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Review article

EGGS IN THE HUMAN DIET - FACTS AND CHALLENGES

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ABSTRACT

Eggs are a good source of balanced nutritional and biologically active substances - proteins, lipids, some irreplaceable nutritional components such as amino acids, polyunsaturated fatty acids, vitamins, macro- and microelements, etc. It is identified as the cheapest animal source of proteins, lipids, vitamins A, B12, riboflavin, choline, iron, zinc, phosphorus and calcium. At the same time, the dangers to human health that eggs can carry are also taken into account.

Material/Methods: The literature used is based on databases PubMed, Embase and as well as data from own studies.

Review Results: In the present review, we provide data on the importance of the composition of eggs in human nutrition are presented and the risk of their use is evaluated.

Conclusions: The high biological and nutritional value of eggs are grounds for their use in the daily life of healthy people, without additional restrictions of cardiovascular diseases. There is a risk of food poisoning, which can be limited to acceptable levels by following good hygiene practices.

Keywords: eggs, safety, salmonellosis, food control

BACKGROUND

Humans have used eggs as food since prehistoric times. Throughout time, we've mostly consumed bird eggs, today mainly domestic ones. In this presentation, we consider eggs as a food product with the main emphasis on chicken eggs, the consumption of which has the largest relative share compared to that of eggs from other animal species. The industrial production of raw whole eggs in the world is from about 3 billion hens. [1] Average annual egg consumption per capita varies. In Mexico, it is 358 units, in Russia – 297, in India – 62, in African countries – 36. In our country, the consumption is about 160 eggs per year. In 2021, 1.326 billion eggs were produced in our country. According to WHO, the medical annual norm for the use of eggs is 260 eggs. Eggs are a good source of balanced nutritional and biologically active substances - proteins, lipids, some irreplaceable nutritional components such as amino acids, polyunsaturated fatty acids, vitamins, macro- and microelements, etc. It is identified as the cheapest animal source of proteins, lipids, vitamins A, B12, riboflavin, choline, iron, zinc, phosphorus and calcium. [1, 2, 3]

At the same time, the dangers to human health that eggs can carry are also taken into account. Some of them today are considered "myths" that led mankind to limit the consumption of foods rich in essential substances. [4] The first "myth" is related to the high concentration of cholesterol in the yolk, considered a risk of atherosclerosis with its consequences - cardiovascular diseases (CVD) and cerebrovascular pathologies. [5, 6, 7, 8] The second "myth" is the risk of salmonellosis associated with massive or sporadic enterocolitis after consumption of meals prepared with eggs. [9, 10]

The **purpose** of this article is to inform food consumers about the benefits of eating eggs, their biological value, as well as the potential risks of not following good hygiene practices.

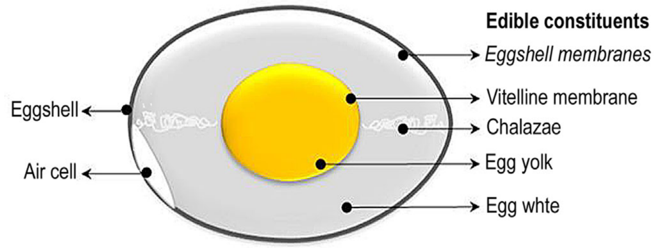
MATERIAL/METHODS:

The literature used is based on databases PubMed, Embase and as well as data from own studies.

REVIEW RESULTS

The structure and composition of chicken eggs are well known, and the information is constantly being supplemented by modern methods. The anatomy of the egg is an example of biological expediency with its purpose – providing optimal conditions for the developing embryo. [2] The shell is made of calcium carbonates and phosphates and provides protection of the content from impact. The outside is covered with a fine cuticle as an additional barrier against moisture loss and bacterial penetration. In the European Union, it is forbidden to wash the eggs after laying in order to preserve the barrier functions of the cuticle (E.U. Regulation No. 589/2008). The shell is not hermetically sealed, with numerous labyrinth-like canals and 6,000 – 10,000 pores with dimensions of 12-20 ìm, carrying out the gas exchange processes. Practically, the shell is not an insurmountable obstacle to the penetration of unwanted chemical substances, gases, bacteria, including Salmonella spp. Under it is a double subshell zipper, which forms an air chamber at the blunt end of the egg. The egg white is multi-layered, consisting of more liquid and denser layers that surround the yolk located in the center. The yolk is surrounded by a vitelline membrane, on its surface is the disc of the embryo, called the blastodisc. The yolk is also a multi-layered body containing the essential nutrients necessary for the development of the embryo. It is held in the middle of the egg by two ligaments of denser protein called "chalazae" (Figure 1).

