Obtaining eggs enriched in polyunsaturated fatty acids (PUFA) 2. Clinical studies, consumer perception and market of the PUFA-enriched eggs: A review

Raluca Paula Turcu*[1], Mihaela Sărăcilă[1], Petru Alexandru Vlaicu[1], Petruța Vișinescu[2] and Rodica Diana Criste[1]

*****Corresponding author email: raluca.socoliuc@yahoo.com*

[1]*National Research-Development Institute for Animal Biology and Nutrition (IBNA), Calea Bucuresti, no 1, Balotesti, 077015, Ilfov, Romania*
[2]*SC Avitor SRL, Str. Islazului, no 27, Dragos Voda, 917085, Calarasi, Romania*

ABSTRACT

Egg is a product with a high biological value, which makes it particularly important for human nutrition. Since consumers are becoming more informed and therefore more demanding when purchasing a product, egg production strategies in recent years have changed. It is intended that beyond the basic nutrition, eggs provide additional benefits to the health of consumers. This is not easy to do, but the nutritional value of the eggs can be improved by using functional compounds in laying hen diet, such as omega-3 polyunsaturated fatty acids. The obtained information from the studies carried out on the consumption of polyunsaturated fatty acids enriched eggs on the health status of consumers, as well as their perception and reasons underlying their choices when purchasing a product are presented in this mini review.

Keywords: consumer perception, eggs, health, PUFA

INTRODUCTION

The forecasts show that the world population will reach 9 billion by 2050, which suggests that the global demand for food will increase steadily in the close future (Malingreau et al., 2012). The demand for food will increase both because of the growing world population, and because of the increasing incomes. The demand for cereal grains will reach about 3 billion tons by 2050, and FAO estimates that the annual production of cereal grains will have to increase by almost 1 billion tons (2.1 million tons) and the poultry meat production by more than 200 million tons, to reach a total of 470 million tons by 2050 (FAO, 2017). According to FAOSTAT, (2015), the global poultry industry has one of the highest rates of development. The world egg production reached 68.26 million tons (2013), a 94.6% increase from 35.07 million tons in 1990 (FAOSTAT, 2015). For decades, the poultry

meat and eggs have been the most important sources of protein for the world population (Magdelaine, 2011).

As the economy develops, the eggs, meat and meat products are used not just to supply the required nutrients, but they are also expected to have additional functions preventing diseases and improving consumer mental state and welfare (Roberfroid, 2000; Siró et al., 2008). The current researches focus on the strategies to improve the nutritional value of the eggs, meat and meat products (Zhang et al., 2010). The nutritional value can be improved by adding functional compounds to the diets, among which the omega-3 fatty acids (Zhang et al., 2010).

The foods whose nutritive value is enriches and which provide specific benefits for health beyond the basic nutrition, are known as functional foods. Recently, the use of functional foods as strategy to promote consumer health and prevent the risk of diseases came to the public attention. This concern provides big opportunities for the food industry. Although the demand for healthy food is significant, consumers are reticent to change their eating habits (Martinez et al., 2012). This suggests a great potential for the usual foods when they are transformed in functional foods by changing the composition to include ingredients that are beneficial to health (Herron and Fernandez, 2004).

The necessity for foods and ingredients supplying benefits beyond their traditional nutritional value gave rise to an extraordinary academic, commercial, functional and public interest. This is due first to the acknowledgement of the fact that disease prevention is preferable to curing a disease. Thus, disease prevention and health promotion by eating functional foods and nutraceuticals received attention worldwide, different such foods being now available on the market (Chibisov et al., 2019; Elmaliklis et al., 2019).

The traditional animal foods contribute to the total supply of lipids, cholesterol and saturated fatty acids in human diets. The hen eggs are among the most popular foods, being consumed worldwide because their high nutritional value (Ayasan and Okan, 2000; Ackermann et al., 2019). The poultry meat is healthier, with a lower level of fat than the meat from other animals. The success of the poultry industry depends on the improvement of performance and carcass characteristics, on lower fat deposits in broilers and on improving the supply of products to consumers. Nutrition plays an important role in broiler production (Ibrahim et al., 2018; Kim et al., 2019).

Concept of functional foods

The functional foods are one of the most interesting areas of research sand innovation in the food industry (Annunziata and Vecchio, 2011). The concept of functional food has developed as a convenient and cheap solution to chronic health problems, changing its meaning depending on the country

and culture. This concept was used for the first time in Japan, in the late 80s. In 1991, the functional foods were regulated according to the Japanese legislation under the name of "Foods with the specific health use" (FOSHU) (European Commission, 2010; Martirosyan and Singh, 2015). Exhaustive were conducted subsequently to identify and determine the ingredients of functional foods (Siró et al., 2008).

At present, there is no general definition of functional foods and therefore there is no clear situation of their availability for use. Therefore, any food that offers additional health benefits beyond its nutritional value is considered a functional food, due to its chemical composition in particular nutrients or bioactive compounds (European Commission, 2010; Tomar et al., 2013; Singh et al., 2016).

