REVIEW

Poultry products enriched with nutricines have beneficial effects on human health

Gordana Kralik, Zlata Kralik

Department of Special Zootechniques, Faculty of Agriculture in Osijek, Croatia

ABSTRACT

The paper presents nutritive value of broiler meat and table eggs, as these animal products are used for human nutrition on a daily basis. In the Republic of Croatia, average consumption of poultry meat amounts to 18.3 kg and to 160 eggs per capita.The most quality parts of broiler carcass are breasts and drumsticks with thighs. Breast muscles contain 21-23% protein, 1.90-1.97% fat, 75.28-76.01% water and 0.74-0.77% collagen. Thigh muscles contain 4.70-6.05% fat, 19.03-19.93% protein and 0.91-1.13% collagen. White meat contains more potassium and magnesium and less zinc and iron than dark meat. In 100 g of edible egg part there is 12.5-13.5 g protein, 10.7-11.6 g fat and 1.0-1.1 g minerals. Caloric valueof eggs is 167 Kcal. Eggs contain high amount of essential amino acids, especially leucine, isoleucine, lysine, arginine, valine and phenylalanine. Furthermore, eggs contain many vitamins, especially A, D, E, K and B-complex, as well as various macroelements and microelements. Eggs and meat enriched with one or more functional ingredients – nutricines (polyunsaturated fatty acids n-3), eicosapentaenoic acid, docosahexaenoic acid, selenium and lutein) meet the criteria of functional food because of their added value and benefits for human health.

Key words: eggs, meat, EPA, DHA, cardiovascular disease

Corresponding author:
Gordana Kralik
Faculty of Agriculture,
Josip Juraj Strossmayer
University of Osijek
K. P. Svačića 1d, 31000 Osijek, Croatia
Phone: +385 31 554 863;
Fax: +385 31 554 853;
E-mail: gkralik@pfos.hr

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INTRODUCTION

Poultry production in the Republic of Croatia is characterized as industrial production that takes place throughout the year,mostly in an intensive way. Poultry meat and eggs are animal products that are important in human nutrition (1). The content of nutrients in broiler meat depends on different factors such as genotype (hybrid), age, feeding, keeping, carcass parts, and type of meat (2). Breast meat (white meat) is richer in protein, but poorer in fat than meat of drumsticks and thighs (darkmeat). There is a difference in nutritive value between these two types of meat that occurs because of its composition and chemical content (3). In Croatia, consumption of poultry meat amounts to 18.3 kg and to 160 eggs per capita (4). In the EU, there are countries with different data on consumption of poultry products. In 2014 poultry meat was most consumed in Portugal (39.4 kg/capita), then in Spain (31 kg/capita), and least consumed in Sweden (13 kg/capita) and Finland (18.1 kg/capita). On average, annual consumption of poultry meat in the EU amounts to 26 kg per capita (5). Average consumption of eggs in the EU refers to 200 pieces per capita, ranging from 210 pcs per capita in Italy, and 188 pcs per capita in the Netherlands (5).

NUTRITIVE QUALITY OF POULTRY MEAT

Hybrids with high genetic potential are used in production of chicken meat (6). Nutritive valueof broiler meat is assessed as of carcass conformation (muscle presence), as well as of the content of nutrients, especially protein and its biological value. For no reasons, less attention is paid to the content of other nutrients such as fat, minerals and vitamins (2). Table 1 presents the quality of carcass (relativeshare of breast and drumsticks with thighs) of the Cobb 500 and Hubbard Classic hybrid broilers, according to broiler sex at the age of 42 days in Croatia (7). It was determined that broiler hybrid and sex had significant effect on carcass quality. Identical results were obtained by Rondeli et al. (8) as well as Nokolova et al. (9).

