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RESEARCH ARTICLE

Physicochemical Properties and Oxidative Stability of Hen Egg-Yolk Oils Based on Different Laying Periods

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HIGHLIGHTS

> Nutritional value of hen egg-yolk oils based on different laying period was studied
> Palmitic, stearic, oleic, and linoleic acids were determined at the highest levels in all periods
> Cholesterol and campesterol were the two dominant sterols.

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ABSTRACT

The aim of this study was to investigate and compare the physicochemical properties and nutritional value of hen egg-yolk oils based on different laying periods. Hen egg-yolk oils were extracted using solvents from double yolk (18 weeks), guide (24 weeks), pullet (30 weeks), and jumbo (80 weeks) eggs. Weight and fat ratios of the hen eggs, as well as the free fatty acid content, peroxide value, iodine value, oxidative stability, fatty acid composition, and sterol composition of the yolk oils were determined in the study. According to the results of the analyses of white-shell eggs, the fat contents of the boiled egg (both the white and yolk), fat contents of the egg yolk, free fatty acid values, peroxide values, and oxidative stability values were between 7.85 and 11.25%, 18.58 and 34.71%, 1.03 and 2.32%, 8.58 and 9.54 meq O2/kg, and 8.0 and 10.2 h, respectively. Palmitic and oleic were determined at the highest levels in all samples in the fatty acids. Cholesterol and campesterol were the two dominant sterols among the 10 sterol components. We determined that the physicochemical properties of white-shell egg-yolk oils varied according to different laying periods in terms of animal fat, and based on the 80-week laying period, egg-yolk oils were suitable for both internal and external consumption; the most ideal egg-yolk oils were extracted during the 30-week (pullet) period.

Contents

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1. Introduction

Hen (*Gallus* sp.) eggs are produced by ovulation in sexually mature hens without copulating with a cock. Eggs are produced in the ovaries as a result of more than 30 natural hormones and the physiological effects of light stimulation. It has been reported that the time that hens begin to lay according to their genetic structure and feeding, for instance in the LOHMANN white types, laying can begin after 16 weeks of age [1–3].

An egg is a natural food containing macro- and micronutrients, is widely consumed throughout the world, and is used as a preservative against various diseases. Ninety-four percent of an egg has nutritional value for humans because it contains all the essential nutrients needed for an adequate and well-balanced diet. Eggs, which have the highest protein quality among all animal products, are rich in vitamins A, D, E, K, and B and in minerals iron and phosphorus [4–8].

Eggs comprise three parts—the shell, albumen (the white), and yolk—with the highest fat content found in the yolk. It has been reported that the fat content of egg yolks varies between 22.96 and 25.09% depending on the species (duck, hen, quail). In hen egg yolks, this has been reported to be 25.09% [9]. Hen egg-yolk oil is rich in palmitic acid as a saturated fatty acid and oleic and linoleic acids as mono- and polyunsaturated fatty acids, respectively. These fatty acids are crucial to human nutrition for cardiovascular health and cell-membrane permeability. Egg yolks also contain 400 mg/100 g cholesterol, which, contrary to previous beliefs, does not increase the amount of cholesterol in the blood and is an excellent animal food source with very high nutritional value. Eggs are recommended to be included in the daily diets of all consumers, including growing children, young and elderly people, pregnant women and breastfeeding mothers, obese people and diabetics, and even those with cholesterol problems in limited amounts. In traditional medicine, egg-yolk oil is used to treat dermatological diseases, especially wounds, which has led to an increase in commercial sales [10–14].

Previous studies have concentrated on the egg's nutritional components, such as its carbohydrates, proteins, fatty acids, vitamins, and minerals. The aim of the present study was to investigate the changes in the physicochemical properties of commercially obtained egg-yolk oils based on the laying periods between 18 and 80 weeks. These properties included acidity, peroxide value, oxidative stability, and fatty acids and sterol composition in terms of the technical use of animal fat and the egg's nutritional value.

2. Materials and Methods

2.1. Materials

The white-shell eggs used in this study were obtained from three LOHMANN white hens reared on a farm in Afyonkarahisar, Turkey; the hens were observed for 80 weeks. The eggs were gathered from the weeks 18 (double yolk), 24 (guide), 30 (pullet), and 80 (jumbo) laying periods.