The functional foods are promoted as products that have specific benefits to human health beyond the basic nutrition. While several studies show that the reasons behind purchasing such foods is oriented towards the concern for health, other sources (Pappalardo and Lusk, 2016; Barauskaite et al., 2018; Steinhauser and Hamm, 2018) consider that choosing functional foods can be also determined by hedonic or social reasons, less related to health, such as the tendency towards indulgence versus self-control, or the motivation to impress (Urala and Lahteenmaki, 2003; 2006; Niva, 2007; Karelakis et al., 2019).

The food industry plays a particular role in the development of functional foods, by incorporating protection trace nutrients in the food matrix (Tomar et al., 2013). Particular stress is on the development of functional foods with benefits in fighting particular diseases, such as the cardiovascular diseases, diabetes, cancer, anaemia and other chronic diseases (Tomar et al., 2013). On the other hand, not only the food industry has the responsibility to come up with solutions for health problems. Considering that the concept of functional food has changed its meaning over time depending on the country and culture, there is currently a confusion between experts and non-experts as to its exact definition. This makes it necessary to better clarify the meaning of functional food in order to facilitate communication between nutrition scientists, the public, and other groups as well as legitimize functional food science around the world (Martirosyan and Singh, 2015).

Health benefits of the consumption of functional foods

The diet plays a major role in health preservation (Digambar et al., 2018). The interest for improving the quality of life and for preventing diseases generated the concept of functional food (British J. of Nutrition, 1994- Scientific Concepts of Functional Food in Europe- Consensus Document). The diet is one of the most important factors that has significant influences on health. The eggs, by their high biological value, can be a useful

vehicle to increase the consumption of nutrients that are important to human health. This boosted the efforts to develop the dietetic high nutritive components within the eggs, which could modulate the immune functions of the body, can treat diseases and health disorders such as cancer and diabetes, can regulate blood pressure, can decrease the blood cholesterol and alleviate the cardiac disorders and the allergies (Alagawany et al., 2018).

The animal and plant products are usual functional foods used to treat obesity, the metabolic syndrome, type 2 diabetes and sugar diabetes (Singh et al., 2009; Tomar et al., 2013; Singh et al., 2016). This beneficial effect of functional foods is due to their chemical composition rich in amino acids, omega-3 fatty acids, antioxidant compounds, vitamins and minerals (Tomar et al., 2013; Singh et al., 2016).

The supplementation and manipulation of fatty acids composition in poultry foods can be done by feeding the birds fish oils of plant oils (sunflower oil, flaxseed oil, corn oil). This action is implemented for nutritional purposes, for human health (Milanković et al., 2019). The concentration of omega-3 PUFA in animal products depends mainly on the composition of the dietary fatty acids (Ibrahim et al., 2018). There is a potential to enrich the human diet in omega-3 PUFA by modifying the feeding practice of the birds in order to meet the requirements for human health, because the ratio of the animal dietary oils and fats influences the deposition of fatty acids in the eggs and broiler meat (Milanković et al., 2019).

The α-linolenic acid (ALA, 18:3n-3) is an essential fatty acid for the human diet. ALA is a polyunsaturated fatty acid (PUFA), essential precursor for the omega-3 PUFA chain; through a series of enzymatic reactions it is changed into two long-chain fatty acids, the essential eicosapentaenoic acid (EPA 20:5n-3) and docosahexaenoic acid (DHA, 22:6n-3) (Barceló-Coblijn and Murphy, 2009). The omega-3 polyunsaturated fatty acids (PUFA), EPA and DHA, are components of a healthy, balanced diet, having beneficial effects on the development and alleviation of several pathological disorders. However, their world supply, from all traditional sources is not enough to meet the human nutritional requirements. Recently, the efforts of the scientists focused on the development of new products enriched *de novo* in omega-3 PUFA. This allowed the determination of new sources of EPA and/or DHA, already available or susceptible to be available soon. These new sources of PUFA might provide more options and opportunities for the consumers to obtain EPA and DHA in enough concentrations which to support a healthier, more balanced diet (Tocher et al., 2019).

Therefore, the enrichment of foods is, seemingly, the best long-term solution to encourage the supply of omega-3 PUFA, without making significant changes to the diet (Fraeye et al., 2012).

Table 1. Specific recommendations for EPA and DHA (according to Bourre, 2005)