Table 2 presents results of a research on chemical composition of meat of 42-day-old broilers in Croatia (7). Cobb 500 male broilers contain less water ($p<0.001$) and more protein ($p=0.021$) in breast meat, and more water and less collagen in thigh meat ($p<0.001$). Difference in the protein contained in breast meat and thigh meat speak more in favor of Cobb 500 broilers than of Hubbard Classic broilers. Kralik et al. (10) studied the content of nutrients in dark meat of the Ross 308 broilers. They found out that male broilers had higher values of protein and collagen (19.65% and 0.93%, respectively) than females (19.24% and 0.84%, respectively), while the content of water (74.48%:73.20%) and fat (6.44%:6.34%) was higher in females, however without statistically significant differences ($p>0.05$). Intarapichet and Maikhunthod (11) stated that dark meat of male broilers contained

Table 1. Influence of hybrid and sex on shares of the main parts in carcass (7)

Carcass part (%)	Cobb 500		Hubbard Classic		SM	p		
	Males (63)	Females (44)	Males (51)	Females (49)		Hybrid	Sex	Interaction
Breast	35.91*	38.33*	33.03*	34.33*	0.23	<0.001	<0.001	0.132
Drumsticks with thighs	30.47*	28.76*	32.06a	30.84*	0.14	<0.001	<0.001	0.277
Back	22.21*	21.82*	23.09*	23.09*	0.11	<0.001	0.346	0.339
Wings	11.40*	11.09*	11.82*	11.74*	0.06	<0.001	0.112	0.346

*<0.05; SM, standard error of treatment;

Table 2. Influence of hybrid and sex on the chemical composition of breast and thigh meat (7)

Characteristic (%)	Cobb 500		Hubbard Classic		SM	p		
	Male (29)	Female (16)	Male (19)	Female (28)		Hybrid	Sex	Interaction
Breast meat								
Fat	1.95	1.90	1.98	1.97	0.03	0.360	0.601	0.709
Water	75.53*	75.28*	76.01*	75.72*	0.07	<0.001	0.047	0.881
Protein	23.37*	23.93*	23.29*	23.48*	0.06	0.021	0.002	0.118
Collagen	0.74	0.75	0.77	0.77	0.01	0.403	0.934	0.724
Thigh meat								
Fat	4.70*	4.30*	6.05*	5.63*	0.12	<0.001	0.045	0.959
Water	76.27*	76.32*	75.28*	75.73*	0.09	<0.001	0.170	0.275
Protein	19.61*	19.93*	19.03*	19.31*	0.08	<0.001	0.062	0.897
Collagen	0.98*	1.00*	1.13*	1.13*	0.02	<0.001	0.785	0.747

*<0.05; SM, standard error of treatment

19.98% protein and 77.58% water, while female broilers had 19.67% protein and 75.59% water.

In the white meat lipids, there are 48% of phospholipids. The increase of lipids share in tissue affects the lowering of phospholipids share and an increase of neutral lipids, mainly triglycerides. Fraction of phospholipids contains higher concentration of long-chain polyunsaturated fatty acids (20 and more C atoms), which indicates the fact that phospholipids are more susceptible to oxidation and quality jeopardy than neutral lipids. Cholesterol contained in broiler breast muscle amounts to 43.4-61.7 mg/100 g. In thigh muscle, its level ranges between 84.6 and 87.7 mg/100 g (3).

Results of research into macro elements of potassium, sodium and magnesium, as well as into microelements of zinc, manganese and iron, proved that there were differences between white and dark meat. Kralik et al. (12) determined that white meat contained more potassium and magnesium, and less zinc and iron than dark meat. According to the nutrition facts of Kulier (13), 100 g of broiler meat contains the following macro and microelements: potassium 230 mg, magnesium 25 mg, iron 89 mg, zinc 1.54 mg, copper 0.04 mg and manganese 0.01 mg.

NUTRITIVE QUALITY OF TABLE EGGS

Under the term eggs, we understand chicken eggs that can be hatching eggs (for reproduction – heavy lines) or table eggs (for consumption and processing). Eggs have high nutritional value because they contain almost all ingredients that are needed by a human organism. According to Souci et al. (14), 100 g of edible chicken egg contains 72.5-75 g water, 12.5-13.3 g protein, 10.7-11.6 g fat, 0.7 g carbohydrates and 1.0-1.1 g mineral substances. Human organism uses nutrients from eggs in a high percentage. Proteins are used up to 97%, fats 95%, carbohydrates 98%, and minerals 76% (14). Egg is also rich in reserve nutrients, which allows an embryo to develop from its mother (14). There is a high content of essential amino acids in eggs, especially leucine, isoleucine, lysine, arginine, valine and phenylalanine. Eggs contain also enough vitamins, especially vitamins A, D, E, K and the B-complex, as well as various macro elements and microelements. Table 3 overviews the main ingredients in edible egg (14).