2.2. Preparation of Egg Yolk Samples

The yolk and fat extracted from the eggs were analyzed using a 4 × 6 × 3 trial pattern and the following methods. First, white-shell eggs obtained during different laying periods were grouped for the laboratory studies. To prepare them for analyses, the eggs were boiled for 10 min, after which the yolks were separated from the albumen and dried in an oven at 105 °C for 2 h.

2.3. Oil Content

Oil amounts of the dried egg yolks were determined using the soxhelet method. Accordingly, 10 grams of crushed egg yolk sample from each sample was weighed into a soxhelet cartridge and extracted with n-hexane for 3 hours at 85 °C. The n-hexane in the extract was removed under vacuum at 45 °C in a rotary evaporator. After cooling in the desiccator, the amount of oil was determined as a percentage by using the weight differences [15].

2.4. Physico-chemical Analysis

Egg yolk oils; free fatty acidity, peroxide number, iodine number were analyzed according to AOCS methods [16].

2.5. Fatty Acid Composition Analysis

Fatty acid methyl esters were prepared by treating oils with potassium hydroxide and n-Heptane, and then determined by gas chromatography. Gas chromatography with SHIMADZU-2025 GC (Kyoto, Japan) brand was used in the analysis. Flame Ionization Detector (FID) is used on the device. The column is the brand of RTX-2330 and has a length of 60 m, a diameter of 0.25 mm and a film thickness of 0.20 μm [17]. In Table 1, Operating conditions of Gas chromatography are given.

Table 1 Gas Chromatography operating conditions

Stationary phase		10% Diethylene Glycol Succinate (DEGS)
Support material		Chromosorb W (AW-DMCS) (60-80 mesh)
Detector		FID
Temp	Column	180 °C
	Injection	200 °C
	Detector	200 °C
Flow rate	Carrier gas (N_2)	30 ml/min
	Flammable gas (H_2)	28 ml/min
	Dry air	220 ml/min
Injection amount		1 μl

2.6. Sterol Composition Analysis

Sterol compositions for egg yolk oils were determined using a method as described by Lencher et.al., (1999). SGE BP-5 column (30m length × 0.25 mm i.d., 0.25 μm film thickness) and a Perkin Elmer Boston, MA, USA GC autosystem were used. All gas (He, He-2 and air) flow rates were 45 mL min^{-1}.

The column temperature was increased from 0 to 60 °C (2min) and then from 60 to 220 °C (18 min) and finally held at 220 °C (35 min) [18].

2.7. Oxidative Stability Analysis

In this study, the induction time was determined with Metrohm 743 Rancimat device (Methrom) and ransimat device by using 3 grams of egg oil obtained from each period for oxidation stability. Oxidative stability was measured at an airflow rate of 10L / hour set at 110 degrees. Conductivity of 0.055 µs ultra pure water was used in the study [19].

2.8. Statistical Analysis

The data obtained in the study were analyzed using the SPSS (Statistical Package for Social Sciences) Windows 22.0 program. In the evaluation of the data, as descriptive statistical methods, mean standard deviation and comparing quantitative continuous data between more than two independent groups, *One-Way* Anova test and Duncan multiple comparison test were used [20, 21].

3. Results and Discussion

Table 2 shows the fat contents in the parts of the eggs (albumen + yolk) based on the different laying periods tested. These were determined to be between 7.85 and 11.25%; with the fat ratios in the yolks between 18.58 and 31.17%. The lowest fat content in the egg yolk (18.58%) was observed in the 18-week double yolk; the highest (31.17%) was observed in the 24-week guide egg. Various studies have been conducted on the total fat content of eggs (albumen + yolk). Decker and Cantor (1992) [22] have determined that the total fat content of eggs is 11.2%. Liu et al. (2005) [23] have found that the fat content in different hen egg yolks is between 26.65 and 46.33%. Other researchers have observed similar values for fat content in the yolks [9, 22–24].