Fig. 1. Construction of the egg



According to data from the French Agency for Food, Environment, Health and Safety at Work ANSES-CIQUAL, 2019 [1], the main nutrients in the egg white and yolk are distributed as follows (see Table 1):

Table 1. Distribution of the main nutrients substances in egg white and yolk [1]

Main nutrients	Egg white	Egg yolk
Water, %	87,72	55,02
Protein, %	10,82	15,5
Lipids, %	0,19	26,71
Carbohydrates, %	0,85	1,09
Ash, %	0,42	1,68

The yolk consists of aggregates of insoluble proteins and a liquid phase - plasma with soluble proteins. In aggregates, 68% are high-density, and 16% are low-density lipoproteins, plasma contains 10% livevitin and 4% phosphovitin. The vitelline membrane is also made of proteins. The best-studied yolk proteins are apolipoprotein B, apovitelin-1, vitellogenins, serum albumin, immunoglobulins, ovalbumin, and ovotransferrin. [11]

The white is free of lipids and contains ovomucins, ovalbumin, protease inhibitors, lysozyme, etc. About 150 types of proteins have been identified, the predominant (about 50%) being ovalbumin, providing the basic essential amino acids for embryo growth. Lysozyme, avidin and other proteins protect against the entry of unwanted microorganisms. The antimicrobial effect of lysozyme is the reason for its use in pharmacy and as a preservative in foods.

The whole egg contains all the essential amino acids. According to research on amino acid composition (USDA, 2019 [1]), 52.23% of them are essential. The whole egg white is taken as the standard of biological value in comparisons and evaluation of the nutritional and biological characteristics of the proteins of other foods.

The composition of the egg is an example of a balanced source of vitamins and minerals. According to the USDA, 2019 [1], the whole egg contains vitamins of group B (c) – B1 – 0.77 mg/100 g; B2 – 0.419 mg/100 g; B6 - 0.063 mg/100 g; B7 – 335 mg/100 g; B9 (folate) - 71 µg/100g; B12 – 1.02 µg/100g. Of the fat-soluble vitamins in a whole egg, cholecalciferol (vit. D3) – 2.46 µg/100 g, vitamin A – 180 µg/100 g and vitamin E – 1050 µg/100 g were determined. [2, 3] Egg yolk is a rich source of lutein (230 µg/100 g) and zeaxanthin (229 µg/100 g). [3] The egg is also a source of calcium, phosphorus, potassium, moderate amounts of sodium, the trace elements iron, zinc, iodine, selenium. [2, 3]

The carbohydrates in the egg are in miniscule quantities - only 0.2 g/100 g are present in the form of glucose. No dietary fiber at all.

Proteins are contained in the egg's white yolk, membranes and shell. Hundreds of egg proteins (about 550) have been identified, and only about 20 of them have known specific physiological functions.

Lipids are concentrated in the yolk, and their total amount in 100 g of whole egg is between 8.7 g and 11.2 g. Factors such as the diet of laying hens hardly change the total lipid content but significantly affect the fatty acid (F.A.) profile. For example, when the diet of hens is enriched with ù-3 F.A. by adding flaxseed, these essential F.A. appear in the lipid profile of the eggs. [5]