Table 3. Main ingredients in 100 g of edible egg (14)

Ingredients	Share	Ingredients	Share
Water	72.5 - 75.0 g	**Minerals and microelements**	
Protein	12.5 - 13.5 g	Sodium	122 - 156 mg
Fat	10.7 - 11.6 g	Potassium	128 - 155 mg
Carbohydrates	0.7 g	Magnesium	11 - 13 mg
Mineral substances	1.0 - 1.1 g	Manganese	0 - 0.05 mg
Vitamins		Calcium	54 - 60 mg
Vitamin A	122 - 156 mg	Iron	1.5 - 2.7 mg
Carotene	128 - 155 mg	Copper	0.05 - 0.23 mg
Vitamin D	11 - 13 mg	Zinc	0.8 - 2.0 mg
Vitamin E	0 - 0.05 mg	Phosphorus	206 - 225 mg
Vitamin K	54 - 60 mg	Fluorine	0.01 - 0.12 mg
Vitamin B1	1.5 - 2.7 mg	Chlorine	170 - 180 mg
Vitamin B2	0.05 - 0.23 mg	Iodine	1 - 40 mg
Nicotinamide	0.05 - 0.10 mg	**Amino acids**	
Pantothenic acid	1.1 - 1.8 mg	Isoleucine	0.66 - 1.08 g
Vitamin B6	0.09 - 0.18 mg	Leucine	1.01 - 1.25 g
Biotin	0.1 mg	Valine	0.85 - 1.13 g
Folic acid	4.1 - 5.0 mcg	Methionine	0.18 - 0.59 g
Vitamin B12	0.84 - 3.13 mcg	Cysteine	0.17 - 0.38 g
Other ingredients		Phenylalanine	0.58 - 1.03 g
Oleic acid	5.0 g	Tyrosine	0.34 - 0.76 g
Linoleic acid	2.03 g	Threonine	0.49 - 0.94 g
Linolenic acid	0.31 g	Tryptophan	0.15 - 0.27 g
Cholesterol	0.47 g	Lysine	0.65 - 1.01 g
Caloric value	167 kcal	Histidine	0.18 - 0.59 g
		Arginine	0.72 - 1.25 g

Egg weight depends on the poultry type, laying cycle, hens' age, sexual maturity, seasons (temperature, light), feeding and many other factors. Different sorts, breeds and hybrids of poultry produce eggs of characteristic weights. Older hens lay on average heavier eggs. At the beginning of lying, hens produce smaller eggs, but after 2-3 weeks, their eggs are of average characteristic weight (2).

A visible change that occurs in eggs during storage time refers to a change of the air chamber. In hens body, egg is at a temperature of 40-41^{o}C. After lying, eggs are kept at a temperature that is lower than hen's body temperature and, therefore, the egg content shrinks. Since egg shell is a firm formation, and an egg cannot change its shape, there is an air chamber created between a membrane beneath the shell and a membrane that surrounds albumen. That air chamber increases proportional to the length of egg storage. Researches proved that storage conditions, as well as egg shell protection by appropriate coatings affect the size of the air chamber (2). Over 60 days, eggs with coated shell lost 0.45% of their weight, and uncoated eggs lost 6.5% of their initial weight. Over that period, the size of air chamber in coated eggs increased from 2.5 mm to 3.0 mm and in uncoated eggs to 7.2 mm. The loss of egg weight is greater if eggs are stored at higher temperature (15).

Quality of eggs is a complex issue, which is mostly determined byanalysis of physical and chemical properties of eggs. In literature, there is a common division into external and internal quality of eggs (16). Indicators of the external egg quality include egg weight, shape index, shell firmness, as well as shell thickness. An analysis of internal egg quality comprises more indicators, such as index of yolk and albumen, pH value of yolk and albumen, Haugh units (HU), value number (VN), egg aging (EA), basic chemical ingredients, etc. (16).

ENRICHMENT OF POULTRY PRODUCTS WITH NUTRICINES

Eggs and meat enriched with polyunsaturated fatty acids, conjugated linoleic acid, vitamin E, carotenoids and other nutrients are classified as designed products. Designed eggs and meat that differ in their nutritive composition from standard table eggs and meat available on the market can be produced by laying hens and broilers as bioreactors. Eggs and meat enriched with one or more nutrients contribute to increased daily intake of those nutrients, thus assuring positive influence on human health and meeting the criteria for labelling as functional food (17).