Table 2 Physicochemical properties egg-yolk oils from different laying periods

Period –	**18.week**	**24.week**	**30.week**	**80.week**
Commercial Name	Double yolk	Guide	Pullet	Jumbo
Albumen + Yolk Fat (%)	8.14c ± 0.26	11.25a ±0.50	9.28b ± 0.71	7.85d ± 0.33
Yolk Fat (%)	18.58d ± 0.69	31.17a ± 1.02	29.28b ± 0.94	26.33c ± 0.80
Acidity (%)	1.84b ± 0.55	1.40c ± 0.61	1.15d ± 0.47	2.15a ± 0.79
Peroxide Value (meqO2/kg)	8.66a ± 0.48	8.58a ± 0.35	8.62a ± 0.51	9.57b ± 0.85
Iodine Value (mgI2/100g)	71.1c ± 0.47	72.5b ± 0.88	72.3b ± 0.16	76.6a ± 0.96
Oxidative Stability (h)	10.2a ± 0.55	9.5b ± 0.61	9.3b ± 0.47	8.0c ± 0.79

[a–d] values marked with different letters are statistically different from each other ($p < 0.005$)

We observed that the free fatty acidity of egg-yolk oils varied between 1.15 and 2.15%, with the lowest observed in the 30-week pullet and the highest in the 80-week jumbo. Liu et al. (2005) [23] have determined that the free fatty acidity values of hen egg-yolk oils extracted using various methods were between 1.20 and 14.83 mg KOH/g [23].

The iodine value was observed to vary between 71.1 and 76.6, with the lowest observed in the 18-week double yolk and the highest in the 80-week jumbo. Based on these values, egg-yolk oil was determined to be part of the group of nondrying oils, such as palm, coconut, and butter [25, 26].

We observed that the peroxide values varied between 8.58 and 9.57 meq O_2/kg, with the lowest observed in the 24-week guide egg and highest in the 80-week jumbo. The oxidative stability of the egg-yolk oils varied between 8.0 and 10.2 h, with the lowest observed in the 80-week jumbo and the highest in the 18-week double yolk egg. We did not find any studies regarding the peroxide value and oxidative stability of egg-yolk oils that indicated their resistance to oxidation, especially under storage conditions.

Table 3 Fatty acid compositions (%) of LOHMANN white white-shell egg-yolk oils from different laying periods

	Period – Commercial Name			
Fatty Acid Composition (%)	**18.week Double Yolk**	**24.week Guide**	**30.week Pullet**	**80.week Jumbo**
Myristic	0.40	0.26	0.28	0.31
Palmitic	27.78	24.73	25.60	24.26
Stearic	8.16	9.17	8.26	6.86
Behenic	0.12	0.18	0.10	0.09
Saturated Fatty Acids	36.46 ± 1.15[a]	34.34 ± 0.99[b]	34.24 ± 1.05[b]	31.52 ± 0.7[c]
Palmitoleic	3.49	2.98	3.30	3.29
Oleic	40.48	42.51	43.69	45.50
Linoleic	17.65	18.03	16.91	18.38
Linolenic	0.96	0.75	0.90	0.98
Arachidonic	0.97	1.38	0.95	0.37
Unsaturated Fatty Acids	63.54 ± 0. 97[c]	65.66 ± 0.97[b]	65.86 ± 1.19[b]	68.52 ± 1.7[a]

[a–d] values marked with different letters are statistically different from each other ($p < 0.005$)

As seen in Table 3, the percentage of total saturated fatty acid of white-shell egg-yolk oils varied between 31.52 and 36.46%, with the lowest observed in the 80-week jumbo commercial egg and the highest in the 18-week double yolk egg. The total unsaturated fatty acid content varied between 63.54 and 68.52%, with the lowest observed in the double yolk egg and the highest in the jumbo egg. In addition, the dominant saturated fatty acids in white-shell egg-yolk oils were observed to be palmitic (24–27%) and stearic (6–9%), while the dominant unsaturated fatty acids were palmitoleic (2–3%), oleic (40–45%), and linoleic (16–18%).

Nyberg (2017) [27] and Sehu et al. (2012) [28] have found oleic acid to be the dominant fatty acid in egg yolk. It has been reported that most of the fatty acids (53–56%) in an egg are unsaturated [27–29]. In their study on the fatty acid composition of eggs, Stibilj et al. (1999) [30]have determined the following ratios: myristic acid (0.28%), palmitic acid (21.67%), palmitoleic acid (3.58%), stearic acid (9.80%), oleic acid (43.86%), and linoleic acid (14.92%).