Lipids are part of the lipoproteins of the yolk. The amount of unsaturated F.A. is much greater than that of saturated. According to ANSES-CIQUAL, 2019, 100 g of whole egg contains 5.31 g of unsaturated and 2.64 g of saturated F.A. – a ratio that is unique among other animal foods. [1, 2] Egg lipids do not contain short-chain F.A.s. Of the saturated F.A.s, the relative share of F.A. 16:0 and F.A. 18:0 is the most significant, the concentration of F.A. 14:0 is low. Unsaturated fatty acids predominate with the largest share of oleic and linoleic, a small amount of arachidonic acid is present. The polyunsaturated ϖ-3 F.A.s, according to this study, are in negligibly low amounts. The average content of F.A. and cholesterol in whole egg and in egg yolk (g/100g) is presented in Table 2. [2]:

Table 2 Content of fatty acids in chicken eggs (mg/100 g)

Fatty Acids	Whole Egg	Egg Yolk
• Saturated	2.64	8.47
MK 4:0 (butyric)	< 0,05	0
MK 6:0 (caproic)	< 0,05	0
MK 8:0 (caprylic)	< 0,05	0.009
MK 10:0 (capric)	< 0,05	0.009
MK 12:0 (lauric)	< 0,05	0.009
MK 14:0 (myristic)	0.024	0.091
MK 16:0 (palmitic)	1.96	6.04
MK 18:0 (stearic)	0.65	1.73
• Unsaturated	3.66	11.9
MK 18:1 (oleic)	3.51	10.4
• Polyunsaturated	1.65	4.07
MK 18:2 (linoleic)	1.38	3.28
MK 18:3 (α-linolenic)	0.061	0.15
MK 20:4 (arachidonic)	0.12	0.37
MK 20:5 (eicosapentaenoic)	0	0.01
MK 22:6 (docosaexaenoic)	0.09	0.25
Cholesterol	0.398	0.939

Phospholipids are the most prevalent, in particular those in lecithin. "Lecithin" is a conglomerate of lipids that have the properties of a natural emulsifier. It is a mixture of phospholipids (65-70%) and triglycerides (30-35%). Egg yolk contains 9,600 to 11,000 mg/100 g of lecithin. [9] Phospholipids and cholesterol are natural antagonists, which are manifested at the level of cytoplasmic membranes. Phospholipids increase the functional activity of membranes. As a result of their metabolism, the level of high-density lipoproteins is directly related to anti-atherosclerotic processes increases.

Regular intake of lecithin leads to a reduction of cholesterol and also increases the ability of bile acids to extract from the plasma. [9] Phospholipids are a source of choline (vitamin B4), a substance with a key role for the nervous and cardiovascular systems (by participating in the formation of methionine - an antagonist of atherogenic homocysteine), a fat and carbohydrate metabolism, a powerful hepatoprotector. According to the USDA, 2019 [1], the choline content of a whole egg is 335 mg/100 g.

According to the data from Table 3, an egg with a mass of 60 g is a carrier of about 240 mg of cholesterol (with the permissible daily intake of exogenous cholesterol recommended by the WHO being no more than 300 mg). In the past, this recommendation has contributed to serious restrictions on egg consumption in order to prevent hypercholesterolemia and its consequences. For decades, patients with various pathologies and healthy individuals have been recommended to consume no more than 2-3 yolks per week, such as the recommendation of, for example, the American Heart Association (ANA) in 1968. [12, 13]

Today, this restriction has been lifted after about 50 years of discussion on the issue and extensive scientific experiments that reported no relationship between egg intake and high plasma cholesterol levels. In the USA, the restriction of dietary intake of cholesterol (up to 300 mg per day) was also lifted. The topic of dietary cholesterol continues to be on the agenda and is subject to serious discussion and relevant experimental evidence. [14, 15, 16, 17, 18, 19, 20] Related to this topic is the problem of the saturated fatty acids contained in eggs.

It has been found in vivo in monkeys that F.A. 14:0 (myristic) is the main saturated MC raising the level of plasma cholesterol, but in the egg, it is in negligible amounts, while M.K. 18:2 (linoleic) is the one that lowers it and presents in the yolk in high concentration (see Table 3). [2, 18, 19, 20]

Cholesterol has a vital role as a structural element in cell membranes and as a precursor to steroid hormones and bile acids. Its homeostasis is regulated by endogenous biosynthesis, dietary intake, intestinal absorption, utilization by the body and the corresponding excretion of cholesterol. [18, 19, 20] Endogenous biosynthesis of serum cholesterol in humans represents 75-80% of its total amount in plasma. For an individual with 70 kg, this means a daily biosynthesis of 850 mg. In the lumen of the duodenum and jejunum, endogenous cholesterol is poured with the bile juice.