Kralik et al. (18) investigated the effects that laying hens' diets supplemented with selenium had on the increase of Se concentration in eggs and on the preservation of egg freshness. A 4-week experiment was carried out on 360 laying hens of the Hy Line Brown hybrid. Laying hens were divided into three groups (C, E1 and E2) with 120 hens in each group and kept in 24 cages. Hens were fed with layer diets containing 18% of crude protein and 11.60 MJ ME (metabolic energy/kg). Hens in the control group C were fed with diets that contained 0.2 mg/kg of inorganic selenium (sodium selenite). Experimental groups E1 and E2 were given diets with increased concentrations of selenium as follows: E1=0.4 mg/kg of selenium (sodium selenite), E2=0.4 mg/kg of organic selenium (Sel-Plex). Selenium concentration in diets affected significantly the content of selenium in albumen ($p<0.001$) and yolk ($p<0.05$). The highest concentration of selenium was determined in albumen and yolk of eggs produced in group E2 (345 ng/g and 783 ng/g, respectively), then in eggs of group E1 (230 ng/g and 757 ng/g, respectively), and group C had the lowest concentration of selenium in albumen and yolk (181 ng/g and 573 ng/g, respectively). After 28 days of storage at 4 °C, the eggs containing organic selenium had more freshness (VN [Value number]: C [control] = 32.9; E1 = 2.60; E2 = 2.11). It was concluded that higher concentration of organic selenium in eggs was a limiting factor in metabolic processes, which positively affected the indicators of egg freshness.

Škrtić et al. (19) studied the influence of various oils on the profile of fatty acids in egg yolks. Laying hens in the control group were fed diets with 6% sunflower oil, and laying hens in the experimental group were given diets supplemented with combination of rapeseed oil (4%) and fish oil (2%). It was determined that yolk lipids of the experimental group contained statistically significantly less ($p<0.001$) unfavorable saturated fatty acids than the control. Furthermore, experimental group had significantly higher ($p<0.001$) content of monounsaturated fatty acids (MUFA), as well as n-3 polyunsaturated fatty acids (PUFA) in yolk lipids than the control. In addition, more favorable ratio of n-6/n-3 PUFA ($p<0.001$) was determined in yolks of the experimental group (Table 4).

Table 4. Content of fatty acids in egg yolk (19)

	% of total fatty acids		
Fatty acids	**Control group**	**Experimental group**	**P**
Σ SFA	35.42	31.56	<0.001
Σ MUFA	40.43	47.73	<0.001
Σ n-6 PUFA	23.80	17.40	<0.001
Σ n-3 PUFA	0.38	3.20	<0.001
Σ n-6 PUFA/Σ n-3 PUFA	62.63	5.44	<0.001

SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids;

Kralik (20) investigated the influence of various oils supplemented to laying hens feed on the content of n-3 PUFA and tiobarbituric acid reactive substances (TBARS)values in egg yolks. Laying hens were divided into three groups. The control group K had diets supplemented with 5% soybean oil, the experimental group P_1 had diets with 3.5% fish oil and 1.5% rapeseed oil, and the experimental group P_2 was fed with diets with 1.5% fish oil and 3.5% rapeseed oil. Diets were balanced at 17% crude protein and 11.60 MJ/kg ME. Research results proved that the content of alpha-linolenic acid (αLNA), eicostapentaenoic acid (EPA) and docosahexaenoic acid (DHA) was the most favorable in egg yolks of the group P_1, then in the group $P_2$and lastly in the group K.

Halle (21) defined important chemical ingredients of eggs that were more or less changing depending on the feed composition (Table 5).

Table 5. Influence of feed on the changes in the content of nutricines in eggs (21)

Minor and modest changes	Significant changes
Protein	Fatty acids
Carbohydrates	Microelements
Fat	Fat soluble vitamins
Minerals	Water soluble vitamins
Free amino acids	
Amino acids of egg protein	

It was determined that fatty acids in egg yolks changed significantly if influenced by the content of fat in feed (22). Linoleic acid, α-linolenicacid and arachidonic acid are essential fatty acids for poultry. For the time being, great importance is given to eicosapentaenoic acid and docosahexaenoic acid, which are essential for humans (23). According to Singer (24), a human organism requires daily 290 - 390 mg αLNA and 100 - 200 mg EPAand DHA.