	Date	Omega-6/omega-3 Recommended ratio	Specific recommendations
Norway (National Council for Nutrition)	1989	-	0.5 % of the daily energy supply for omega-3 (1-2 g/day)
workshop NATO	1989	-	0.27 % of the daily energy supply (0.8g/day) EPA-DHA
Canada (Scientific Review Committee)	1990	5:1 - 6:1	Omega-3 up to 0.5 % of the daily energy supply
France, CNERNA-CNRS	1992	4:1 - 10:1	0.5 - 1 % of the daily energy supply for ALA
GB (British Nutrition Task force)	1992	6:1	EPA 0.2 - 0.5 % of the daily energy supply, DHA 0.5 % of the daily energy supply
FAO-WHO Expert Committee in fats and oils in human nutrition	1994	5:1 - 10:1	DHA pre-format in pregnancy
ISSFAL-USA Expert workshop	2000	-	EPA + DHA 0.3 % of the daily energy supply, or 0.65 g/day
Crete, Eurodiet-nutrition	2000	-	200 mg long-chain polyunsaturated fatty acids per day
France, CNERNA-CNRS; AFSSA	2001	5:1	0.8 % of the daily energy supply for ALA, 0.2 %. of the daily energy supply long-chain polyunsaturated fatty acids (500 mg for men, 400 mg for women), DHA min 0.05 % of the daily energy supply (120 mg for men and 100 mg for women; 0.1 % of the daily energy supply for aged (100mg/day)
Netherlands (Health Council)	2001	-	200 mg/day long-chain omega-3.

From ISSFAL (2014) and AFSSA (2003); where: DE= daily energy; EPA= acid eicosapentaenoic; DHA= acid docosahexaenoic.

Among the investigated animal products for omega-3 PUFA enrichment, the egg was the most studied, realistic and successful way of incorporating omega-3 PUFA into the human diet. This is due to the fatty acids content of the egg (>4 g) and large fluctuation of lipids and lipoproteins within the hen's organism, which cause swift changes within the yolk lipids (Cherian, 2009; Alagawany et al., 2019; Pérez-Palacios et al., 2019;). As the eggs are a conventional food, which contains nutrients with basic roles beyond

nutrition, one must also consider promoting them as functional foods (Herron and Fernandez, 2004). This calls for clinical studies which to provide the scientific evidences whether the product should be marketed with health claims (CE 1924/2006).

Clinical studies on the effect of consuming PUFA enriched eggs

Human nutrition in the developed countries is characterized by an excessive consumption of foods rich in proteins, cholesterol, saturated fatty acids (SFA), but with a low content of omega-3 polyunsaturated fatty acids and antioxidants. This unbalanced ratio of chemical compounds in foods has negative effects on the consumers health, leading to obesity, different types of diseases, such as chronic or cardiovascular (Mokdad et al., 2003). Many of these health issues are directly linked to human diets (Decker and Park, 2010). In each year, in the USA, the medical costs of the chronic diseases, including the cardiovascular diseases, diabetes, cancer, osteoporosis, are major, obesity exceeding 400 billion USD (DHHS, 2010). According to Decker and Park, (2010), this means that many health challenges might be alleviated by ensuring a healthier diet as preventive health strategy. However, this is easier said than done. Improving food quality must be done without changing dramatically the needs of consumers, such as food quality, ease of access and the expenditure (Decker and Park, 2010). The same authors have shown that the functional foods must be efficient and tasty, convenient as price, so that the consumers purchase them on a regular basis.

Because of the limited supply of omega-3 PUFA to the human diets, various strategies to obtain animals foods enriched in essential fatty acids have been attempted (Cherian, 2002; Kang, 2008). Therefore, the omega-3 long-chain polyunsaturated fatty acids (PUFA) are a category of essential ingredients. These fatty acids are acknowledged as essential constituents for a normal growth and development both in humans and animals (Zhang et al., 2010). Based on the convincing evidences of health support and benefits of the consumption of omega-3 PUFA, various organisations recommend a daily dietary supply of 1.4-2.5 g total PUFA omega-3, with EPA and DHA in the range of 140 la 600 mg/day to reduce the risk of chronic diseases and to improve the health state (Molendi-Coster et al., 2011). The daily supply of PUFA varies significantly in different countries: in the USA and Australia, the average supply of PUFA is of 140 and 190 mg/day, respectively for adults, while the Japanese consume about 1600 mg/day due to their dietary fish-eating habits (Meyer et al., 2003). Meyer et al., (2003) reported that the animal foods represent 43% of the supply of dietary PUFA. However, most western diets contain just about 50% of the recommended intake of the essential alpha-linolenic acid (ALA). Table 2 shows several clinical studies conducted on voluntaries, which evaluated the effects of consuming omega-3 PUFA-enriched eggs on human health.

Table 2. Results of the clinical studies that evaluated the effects of consuming omega-3 PUFA-enriched eggs on human health

Product type	Experimental design	Main results	References
Eggs	Twenty healthy lacto-ovo - vegetarian volunteers (men and women aged 21-90) were assigned randomly to receive one of the three food supplements: eggs enriched in omega-3 PUFA using flaxseeds (6 eggs/week), nuts (28.4 g, 6x/ week) or standard eggs, 6/ week (control) for 8 weeks, each.	The dietetic conformity was observed by the foreseen increase of the alpha linolenic acid (ALA) in erythrocyte membrane, following the dietary nuts and of the docosahexaenoic acid (DHA) following the diet with eggs enriched in omega-3 PUFA. The nut diet decreased the serum triacylglycerol, the total cholesterol and Apo B ($p < 0,05$) compared to the standard eggs. For the lacto-ovo-vegetarian consumers, the eggs enriched in omega-3 PUFA are a source necessary to increase the DHA level of the membranes.	Burns-Whitmore et al., 2014
Eggs	The effect of consuming standard eggs and eggs enriched in omega-3 PUFA (using rapeseed oil) on the lipoprotein markers of glucose and inflammation. Nineteen healthy volunteers consumed additionally for one month, either one standard eggs, or an egg enriched in omega-3. The volunteers were healthy people aged 45+, with no medication that could influence the inflammatory parameters or the blood lipids.	The consumption of eggs enriched in omega-3 PUFA increased significantly ApoA1 (apolipoprotein A1), decreased significantly ApoB / ApoA1 (apolipoprotein B/ apolipoprotein A1) ratio and the plasm glucose, while increasing significantly the alpha-linoleic acid C18: 3 (omega-3).	Öhman et al., 2008