It is also there that the absorption of both endogenous and alimentary cholesterol takes place, which enters enterocytes, liver cells and plasma. Some of the cholesterol and bile acids are not absorbed and are excreted in the feces. [18, 19, 20] The intestinal microbiome also plays a role in absorption.

Only 60% of dietary cholesterol is absorbed, and this represents 22% of what the body uses. [9-16] When taking large amounts of dietary cholesterol Lin DS. and Connor WE, 1980, have found an effect of inhibiting its endogenous biosynthesis and increasing the excretion of bile acids. [18]

The fact that between 15 and 25% of the healthy population, including individuals with genetic dyslipidemia, is hyperreactive to dietary cholesterol should not be underestimated, in these cases, with increased egg consumption, the level of plasma lipids also increases. [18, 19, 20]

We will cite several large targeted studies that have led the US ANA to revise its 1968 recommendations.

An experimental randomized study (2018) on two groups - men and women - found that a daily intake of 100-150 g of boiled eggs increased the level of triacylglycerol but not the total amount of cholesterol in the plasma [20]. We will elaborate on the extensive study by Dehghan M, et al., 2020 [6], which evaluated the relationship between egg consumption and blood lipids, CVD and mortality. The global – studies were conducted in 50 countries with low, medium and high living standards on all continents (177,000 individuals).

Epidemiological surveillance (PURE) with registration of egg intake was conducted over 9.5 years in 21 countries on 146,011 urban and rural individuals without CVD. In parallel, longitudinal multinational studies (ONTARGET/TRANSCEND-2001-2019) were performed on 31,544 patients with CVD. During the study period (2001 to 2019), lipid profile and blood pressure were monitored, CVD events and death were recorded (13,658 CVD and 12,701, respectively). Based on the weekly number of eggs consumed, the groups of the epidemiological study were formed and compared based on the weekly consumption of eggs: <1; 1-<3; 3-<5; 5-<7; ≤ 7 items. [6]

Mean statistics (m ± S.D.) for lipid profile and blood pressure were derived, adjusted hazard ratios (H.R.) were calculated. Subsequently, the influence of additional factors - age, gender, smoking, education, physical activity, energy intake, intake of animal and vegetable foods, energy from carbohydrates, etc. - was evaluated. In Table 4, we present some summary comparisons based on data from the PURE project (Table 3):

Table 3. Mean statistics for plasma lipids in the PURE study [6]

Indicators	Weekly number of consumed eggs				
	< 1	**1- < 3**	**3 - < 5**	**5 - < 7**	**≤ 7**
Number of individuals (n)	23 321	31 096	23 329	14 498	22 371
Total cholesterol, mmol/L	4,90 ± 0,05	4,92 ± 0,05	4,90 ± 0,05	4,91 ± 0,05	4,89 ± 0,05
LDL-C, mmol/L	3,07 ± 0,05	3,09 ± 0,05	3,08 ± 0,05	3,07 ± 0,05	3,08 ± 0,05
HDL-C, mmol/L	1,21 ± 0,02	1,21 ± 0,02	1,21 ± 0,02	1,21 ± 0,02	1,20 ± 0,02
Ratio TC:HDL-C	4,27 ± 0,06	4,27 ± 0,06	4,27 ± 0,06	4,28 ± 0,06	4,30 ± 0,06
Triglycerides, mmol/L	1,57 ± 0,04	1,57 ± 0,04	1,55 ± 0,04	1,56 ± 0,04	1,54 ± 0,04
ApoA1, [2] mmol/L	1,49 ± 0,02	1,49 ± 0,02	1,50 ± 0,02	1,50 ± 0,02	1,50 ± 0,02
ApoB, [2] mmol/L	1,01 ± 0,02	1,01 ± 0,02	1,00 ± 0,02	1,01 ± 0,02	1,02 ± 0,02
ApoB/apoA1,[2] mmol/L	0,71 ± 0,02	0,71 ± 0,02	0,70 ± 0,02	0,70 ± 0,02	0,71 ± 0,02
Systolic blood pressure, mm Hg	132,7 ± 0,74	132,7 ± 0,73	132,1 ± 0,74	131,9 ± 0,75	131,4 ± 0,75
Diastolic blood pressure, mm Hg	83,6 ± 0,62	83,6 ± 0,62	83,3 ± 0,62	83,1 ± 0,62	82,6 ± 0,62

