±154.70[a]	5018.09±114.73
Mg	725.64±33.66[a]	906.27±30.73[b]	815.96±22.79
Mn	1.83±0.16[a]	1.74±0.15[a]	1.78±0.11
Na	6810.06±284.80[b]	5661.86±259.99[a]	6235.96±192.81
P	9587.79±207.05[b]	8174.27±189.01[a]	8881.03±140.17
S	6466.31±91.45[b]	6304.31±83.48[a]	6385.21±61.91
Zn	60.89±1.23[b]	46.79±1.12[a]	53.84±0.83

[a, b] means in a column having a different superscript differ (P<0.05)
* values are given on dry basis
* szárazanyag-tartalomra vonatkoztatva

6. táblázat: A strucctojás belső alkotói ásványianyag-tartalmának alakulása májusban és júliusban
ásványianyagok (1), május (20 ˚C) (2), július (27 ˚C) (3), átlag (4)

Among minerals, the content of Mg increased by 181 mg/kg, whereas the content of Na, P, S and Zn decreased by 1449 mg/kg, 1413 mg/kg, 162 mg/kg and 14 mg/kg from May to July (*Table 6*). *Shameyeva et al.* (2018) found the Fe, K, Mg, Ca and P content to range between 18 (albumen) and 53 mg/kg (yolk), 1030 (yolk) and 1340 mg/kg (albumen), 82 (albumen) and 124 mg/kg (yolk), 220 (albumen) and 1380 mg/kg (yolk) and 160 (albumen) and 3270 mg/kg (yolk). Several authors measured lower values for all minerals. *Abu Salem* and *Abou-Arab* (2008) claimed that the Ca, P, Fe, K, Na and Zn content of ostrich eggs are 2060, 6830, 110, 4600, 4080 and 52 mg/kg. Their value for Fe was higher but all other minerals showed lower values compared to our results. Data on feeding and husbandry conditions were not available in the cited literature. *Di Meo et al.* (2003) examined the total ash content of ostrich eggs and declared that the total ash content did not change significantly (5.2-5.5 %) during the breeding season. Literature data on the effect of environmental temperature on egg mineral composition was unknown.

Table 7: The amino acid content of ostrich eggs in May and July

Amino acids (m/m %) (1)	May (20 ˚C) (2)	July (27 ˚C) (3)	Mean (4)
ASP	0.97±0.03[b]	0.78±0.3[a]	0.87±0.02
THR	0.61±0.02[b]	0.48±0.02[a]	0.55±0.02
SER	0.77±0.03[b]	0.63±0.02[a]	0.69±0.02
GLU	1.42±0.06[b]	1.13±0.05[a]	1.27±0.04
PRO	0.44±0.02[a]	0.45±0.02[a]	0.45±0.01
GLY	0.28±0.01[b]	0.24±0.01[a]	0.26±0.01
ALA	0.44±0.02[a]	0.39±0.02[a]	0.42±0.01
CYS	0.20±0.01[b]	0.15±0.01[a]	0.17±0.01
VAL	0.57±0.02[a]	0.54±0.02[a]	0.55±0.02
MET	0.26±0.01[a]	0.24±0.01[a]	0.25±0.01
ILE	0.46±0.02[a]	0.44±0.02[a]	0.45±0.02
LEU	0.58±0.03[a]	0.58±0.03[a]	0.58±0.02
TYR	0.49±0.02[b]	0.41±0.02[a]	0.45±0.01
PHE	0.52±0.02[b]	0.42±0.02[a]	0.47±0.02
HIS	0.24±0.01[b]	0.21±0.01[a]	0.23±0.01
LYS	0.54±0.03[a]	0.50±0.02[a]	0.52±0.02
ARG	0.35±0.01[a]	0.30±0.01[a]	0.32±0.01

[a, b] means in a column having a different superscript differ ($P<0.05$)
* values are given on original basis
* eredeti anyagra vonatkoztatva

7. táblázat: A strucctojás aminosav-tartalmának alakulása májusban és júliusban
aminosavak (1), május (20 ˚C) (2), július (27 ˚C) (3), átlag (4)