Eggs	A clinical study was conducted at C.I. Parhon Institute (Bucharest) to evaluate the effect of consuming eggs enriched in omega-3 PUFA on the human health (blood biochemical profile). The study was conducted on 62 volunteers, clinically healthy people assigned to 2 groups: omega 3 (31 people), who consumed eggs enriched in omega-3 PUFA (flaxseeds), supplied by INCDBNA-Balotesti and control (31 people) who consumed conventional eggs. Each person ate 6 eggs per week, for 6 weeks.	The consumption of eggs enriched in omega-3 PUFA, with 2.65 g ALA /100 g (5 times more than the conventional eggs), reduced significantly the plasm triglycerides and fibrinogen. This showed that the eggs enriched in ALA are functional foods.	Manda et al., 2008
Eggs	The effect of consuming eggs with high concentration of docosahexaenoic acid (DHA) on the serum blood lipids, omega-3 polyunsaturated fatty acids and serum phospholipids was investigated in patients with hypercholesterolemia (men, aged 35 to 78). The eggs were enriched in fatty acids using fish oil (menhaden) and flaxseeds. Fifteen subjects were assigned randomly to two groups of treatment and consumed rather 2 control eggs, or two eggs enriched in DHA, at breakfast, for 21 consecutive days, using a double-crossing design.	The enriched eggs supplied 217 mg DHA and 629 mg de total omega-3 PUFA per day. Serum cholesterol remained unchanged and no significant changes were noticed in the lipid level. The enriched eggs increased significantly (23%) the eicosapentaenoic acid (EPA) and DHA level in the serum phospholipids, which can be associated to a lower risk of fatal ischaemic disease.	Gillingham et al., 2005

Eggs	The effect of eggs enriched in omega-3 fatty acids on the maternal milk and blood plasm fatty acids was assessed in eight nursing women. The eggs enriched in polyunsaturated fatty acids (omega-3 PUFA) were obtained using flaxseed oil.	The consumption of two enriched eggs/day, as part of the normal diet, for 6 weeks, increased significantly ($p<0.05$), by 3.6%, the total omega-3 fatty acids compared to 1.9% for the maternal milk and decreased omega-6/omega-3 ratio (6.7 vs 3.0). PUFA omega-3 (C20 and C22) were 1.2% compared to 0.4% in the maternal milk ($p<0.05$). The consumption of eggs enriched in omega-3 did not change the content of C20:4 omega-6 fatty acids in the maternal milk ($p>0.05$). The average value of the total cholesterol and of the plasm triglycerides remained unchanged in the end of the 6-wk experiment. The analysis of maternal milk lipids revealed the predominance ($p <0.05$) of omega-6 and omega-3 PUFA in the milk phospholipids over the triglycerides. The study proved that the omega-3 PUFA level of the maternal milk can be increased without changing the level of plasm cholesterol or triglycerides, when the nursing women eat eggs enriched in omega-3 PUFA.	Cherian et al., 1996

Eggs	The purpose of the study was to monitor the serum lipid profile and thrombocytes in the subjects who consumed eggs enriched in alpha-linolenic acid (ALA) and other omega-3 fatty acids. The eggs were enriched using ground flaxseeds in layer diets. The subjects of this study were five male, healthy volunteers, with the average age of 45.8 ±3.0 years, and an average bodyweight of 80.4 ± 3.0 kg. the subjects were instructed to give up the consumption of eggs (other than the experimental eggs), canola oil, fish, alcohol, aspirin and all the other medicines throughout the 8-wk experimental period, and to refrain from a rigorous physical training.	The consumption of eggs enriched in ALA, for 1 or 2 weeks, determined a significant ($p < 0.005$) decrease, by 35%, of the serum triglycerides after one week, with no change in the total cholesterol of high-density lipoproteins (DHL). A significant (about 60%) increase was also noticed for the docosahexaenoic acid (DHA, 22: 6 omega-3), of the platelet phospholipid in the subjects who consumed eggs enriched in PUFA omega-3. As the serum triglycerides level is known as predictor of the coronary disease, and DHA is physiologically essential for the brain and retina, and as factor alleviating the platelet reactivity,	Ferrier et al., 1992
Eggs	Forty-four volunteers (men and women) consumed, on a daily basis, 2 eggs, for 9 weeks. In the first two weeks, all volunteers received eggs from layers fed on a commercial diet. During the subsequent seven weeks, they received experimental eggs enriched by adding 7% cod-liver oil, canola oil or flaxseeds to layer diets.	The serum cholesterol did not change throughout the 9-wk trial. The high-density lipoproteins decreased, and the low-density lipoproteins increased, but the triglycerides level did not change. Serum concentration of PUFA omega-3 lipids showed increased values at the end of the 9-wk period, in the subjects treated with eggs from the layers fed cod-fish oil and canola oil.	Farrell and Gibson, 1991