With such a stark absence of significant differences between the groups consuming different numbers of eggs, the authors concluded: "we found no significant associations between egg intake and blood lipids, mortality, or major CVD events." This is one of the studies that motivated the ANA's current recommendations.

However, there are also scientific developments that support the thesis that the risk of increased CVD morbidity with high dietary cholesterol intake, resp. of eggs cannot be ignored. Bin Z, et al. 2022 [19], after a prospective analysis of 27,078 male smokers in Finland (1988-1993), found a significant increase in total and CVD mortality with an additional intake of 300 mg or 1 egg of 50 g per day. The authors report results from cohort studies with the consumption of an additional 1 egg per day in a large cohort of participants (3,601,401 individuals) from different geographic regions, showing an increased risk of CVD in the American and European cohorts and no risk in the Asian cohorts.

Zhong V. et al., 2019, observed and recorded egg consumption and cardiovascular events over 17.5 years in 29,615 volunteers. [20] Such an association was also observed in a 12-year cohort study in 2022 in Iran on 6504 individuals over 35 years of age without a history of CVD at baseline. The conclusion of this study was that higher egg consumption was not associated with an increased risk of myocardial infarction, ischemic heart disease, stroke, and other vascular events. [20]

A review of the available sources gives grounds for the belief that for the healthy population, the harm of weekly consumption of more than 2-3 eggs is a "myth". The myth has been debunked, but researchers believe that the daily intake of eggs should not entail a massive risk of atherosclerosis and its vascular consequences. For more vulnerable contingents, the approach should be more careful. It is obvious that research in this direction will and needs to continue.

The second danger associated with the consumption of eggs is of a completely different nature - the risk of salmonellosis. Even today, the problem has not lost its relevance. It is no coincidence that the first topic of the WHO/FAO "Microbiological Risk Assessment" series of monographs, in which a detailed assessment of the risk of pathogenic microorganisms in different types of food is made, is dedicated to Salmonella in eggs and broilers. [21] The monograph points out that the spread of Salmonella enterica among industrially raised broiler chickens is directly proportional to the incidence of salmonellosis in humans, and its reduction is a major intervention measure to reduce this risk throughout the food chain.

Birds are a natural host of the Salmonella spp., they are emitted with faeces and urine and spread in different ways in the environment. Unconditionally, egg contamination is directly dependent on "healthy", i.e. asymptomatic carriage of Salmonella among poultry flocks in farms, but also among poultry. This carrying capacity is variable and is due to many factors in the ecosystems of different countries and regions. The relationship with the epizootiological status in the territories where the poultry farms are located is unconditional.

Contacts with wild and synanthropic rodents, birds and others, natural biotopes and reservoirs of infection cannot be excluded; the role of contaminated feed, water, other elements of the environment cannot be ruled out. According to Rodriguez A. et al., 2006, the frequency of contamination of poultry farms in the USA is from 10% to 26%, according to other sources, it is an average of 19.2±10.4%. [22, 23]

According to Chugunova E. et al. (2014), the frequency of infection of poultry flocks with Salmonella in poultry farms of a large region of Russia during the period 2000-2012 varied annually - from 0% in 2000 and 2008 to 17.65% in 2004, during the last three years of the observed period it varied from 3.15% to 5.49%. The same authors isolated Salmonella in in 1.87 % of the produce exported commercially. [24] In 2007, EFSA carried out a survey of the level of contamination of farms for laying hens and found an average frequency of 30.8% for the different E.U. member states – ranging from 0 to 79%. [10]

In a 2009 publication, EFSA indicated a level of egg contamination of 0% to 5.8%, setting an average prevalence of Salmonella in eggs of around 0.8% [6]. In the U.S., there is also a difference of opinions about the levels of Salmonella contamination in eggs. According to Hope BK, et al., 2008, of the 69 billion eggs produced annually, only 2.3 million are contaminated, which is equivalent to 1 infected in 30,000 eggs. [25] This data is justifiably doubtful. The information on the probability of eggs sold for consumption being carriers of Salmonella is extremely conflicting, but the fact that they are carriers is not denied in any of the research analyses.