Among amino acids, the content of asparagine, threonine, serine, glutamine, glycine, cystine, tyrosine, phenylalanine and histidine decreased significantly from May to July. *El-Shawaf et al*. (2011) found valine, methionine, isoleucine, leucine, phenylalanine, histidine, lysine, arginine, tryptophan, proline, glycine and cystine to be 1.03, 0.47, 0.87, 1.52, 0.81, 0.41, 1.19, 0.91, 0.77, 1.33, 0.01 and 1.76 g/100 g. Except for glycine, the authors measured much greater values for the examined amino acids. Data on feeding were not available. According to other authors, the amino acid composition of ostrich egg is the following: THR – 1.01, SER – 0.83, ALA – 0.32, VAL – 0.81, MET – 0.39, ILE – 0.67, LEU – 1.33, TYR – 0.55, PHE – 0.60, HIS – 0.28, LYS – 0.95, ARG – 0.53 m/m % (Angel, 1993; Du Preez, 1991). Regarding their findings, all their values were higher than our results, except for alanine. Diet and husbandry conditions were not available to draw further conclusions. Amino acids play a key role in embryo development and post-hatch growth. In ovo injection of L-Glutamine (*Rufino et al*., 2019) and L-Lysine (*Coskun et al*., 2018) on the 16th and L-Arginine (*Subramaniyan et al*., 2019) on the 14th day of incubation enhanced the embryo development and the incubation results. The effect of environmental temperature on egg amino acid composition is not published in the literature. Nor changes in ostrich egg amino acid content were available.

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***Table 8*: The fatty acid composition of ostrich eggs in May and July**

Fatty acids (m/m %) (1)	**May (20 ˚C) (2)**	**July (27 ˚C) (3)**	**Mean (4)**
Saturated fatty acids (SFAs) (5)			
C8:0	0.01±0.00[a]	0.01±0.00[a]	0.01±0.00
C10:0	0.01±0.00[a]	0.01±0.00[a]	0.01±0.00
C12:0	0.01±0.00[a]	0.01±0.00[a]	0.01±0.00
C14:0	0.23±0.04[a]	0.46±0.04[b]	0.34±0.03
C15:0	0.15±0.02[a]	0.19±0.01[b]	0.17±0.02
C16:0	22.13±1.67[a]	32.39±1.53[b]	27.26±1.13
C18:0	10.23±0.58[a]	11.88±0.53[a]	11.06±0.39
C20:0	0.18±0.01[a]	0.07±0.01[a]	0.13±0.01
Total (SFA) (6)	33.37±1.42[a]	45.46±1.29[b]	39.42±0.96
Mono-unsaturated fatty acids (MUFAs) (7)			
C14:1	0.04±0.01[a]	0.05±0.01[a]	0.04±0.01[a]
C15:1	0.12±0.02[b]	0.01±0.02[a]	0.07±0.02
C16:1	4.26±0.46[a]	5.62±0.42[b]	4.94±0.31
C18:1	32.91±0.83[b]	27.44±0.69[a]	30.18±0.54
C20:1	0.17±0.03[a]	0.18±0.02[a]	0.18±0.02
Total (MUFA) (8)	37.74±1.15[b]	33.25±1.05[a]	35.49±0.77
Poly-unsaturated fatty acids (PUFAs) (9)			
C18:2n6	15.70±0.66[b]	13.44±0.60[a]	14.57±0.45
C18:3n3	1.57±0.11[b]	1.08±0.10[a]	1.32±0.07
C18:3n6	0.15±0.01[a]	0.15±0.01[a]	0.15±0.01
C20:3n6	0.17±0.04[a]	0.24±0.03[a]	0.21±0.03
C20:3n3	7.52±0.87[b]	4.54±0.73[a]	6.03±0.57
C22:6n3	3.72±0.92[a]	1.32±0.78[a]	2.52±0.60
Total (PUFA) (10)	28.83±2.21[b]	21.00±1.78[a]	24.81±1.49
SFA/UFA (11)	0.51±0.03[a]	0.84±0.03[b]	0.67±0.02

[a, b] means in a column having a different superscript differ ($P<0.05$)

* values are given on original basis

* eredeti anyagra vonatkoztatva

8. táblázat: *A strucctojás zsírsavösszetételének alakulása májusban és júliusban*

zsírsavak (m/m %) (1), május (20 ˚C) (2), július (27 ˚C) (3), átlag (4), telített zsírsavak (5), összes telített zsírsavarány (6), egyszeresen telítetlen zsírsavak (7), összes egyszeresen telített zsírsavarány (8), többszörösen telítetlen zsírsavak (9), összes többszörösen telítetlen zsírsavarány (10), telített/telítetlen zsírsavarány (11), Omega-6/Omega-3 arány (12)