Eggs & meat	A clinical study was conducted on 29 volunteers of both sexes (17 women and 12 men, with an average age of 32 ± 5.6 years). The experimental group consumed 250 g broiler meat (≈ 228mg omega-3) and 3 eggs (≈1590mg omega-3) each week. The control group consumed the same amount of broiler meat and eggs, but not supplemented, for 14 weeks. The foods were enriched in omega-3 by feeding the poultry 0.5-0.8 g/day cod-liver oil. The subjects consumed the poultry products prepared in different ways, without using fat (boiled, grilled, etc.).	The results showed that the consumption of enriched poultry products in omega-3 fatty acids led to the improvement of the health of the people in the study. This was highlighted by the increase of HDL concentration and decreased atherogenic rate related to cardiovascular disease.	Arias-Rico et al., 2018
Eggs & meat	For 6 months was performed a study on 161 healthy participants, divided into two groups to consume at least 3 servings / week of chicken meat and eggs enriched in omega-3-PUFA fatty acids.	The results of the study showed that the consumption of eggs and meat enriched in PUFA omega-3 for 6 months led to an increase in plasma DHA level. At the same time, in people who consumed chicken meat there was an increase in plasma EPA level. Regular consumption of these foods enriched in omega-3-PUFA has led to an increase in plasma levels of omega-3-PUFA and a halving in the number of subjects with a high-risk omega-3 index.	Stanton et al., 2018

DISCUSSION

Presently, consumers are increasingly concerned about their diet and about the health benefits of the food. There are several underlying factors for consumer interest to understand and prefer specific ingredients (Aschemann-Witzel et al., 2019). These include motivations for a healthy diet; genetic predisposition to diseases, sensitivities or allergies; concern for the environment or sustainability of the impact of the food chain practices; preference for local foods or risk avoidance (Sautron et al., 2015). Given these considerations, the trend is to consume foods that are processes as little as possible, and which do not contain ingredients perceived as negative, such as allergens or synthetic additives (Aschemann-Witzel et al., 2019). An important factor that generally influences consumer perception of the food ingredients and synthetic additives is the perception of the risk (Bearth et al., 2014) and the experience of the food scandals concerning such additives (Chen, 2017). In agreement with the general trend of the consumers to prefer "naturalness" (Román et al., 2017), the research has shown that the natural feed additives are preferred to the detriment of the synthetic ones (Carocho et al, 2015). Avoiding synthetic ingredients can be understood, as the consumers are sceptical about the new food processing technologies (Hung et al., 2016). Such focusing of the consumer on avoidance was called negative prejudice because consumer attitude is influenced by his/her personal values and affective evaluation (Aschemann-Witzel et al., 2019).

There is a pressure in many sectors – food industry, research, medical professionals, regulating authorities – to develop products which to answer this demand (Prakash et al., 2017). Recently, sciences proposed to improve consumer health through the so-called functional foods, which use products of vegetal origin and who have the property of reducing the risk of diseases due to diets deficient in nutrients, high in saturated animal fats and refined products (Fernandes et al., 2019; Quintin et al., 2019). The market for innovative functional foods and food supplements from natural compounds increases. Consequently, the evaluation of the potential sources that can be used to this purpose and the study of the new extraction technologies are of major importance.

The acceptance of the functional foods and their ingredients by the consumers is the key factor for success (Bornkessel et al., 2011). Zhang et al., (2010) studied the global state of consumer acceptance and the market for functional foods.

One must consider, first, the different technological challenges. This is a major challenge for the food companies with little or no experience in clinical testing. Furthermore, the taste has a major impact on consumer choice of foods (Verbeke, 2006). Food fortification with specific ingredients to add value can influence the sensorial characteristics of the product.

Second, the risks of adopting and spreading the new products generally affect the launching of products for all the segment of the industry and for all categories of products. There also are specialised market challenges for the functional food segment. As many food ingredients currently become basic products, there may appear difficulties in communicating the additional value (Siro et al., 2008).

Third, the intellectual rights challenges include, for instance, the patenting behaviour of the companies, which differ between the different industrial segments and countries due to the individual legal framework (Siro et al., 2008). Fourth, within the legal challenge, the authorization of a health claim is very important, being strictly regulated particularly in Europe (Siro et al., 2008). The regulation for health claims (CE no. 1924/2006) manages the labelling foods with additional health benefits, which leads to regulating barriers for innovation and trading of the new products in the functional food sector (Herath et al., 2008). As consumers are rather open to a wide range of formulations of the health claims (Van Trijp and Van der Lans 2007), the opportunity of a general health claim might encourage the companies towards innovation (Herath et al., 2008). Overall, the described challenges show interconnected relations, which involve a high level of complexity, such as the formulation of the health claim, which must observe the legal requirements from the individual countries and, most important, it must be understood by the consumers (Siro et al., 2008).