According to the US Centers for Disease Control and Prevention (CDC), from 2009 to 2021, there were 2,785 outbreaks of foodborne salmonellosis, with 61,622 cases, 10,072 hospitalizations, and 95 deaths. [8,11] The most frequently isolated serological variants are *S.enteritidis, S.typhimurium, S.newport, S.heidelberg,* and *S.montevideo* [26]. In another study in the USA for the period 2006-2011, a total of 469 outbreaks of salmonellosis were registered, 367 of which were from animal foods and 102 from plant foods (mainly fruits and sprouts). [26] Interestingly, 145 or 30.9% of salmonellosis outbreaks were from poultry and 117 or 24.9% from eggs.

Also, in the U.S. during the same period, 661,633 cases of salmonellosis were reported annually after consumption of eggs. Serovars *S. enteritidis* and *S. typhimurium* were the leading cause, but also *S. kentucky*, *S. seftenberg*, *S. thompson*, *S. montevideo*, etc. were present. [27] These serotypes rarely cause clinical symptoms in birds, and this complicates the epidemiological diagnosis of carriage. Clinically manifested salmonellosis in birds is most commonly due to S. pullorum and S. gallinarum, which rarely manifest as human pathogens. This specificity in the pathogenicity of different serovars was described as early as 1909 by Rettger L. [28]

According to the annual reports of the European Center for Disease Prevention and Control (ECDC) to the European Food Safety Authority (EFSA) [10], salmonellosis in Europe ranks second among the causes of zoonotic diseases after Campylobacter. The statistics in the period 2017 - 2021 recorded confirmed cases of disease and morbidity per 100,000 people of the population as follows (Table 4):

Table 4. Statistics on the incidence of salmonellosis in Europe.

Observed statistic data	**Years**				
	2021	**2020**	**2019**	**2018**	**2017**
Total number of patients (confirmed cases)	60 050	52 690	87 908	91 858	91 587
Total number of patients/100,000 people	15.7	13.7	19.5	19.6	19.4
Total number of patients in mass outbreaks	6 755	3 686	10 240	11 631	9 607
Total number of mass outbreaks of Salmonella	773	694	1 284	1 588	1 241

Outbreaks of salmonellosis are mainly due to two serovars - *S. enteritidis* (in about 60% of diseases) and *S. typhimurium*, but *S. Infantis*, *S. derby*, monophasic *S. typhimurium* (1, 4, [5],12:i:-) etc. [10] Salmonella food monitoring in the European Union for 2021 shows a different level of contamination in different food categories. Fresh meat takes first place: from broiler chickens - 4.4%, from turkeys - 3.6%, from pigs - 1.5%, from cattle - 0.26%, fish - 0.65%. In eggs and egg products, monitoring shows 0.85% contamination, in dairy foods – 0%, in fruits and vegetables – 0.06%, etc.

Eggs are infected either endogenously in the reproductive tissues of infected birds or more often exogenously, on the shell during laying, which takes place through the cloaca of the birds, but also through contact with contaminated surfaces in farm settings. A study by FSIS (1998) determined an incidence of 0.00489% of endogenous contamination of eggs with *Salmonella*, with the amount of the bacteria averaging about 40 cfu. [20] Exogenously, the eggshell is contaminated with all microorganisms, including Salmonella, contained in the cloacal excreta of the birds

Depending on the duration and conditions of storage, microorganisms penetrate through the pores or through microscopic cracks of the shell, overcome the membrane barrier and infect the inside of the eggs as well. [22] Refrigerated storage at a temperature not higher than 7.0°C limits the probability of Salmonella spreading in the egg white and yolk [29]. Exogenously contaminated eggs are a potent source of contamination of derived egg products.