Table 4 Sterol compositions (%) of LOHMANN white white-shell egg-yolk oils from different laying periods

Sterol Composition (%)	Periods (Commercial Name)			
	18.week (Double yolk)	24.week (Guide)	30.week (Pullet)	80.week (Jumbo)
Cholesterol	95.91 ± 1.20[c]	95.53 ± 1.36[c]	97.83 ± 1.51[a]	96.37 ± 1.33[b]
Brassicasterol	0.31 ± 0.09[a]	0.39 ± 0.09[a]	0.37 ± 0.05[a]	0.31 ± 0.03[b]
Campesterol	3.19 ± 0.67[ab]	3.35 ± 0.82[a]	1.29 ± 0.48[c]	2.87 ± 0.80[b]
Stigmasterol	0.46 ± 0.06[b]	0.56 ± 0.08[a]	0.51 ± 0.03[a]	0.45 ± 0.01[b]
Δ5,23-Stigmastadienol	nd.	nd.	nd.	nd.
Δ5,24-Stigmastadienol	nd.	nd.	nd.	nd.
Δ5-Avenasterol	nd.	nd.	nd.	nd.
Δ7-Avenasterol	nd.	nd.	nd.	nd.
Δ7-Stigmastenol	0.12 ± 0.03[a]	0.12 ± 0.05[a]	nd.	nd.
β-sitosterol	nd.	0.063 ± 0.07[a]	nd.	nd.

[a–d] values marked with different letters are statistically different from each other (p < 0.005). nd. Not determined

As shown in Table 4, among the 10 sterol components of the egg-yolk oils obtained from the different laying periods, cholesterol and campesterol were observed to be dominant. The cholesterol in white-shell egg-yolk oils varied between 95.52 and 97.83%, with the lowest observed in the 24-week guide and the highest in the 30-week pullet. The campesterol content varied between 1.29 and 3.35%, with the lowest observed in the 30-week pullet and the highest in the 24-week guide (3.35%). In white-shell egg-yolk oils, except for those sterols, brassicasterol, stigmasterol, Δ7-stigmastenol, and β-sitosterol were found in different proportions. These sterols in the egg-yolk oils are important for human health and nutrition because they have been reported to provide protective effects against cardiovascular diseases by reducing the risk of heart attack by 15–45% and against certain cancers and by strengthening the immune system [31–34]; therefore, these biologically active substances have been extensively studied for neutrocytic and the production of functional foods [35]. Liu et al. (2005) [23] have stated that the amount of cholesterol in egg oils varies between 28.51 and 38.15 mg/g. Shahid et al. (2015) [36] and have indicated that the cholesterol levels in egg yolks are 11.65 to 19.27 mg/g [23, 36]. Faitarone et al. (2013) [37]have determined that the cholesterol in egg yolks obtained from different laying periods is 792–1061 mg/100 g. Beyer and Jensen (1989) [38] have stated that 5.2% of egg lipids consist of cholesterol, and that the cholesterol content in the egg is ~213 mg. The studies have focused mainly on the amount of cholesterol in the egg and yolk; no study was found on the sterol composition of egg-yolk oil. Several researchers have reported that feeding, maintenance, environmental conditions, age, and climate may have an effect on the macro- and micronutrient composition of hen eggs [39–41].

4. Conclusion

The fat ratios in the whole egg and egg yolk, as well as the free fatty acidity, peroxide value, iodine value, oxidative stability, total saturated and unsaturated fatty acids, and sterol composition of egg-yolk oils varied physico-chemically based on the laying periods with a statistically significant level of $p < 0.05$. These results also suggested that egg-yolk oil is a good source of nutrients in terms of percent fat amount, saturated and unsaturated fatty acids, and sterol composition. Based on the 80-week laying period, the results suggested that the egg-yolk oils were suitable for both internal consumption and external application with the most ideal egg oils extracted from the 30-week pullet. Further studies are needed on the results from different extraction methods, such as cold press and CO_2, for the consumption of egg-yolk oil as an animal fat, which has increased as a trade throughout the world.

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