Therefore, besides the aspects of the intellectual rights, the regulatory and market technological challenges, the knowledge and acceptance of the functional ingredients by the consumers, play a very important role in the market success of the new functional foods (Verbeke, 2005). Bornkessel et al., (2011) classified three major areas of focus for consumer acceptance of the functional foods: acceptance by the consumers of functional foods in general; consumer acceptance focused on health aspects and consumer acceptance focused on unique ingredients (Table 3).

Therefore, there is a vast literature in consumer acceptance of the functional foods (Siro et al., 2008). It is generally dominated by aspects arguing the reasons for choosing functional foods and the socio-demographic differences (Urala and Lähteenmäki, 2003; Verbeke, 2005). According to Bornkessel et al., (2011), the perception of consumers regarding the acceptance of these new foods on the market is a determining factor in the functional food industry. Consumers choice is based on three factors: their preferences regarding a certain type of products, the characteristics that they must have and the circumstances of purchase.

Table 3. Studies on consumer acceptance of the functional foods (Bornkessel et al., 2011)

Research objectives	Study	Title	Major results
Consumer acceptance of the functional foods in general	(Van Kleef et al., 2002)	The development of functional foods consumer - oriented: how well does the functional discipline reflect the "consumer voice"?	→ Examines both consumer and life science needs
	(Urala and Lähteenmäki 2003)	The consumers reasons for choosing functional foods.	→ Functional foods safety: multidimensional factor of choice → Taste: key-issue for most products
	(Verbeke, 2005)	Consumer acceptance of functional foods: socio-demographic, cognitive and attitudinal determinants	→ Differences in the public perception between EU and USA consumers
	(Krystallis et al., 2008)	Motivations and cognitive structures of consumers in the purchase of functional foods	→ Young adults' interest: attributes of enhancing energy and added vitamins and minerals → Early interest of the middle age: disease prevention attributes
	(Sparke and Menrad 2009)	Segmenting consumers in functional food products to develop new products	1. Four reasons to buy functional foods 2. Three reasons to reject them 3. Eight different factors

Consumer acceptance of functional foods focused on health aspects	(Roininen and Tuorila 1999)	Health and taste attitudes in predicting frequency use and choosing between less healthy and healthier snacks	Major choice reasons: health, calories content, good taste, instant desire and price
	(Bech-Larsen and Grunert 2003)	Perceived safety of functional foods - a conjugate study of danish, finnish and american consumer perceptions of functional foods	→ Health claims can enhance consumer perception on the role of functional foods for health
	(Verbeke, 2006)	Functional foods: Consumer availability to compromise health taste?	→ Primary role of conviction for health
	(Drescher et al., 2009)	Consumer demand for healthy eating, given diversity - an economic approach to german citizens	→ Healthy dietary diversity is significantly related to 1. Household characteristics, such as the incomes 2. Consumer characteristics, such as the age 3. Knowledge, variable attitudes and behaviours due to education, attendance of health and sport training courses
	(Verbeke et al., 2009)	Consumer call for nutrition and health claims	→ In general, the health claims exceed the nutritional performance, and both exceed the disease risk reduction performance.

Consumer acceptance of functional foods focused on functional ingredients	(Ares et al., 2008)	Does information on the source of functional ingredients influence consumers' perception of functional dairy desserts?	→ Stating the ingredients at generic level, because the information on the source of functional ingredients reduced significantly the expected benefits, perceived health and the desire to purchase
	(Lampila et al., 2009)	Consumers' attitude towards increased flavonoid content in fruits	→ Flavonoids are perceived positively → Will consume products containing flavonoids: need for information
	(Krutulyte et al., 2011)	Appropriate perception of different combinations of functional ingredients and their effect on purchasing intent	→ Strong predictor of the purchasing intention: perceived matching of the combination's carrier-ingredient-combinations

Consumer characteristics concern the personal health state and awareness of the additional benefits of some ingredients (Kroeber-Riel et al., 2009).

For the buying circumstances, an important have both the recommendation of the product by health professionals, and the familiarity with a brand (Bornkessel et al., 2011).

Brand management is very relevant (Schramm et al., 2005), because familiarity with a brand implies trust (Roe and Sheldon 2007). However, generally, the Europeans are more critical about new products and technologies than the American consumers (Bech-Larsen and Grunert, 2003; Lusk et al., 2004; Lusk and Rozan, 2005).

Product characteristics include the reason to believe a statement regarding the health benefit (Bornkessel et al., 2011), the quality attributes, naturalness and efficacy. Generally, the potential of the food and of its functional ingredients is, among other, a strong predictor of the intention to buy (Krutulyte et al., 2011).