It is rightfully considered that contamination of the egg mass from the shells occurs during manual or automated breaking of the eggs. [28, 29] The methods of processing and use of the egg mass and the conditions of its storage determine the degrees of risk. Eggs and egg products are a wonderful environment for the development and reproduction of bacteria - Salmonella, staphylococci, etc., which imposes specific rules in the hygiene of culinary applications and especially regarding storage periods.

We will share our own experience from related Bulgarian studies of the microbiological safety of eggs and egg products. An experiment was carried out in authentic production conditions with artificial *S. typhimurium* contamination of egg white-caramel cream. Caramel with a temperature of about 170°C is mixed with raw egg whites whipped into foam until a homogeneous mass is obtained - pastry cream.

A test was conducted in which the egg whites were inoculated with a 24-hour culture of the Salmonella test strain, and then automated mixing of the egg whites with the hot caramel was performed. It was established that, regardless of the high temperature of the caramel, viable residual cells of the introduced salmonella strain were found in the finished cream – the thermal conductivity was insufficient to destroy the non-spore-forming microorganisms. [30]

Egg products used as semi-finished products in culinary, confectionery and bakery production are also at risk – these are pasteurized, natural or concentrated, chilled or deep-frozen liquid egg products and pulverized dried egg powder. They are made from whole eggs, yolks and whites, and their production requires strict rules for good production and hygiene practice. [30]

In the 1980s, a research project carried out 5-year observations on the microbiological state of dry egg powder, produced according to the modern technology of the time. We present some more important results of the studies. [31, 33] Raw egg mass, intermediate and finished products were examined - a total of 329 batches of raw egg mass, 2,663 - pasteurized egg mass, 1,089 batches of finished dry melange, 358 - dry egg white, 361 - dry yolk.

Studies of egg mass-melange intended for pasteurization and thermal spray drying show the following [31,32]: In the raw egg mass, the total number of mesophilic aerobic microorganisms reaches 108 cfu/g, and in 87.8%, it is above 105 cfu/ g. Salmonella spp. present in 4% of lots. Coliforms are isolated in 100%, and only 8% of batches are below 104 cfu/g, the rest reach 108 cfu/g, and in the summer season, are much more alarming.

Proteus spp were found in 30.3%. in amounts of 104 cfu/g to 106 cfu/g. *Pseudomonas* spp. were isolated in isolated cases in negligible quantities. No evidence of *S.aureus*. Obviously, the automated egg-washing mode is not effective and does not remove the microbial faecal flora on the shells.

In pasteurized egg melange, Salmonella spp. proved in 1.22 %. Coliforms and Proteus spp. are isolated in 9.82 % and 2.25 %, respectively. No *Pseudomonas* spp. and coagulase-positive staphylococci were found. But if the pasteurized egg mass is allowed to stand for several hours in the tank before the pulverization drying, the frequency of isolation of Coliforms reaches 34.38%, and in the finished product, the residual microflora increases sharply - Coliforms are isolated in 18.5%, and Proteus spp. – in 3.6%. [32, 33] These observations caused serious adjustments to the technological regime.

Thermal pulverization drying is carried out at a temperature of 185°C - 200°C, the loss of moisture is rapid, which is fatal for the microflora in the raw material, but not completely. T Tests have proven that the actual temperature in the emulsion particles during the pulverization of the egg mass is no higher than 60°C, which explains the presence of residual microflora. Salmonella spp. were isolated in 0.26% to 0.89% in different seasons in the finished pulverisation-dried egg powder. There are much more alarming literature data, according to which the frequency of contamination with *Salmonella* spp. of dry egg powder varies from 5 % to over 50 %. [33]

These wide ranges are apparently due to differences in technology and variable epizootology in different countries and regions. Our data is obviously the result of the effective decontaminating mode of pulverization drying, of the hygiene control in the period of the tests and of the favorable epizootiological status in the region of the poultry farms-suppliers during the period of the conducted studies. In the same period, in imported batches of dry egg melange *Salmonella* spp. proved to be over 10.0%. The total number of aerobes illustrates the effect of heat drying.