An issue related to the consumption of eggs and their negative „image“ is raised because of the significant content of cholesterol. Strong propaganda on negative effects of cholesterol related to the occurrence of cardiovascular diseases led to decreased consumption of eggs (from 1975 to 1997 the decrease in USA amounts to 54%) (25). Such an opinion has changed because recent research proved that cholesterol from food is not the only cause of highblood cholesterol (26). Daily consumption of 1-2 eggs did not have any influence on the blood cholesterol level (26). Unfavourable ratio of n-6/n-3 PUFA, saturated fatty acids, as well as trans fatty acids are considered as responsible for increased blood cholesterol (26). Polyunsaturated fatty acids of the n-3 group improve the ratio of HDL and LDL cholesterol; they lower the level of total fats in blood and slow the formation of atherosclerotic plaques in blood vessel walls (26).

In an attempt to improve the nutritional value of broilers' meat by enhancing its unsaturated fatty acid (FA) proportion, plant oils were added to the diet from 22 to 42 days of age in concentration of 50 g/kg and four experimental groups were defined (sunflower – SFO, soybean – SBO, rapeseed – RSO and linseed – LNO), Kralik et al. (27). The greatest increase of n-3 PUFAs was found in LNO compared to other groups ($P<0.05$), as well as the lowest n-6/n-3 ratio ($p<0.05$). They concluded that the meat of broilers fed with linseed oil achieved the best muscle tissue FA profile favorable for human diet, but at the same time the highest proportion of lipid and protein oxidation products, particularly in thigh meat (TM). Moreover, our results indicate that the biochemical mechanism of tissue damage by increased meat PUFA proportion is different for white and dark meat. It also seems possible that in the same muscle tissue oxidation of lipids and proteins takes place independently.

Producers of functional food have to use strong marketing tools to inform consumers about all advantages of functional products over standard, conventional products. Diplocket al. (28) pointed out that food could be characterized as functional if it had satisfactory beneficial effects on one or more target functions in human organism.

In conclusion, poultry products – meat and eggs are significant in human nutrition. They have high nutritive value, contain significant proteins, vitamins, as well as macro and microelements. They are also suitable for the enrichment with functional ingredients - nutricines. Within that procedure, poultry meat and eggs, in addition to their nutritive value, exhibit added value and can be therefore considered as functional products.

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TRANSPARENY DECLARATION

Competing interest: none to declare.

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Peradarski proizvodi obogaćeni s nutricinima pogoduju ljudskom zdravlju

Gordana Kralik, Zlata Kralik
Zavod za specijalnu zootehniku, Poljoprivredni fakultet u Osijeku, Osijek, Hrvatska

SAŽETAK

U radu se prikazuje nutritivna vrijednost mesa tovnih pilića i konzumnih jaja s obzirom da se ovi animalni proizvodi svakodnevno upotrebljavaju u prehrani ljudi. U Republici Hrvatskoj prosječno se troši po stanovniku 18,3 kg mesa peradi i 160 komada jaja. Najkvalitetniji dijelovi trupa pilića su prsa te bataci sa zabatacima. Prsni mišići sadrže 21% do 23% proteina, 1,90% do 1,97% masti, 75,28% do 76,01% vode i 0,74% do 0,77% kolagena. Mišići zabataka sadrže 4,70% do 6,05% masti, 19,03% do 19,93% proteina i 0,91% do 1,13% kolagena. Bijelo meso sadrži više kalija i magnezija, a manje cinka i željeza od tamnog mesa.U 100 g jestivog dijela jajeta sadržano je 12,5 g do 13,5 g proteina, 10,7 g do 11,6 g masti te 1 g do 1,1 g mineralnih tvari. Kalorijska vrijednost jaja je 167 Kcal. Sadržaj esencijalnih aminokiselina u jajetu je vrlo velik, osobito leucina, izoleucina, lizina, arginina, valina te fenilalanina. Jaje sadrži i dosta vitamina, posebno vitamina A, D, E, K i B-kompleksa, kao i različite makroelemente i mikroelemente.Jaja i meso, obogaćeni s jednim ili više funkcionalnih sastojaka – nutricina (polinezasićenih masnih kiselina n-3), eikozapentaenskom, dokozaheksaenskom, selenom i luteinom), udovoljavaju kriterijima za naziv funkcionalne hrane jer posjeduju dodanu vrijednost i povoljno djeluju na ljudsko zdravlje.

Ključne riječi: jaja,meso, EPA, DHA, kardiovaskularne bolesti