Egg market

Understanding the factors that influence consumer behaviour within the functional food purchasing process is a problem yet to be solved. An unexplored problem regards the relation between the consumption of functional foods and dietary values. Food value is a potentially important factor for consumer behaviour in a wide range of situations, including the buying decisions (Pappalardo and Lusk, 2016). The values of food, such as safety or origin of the product, are methods to identify constant consumer preferences (McCluskey et al., 2005; Low et al., 2015). Buying a specific product or product attribute is conceptualized as a way of attaining the desired destination, and this might explain why consumers prefer a particular product over another (Lusk and Briggeman, 2009; Lusk, 2011). Table 4 shows the factors considered by consumers when selecting the ingredient for a functional food.

Table 4. Factors considered when selecting the ingredient for a functional food (Decker and Park, 2010)

- To whom is the bioactive compound addressed?
- Is there evidence for the effectiveness of the bioactive compound on human health?
- What is the availability of the bioactive compound?
- What are the factors that affect the availability of the bioactive compound?
- What are the effects of the bioactive compound on the quality of the product in which it is incorporated?
- What is the legislation regarding the use of the bioactive compound in foods?
- Are there any clinical studies on the beneficial effects of the bioactive compound for the consumer?

There are a few studies that have shown the connection between lifestyle and consumption of functional foods, in order to improve the health status of consumers. It should be mentioned, however, that a healthy lifestyle is based on certain socio-economic variables, such as age and education. Awareness of the importance of a healthy lifestyle can lead consumers to choose functional foods, to the detriment of unhealthy foods (Moro et al., 2015; Pappalardo et al., 2016). However, even for the functional foods, neophobia can adversely affect the consumption of these products (Siegrist et al., 2015; Stratton et al., 2015).

Consumers reported difficulties in selecting healthy foods in supermarkets (Botelho et al., 2019) because of the environment indexes (variability and brands of the different products, location at eye-level or

sides of the alley) which favour the purchase of unhealthy foods (Cohen & Babey, 2012; O'Brien et al., 2015). Furthermore, consumers want to buy healthy food, but their intention can be cancelled by the moments of attempt (van Kleef et al., 2015), that can be generated by the previously mentioned elements of marketing.

The supply of information about the packed processed food, through the nutritional label, seems to have potential in supporting the conscious choice of foods (Cowburn and Stockley, 2005). After the nutritional facts labels became compulsory for all packed foods (Commission Regulation (EC) 1169/2011), the aware choice of foods became synonymous with the health policy supporting the consumers to make healthy choices. However, the multitude of nutrition and health claims on the label of foods in Europe produced worry because of the lack of a harmonious fundamentation of these claims, and of their potential to mislead the consumer (Nutrition and Health Claims. Evaluation of A) Regulation (EC) no 1924/2006). (Hodgkins et al., 2019). An estimation of global demand for animal protein foods in 2015-2035 ranks the meat and poultry products first, followed by pork and beef products (Mulder, 2017; OECD/FAO, 2017).

Annunziata and Vecchio., (2011) conducted a study to identify the underlying factors for the choice of functional foods by the consumers. The first, and most important, criterion is consumer perception of the health. The other criteria include the safety of, and trust in functional foods, and how much they believe the scientific data about the potential effects of the product. Another factor is the satisfaction. The study showed that consumers did not perceive the functional foods as less tasty than the conventional foods. This is an interesting result, because other studies on the consumption of functional foods showed that taste is one of the main conditions for the acceptance of these products (Tuorila and Cardello, 2002; Verbeke, 2006). Consumers' preferences regarding the type of eggs they consume showed a high percentage for free range eggs, followed by barn / cage free eggs, organic eggs, and lastly caged eggs (Marketing Clinic for EMFA, 2015).

There are two reasons why producers invest in the innovation of products: technical and commercial. Among the technical reasons, nutrition is the natural way to obtain functional animal foods. The feeding strategies for farm animals are preferred because the live animals can distribute efficiently the nutrients to the tissues, while the innovative feeding solutions provide the certainty of obtaining products the supply tolerable amounts of nutrients. Metabolism plays an important role in the transfer of the dietary ingredients towards the target products.

Because of the nutritive profile, variety and low cost as food, the eggs are one of the most popular foods worldwide (Alagawany et al., 2018). In the classification of the highest consumers of eggs (per person and year), Mexico

ranks first (352 eggs), followed by Japan (329 eggs), China (254.8 eggs), USA (252.9 eggs) and Europa (215 eggs) in average (International Egg Commission – Annual Review, 2015).

The consolidation of the internal markets increases competition. Thus, the producers also sought different markets than the classical ones. The functional foods are of interest for the food industry because they are a way the producers can add value to their products.

Another commercial reason why producers invest in the innovation of products is the development of modern trade and of the marketing, which compels the producers to segment the markets, identifying products for each category of clients. This takes into consideration consumer orientation towards premium products, as the purchasing power increases worldwide. The market for eggs had no premium products until the development of innovative products in this field.