Immediately after drying in the finished dry yolk, their number was above 103 cfu/g at only 2.2%, in the albumen – at 7.8%, and in the melange – at 8.1%. Coliforms were isolated in 10% dry yolk, 11.08 in dry egg white, and 9.32 in dry melange. *Proteus* spp. are not found in dry yolk, but in dry egg white and in dry melange, they are isolated in 0.28 and 1.07 %, respectively.

During the storage process, the microflora of dry egg products changes. We experimentally followed the dynamics of 60 batches of pulverization-dried egg powder stored for up to 12 months under standard conditions. The total number of mesophilic aerobic microorganisms, which immediately after production is in the range of 103 cfu/g - 105 cfu/g, significantly decreases with varying intensity, but the majority of batches in 3 to 6 months reduce their number to 102 cfu/g and below 102 cfu/g. The reason is the low level of humidity of the product – about 4.0 %. [32, 33]

Experimentally, three batches of dried egg powder were artificially contaminated with 24-hour cultures of test microorganisms isolated from food and maintained in the laboratory's collection - *S. typhimurium*, *E. coli O119, P. mirabilis, P. aeruginosa, S. aureus.* Infectious doses were 102 cfu/g -103 cfu/g. Monthly examination of the infected batches showed that the experimental strains were detected after 1 and 2 months of storage in large inoculum quantities (10.0 g or 25.0 g of the product).

After 3 months of storage, they were not detected, with one exception - S. aureus was isolated in one of the batches in 10.0 g of the product after 6 months. [31] Powdered eggs are not a favorable environment for the development of bacteria, the microbiological risk in them is due to the residual microflora after production.

The microbiological monitoring of pasteurized liquid egg products - semi-finished products for bakery and confectionary products- carried out by us in recent years showed that the modern manufacturer successfully copes with the microbiological risk. The microbiological criteria and standards of Regulation (E.U.) No. 2073/2005 for egg products were used, supplemented by the determination of the total number of mesophilic aerobic microorganisms.

We present the results of the monitoring in Tables 5 and 6. They show full compliance with the norms established in the above-mentioned European regulation. They are due to the correct technology, the hygiene of production, and the effective functioning of the manufacturing enterprise's internal control system. [30, 33]

Table 5. Total number of mesophilic aerobic microorganisms in pasteurized liquid egg products (TNMAM)

Type of product	Number of examined batches (*n*)	TNMAM - arithmetic mean x (log10/cfu/g)	σ (*log₁₀*)
Melange	226	3,69/4,9 x 10^3	±0,32
Egg white	106	3,64/4,4 x 10^3	±0,22
Egg yolk	119	3,69/4,9 x 10^3	±0,33

Table 6. *Enterobacteriaceae* and *Salmonella spp.* in pasteurized liquid egg products

Type of product	*Enterobacteriaceae*			*Salmonella spp.*		
	n	Results, (cfu/g)*	%	*n*	Results	%
Melange	56	< 10	100	226	Not present in 25 g	100
Egg white	80	< 10	100	106	Not present in 25 g	100
Egg yolk	35	< 10	100	119	Not present in 25 g	100

* CFU - colony-forming unit

In conclusion of the presented literature and our own factual and experimental data related to the risk assessment of Salmonella spp. in eggs, semi-finished products, and egg products, we can conclude that this danger to the consumer's health should not be underestimated. The role of eggs and egg products in the epidemiology of foodborne salmonellosis is not a "myth" but a reality, and this determines the need for serious health control along the entire food chain - from farm to table.

CONCLUSIONS:

1. The high nutritional and biological value of eggs, the balance in the content of essential proteins, lipids and lipoids, fat-soluble vitamins, minerals, gives reason to incorporate them in the daily diet of the consumer, without restrictions and concerns for the healthy population of atherosclerosis and its fatal consequences for the cardiovascular system.

2. An example of a natural cycle of pathogenic microorganisms in the animal world is the spread of Salmonella enterica not only among the wild but also among domestic and industrially raised birds. The epidemic role of their eggs and their products in the incidence of salmonellosis should not be underestimated but controlled by adequate hygiene rules.

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