Regarding saturated fatty acids, the content of C8:0, C10:0, C12:0, C18:0 and C20:0 fatty acids did not differ by month (*Table 7*). However, the content of C14:0, C15:0, C16:0 and total SFAs significantly increased. Among mono-unsaturated fatty acids, the ratio of C15:1, C18:1 and the total MUFAs significantly decreased but the ratio of C16:0 significantly increased. The content of C18:2n6, C18:3n3, C20:3n3 and the total PUFAs fell, whereas the SFA/UFA ratio rose in July compared to May. According to the literature, the content of C10:0, C12:0, C14:0, C15:0, C16:0, C18:0 and C20:0 saturated fatty acids are 0.07, 0.03, 0.65, 0.13, 32.84, 5.57 and 0.02 % (*Sinanoglou et al.*, 2011). The total SFA content was 39.70 %. The authors got lower values for the C15:0, C18:0 and the C20:0 fatty acids but higher for the other SFAs. The total SFA content was also higher in their examination. The ratio of C14:1 in our study was slightly below than the one they experienced, whereas the content of C18:2n6 (8.18 %), C18:3n3 (0.15 %), C18:3n6 (1.57 %), C20:3n6 (0.17 %) and C22:6n3 (3.72 %) showed remarkably lower values in their research (*Sinanoglou et al.*, 2011). Although the authors revealed a higher MUFA ratio, the content of PUFAs was lower compared to our results. The SFA/UFA ratio in their study showed a value of

0.66 which is similar to the 0.67 we calculated. The birds in the experiment of *Sinanoglou et al.* (2011) had a possibility to graze and were fed with corn (60.47 %), soybean meal (12.92 %), cottonseed meal (9.58 %), bran (0.74 %), sawdust (1.0 %), limestone (6.73 %), dicalcium phosphate (1.69 %), salt (0.28 %), mineral premix (0.20 %), vitamin premix (0.20 %) and methionine (0.08 %). *Di Meo et al*. (2003) found that as the laying season progressed, the ratio of saturated fatty acids decreased, whilst the ratio of mono-unsaturated fatty acids increased.

***Table 9*: Change in mineral composition of eggshell in May and July**

Minerals (mg/kg) (1)	May (20 ˚C) (2)	July (27 ˚C) (3)	Mean (4)
Ca	393423.80±165.08[a]	394393.57±139.515[b]	393908.69±108.07
Cu	16.92±2.18[b]	1.56±1.84[a]	9.24±1.43
Fe	8.76±0.42[a]	8.52±0.35[a]	8.64±0.27
K	718.00±27.98[a]	822.00±23.64[b]	770.00±18.31
Mg	1124.40±59.22[a]	1521.00±50.05[b]	1322.70±38.77
Mn	0.26±0.01[a]	0.29±0.01[a]	0.27±0.01
Na	664.60±48.22[a]	664.60±48.22[a]	707.51±31.57
P	570.60±37.35[a]	573.50±31.56[a]	565.66±24.45
S	654.40±21.45[a]	782.71±18.13[b]	718.56±14.04
Zn	9.77±0.64[b]	2.15±0.54[a]	5.96±0.42

* eredeti anyagra vonatkoztatva

9. táblázat: A tojáshéj ásványianyag-tartalmának alakulása májusban és júliusban
ásványianyagok (1), május (20 ˚C) (2), július (27 ˚C) (3), átlag (4)

Among the minerals of eggshell, the content of Ca, K, Mg and S increased from May to July but we could observe a great decline in the content of Cu and Zn. There is a strong relationship between eggshell calcium content and shell thickness (*Clunies et al*., 1991). The higher the calcium content of the eggshell is, the thicker the shell is. Our findings contradicted their results. However, *Tumová et al.* (2014) revealed that at higher temperature (28 ˚C) the Ca content of chicken eggshell is higher compared to a lower temperature (20 ˚C). It is because the Ca coagulation is stronger at higher temperatures (*Cusack et al., 2003*). The authors found a significant decrease in P content of the chicken eggshell in the warmer environment. However, the content of Mg and Zn did not change significantly. The changes in eggshell mineral composition during the biological season are not known in the literature.

Conclusions

In the examined period, mainly the chemical composition of eggs showed significant changes. Regarding the outer quality parameters, the eggshell thickness, yolk diameter and yolk pH decreased from May to July. The breeder diet was of satisfying concentration of metabolizable energy, crude protein, fat and mineral content. Changes may have stemmed from the laying month effects. The crude protein content and the content of most amino acids significantly decreased from May to July which can be explained by the higher environmental temperature in July thus reducing feed intake. The saturated fatty acid content and the saturated/unsaturated fatty acid ratio increased but the mono-unsaturated and poly-unsaturated fatty acid content of the egg declined from May to July. The environmental temperature could have a negative effect on the absorption of the unsaturated fatty acids but literature data was not available. The increase in the environmental temperature could inhibit feed intake and nutrient absorption and could have a negative effect on the endocrine system and nutrient utilisation of birds. The increase of Mg in the egg content and the quantity of K, Mg and S in the eggshell from May to July could not be explained by environmental effects.

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