The world market for products enriched in omega-3 includes the functional foods, the food supplements, infant nutrition products, pet foods and pharmaceuticals. The market relies mainly on retailers, drugstores, internet sales and other sales points. The world market for omega-3 products is highly segmented. Reckitt Benckiser Group PLC, Nestle SA, Sanofi, Herbalife and Unilever are some of the main market players. The small companies operate regionally and nationally and hold an important part of the market for omega-3 products. Most companies operating at the regional level are private, so that their visibility on the market is smaller than that of the important companies from the surveyed market. Global omega-3 products market is estimated to grow in 2019-2024 with an annual compound growth rate of 7.4% reaching approximately 56.16 billion USD (https://www.mordorintelligence.com/industry-reports/omega-3-product-market).

The world market for functional foods expanded dramatically during the past decade and it is estimated to grow at a constant rate, reaching 255.10 billion USD by 2024 (Grand View Research, Inc., 2016). This growth is determined not just by the food industry innovations, but also by the change of consumer lifestyle and by the increasing consumer health awareness (Barauskaite et al., 2018). The researchers found out that the functional foods are one of the most interesting research and innovations areas in the food industry (Bigliardi and Galati, 2013).

It is now rather difficult to estimate the market volume of these products because of their different definitions (Tripathi et al., 2019). The market for functional foods generated a global incomes of about 299.32 billion USD by the end of 2017, and it is estimated to reach 441.56 billion USD by 2022 (https://www.statista.com/statistics/252803/global-functional-food-sales/). The most significant and dynamic market is the USA market, with over 50% of the world market, with functional foods with specific health

claims (Hufnagel, 2000). The high number of old people (80+) in the countries with high incomes (Japan, for instance) can cause the decline of the world development, particularly the world production of functional foods and other facilities (Bongaarts, 2016). The food technologies and industries try to develop new functional foods and to modify the regulatory framework for this sector (Tripathi et al., 2019).

The eggs are rich in high quality proteins that contain all the essential amino acids and other valuable ingredients, such as vitamins and minerals (vitamin B12, riboflavin, vitamin B6, folic acid, vitamin D, vitamin A, selenium, iron, iodine, zinc, choline). Furthermore, the eggs and their constituents have important techno-functional properties that make the eggs a functional ingredient for many foods (Huopalathi et al., 2007). Although they have a rich nutritive profile, the eggs have been challenged by the health agencies and nutrition experts due to their cholesterol (about 200-300 mg / 100 g) and saturated fats (about 3 g / 100 g) in their composition (Li et al., 2013). Hence, consumers were warned on the high consumption of eggs and the potential association of the cholesterol with the cardiovascular diseases (Alagawany et al., 2018). Nevertheless, subsequent research showed that, compared to the saturated and total fatty acids, the specific type of egg cholesterol has a limited impact on its blood level and on the cardiovascular diseases. However, the increasing phobia, of the high cholesterol level, decreased the overall consumption (Djousse and Gaziano, 2008; Eilat-Adar et al., 2013).

Presently, there are retail market for functional eggs, marketing eggs enriched in omega-3 PUFA or low-cholesterol eggs (Fraeye et al., 2012; Elkin et al., 2015). The production of eggs enriched in omega-3 PUFA is a fast-growing niche market.

This is because consumers realized that the health benefits of a diet rich in omega-3 PUFA are greater than the higher cost of these eggs. This trend is forecast to grow, providing not just an excellent health-protection way for the consumers, but also a new way for the producers to increase competitiveness and improve their image in the field of healthy food (Mavromichalis, 2011).

The omega-3 polyunsaturated fatty acids composition of eggs can be enriched using certain sources rich in omega-3 PUFA in hen's feed or during processing (Javed et al., 2019). There is a limited range of sources with adequate profile and price to do this: fish oil and fishmeal, rapeseeds and rapeseeds oil, flaxseed and flaxseeds oil, soybean oil, palm oil (Alagawany et al., 2019). Like all monogastric animals, the birds store lipids in their body, therefore in eggs too, without changing the form which they ingested through the feed (Réhault-Godbert et al., 2019).

The omega-3 eggs are enriched in fatty acids such as alpha-linolenic (ALA), eicosapentaenoic (EPA) and docosahexaenoic (DHA). Consumers

consider that a heathy diet with highly nutritive foods, natural/organic foods, with any food that has additional benefits, is one of the best ways to live a healthy lifestyle. This specific interest of the consumers has a positive impact for the eggs enriched in omega-3 PUFA (El-Samee et al., 2019; Réhault-Godbert et al., 2019).

Generally, these eggs are produced by modifying layer diets, but too little attention has been given to the development of designer eggs by technological methods (Fraeye et al., 2012; Elkin et al., 2015). Designer eggs can supply more than 600 mg omega-3 PUFA and 6 mg tocopherol. There also are other beneficial health effects due to the balanced omega-6 / omega-3 PUFA (1:1) and PUFA/SFA (1:1) ratios. Therefore, the functional egg can be an alternative to conventional foods for the worldwide consumers (Raghuveer and Tandon, 2009; Miranda et al., 2015). The designer eggs are available on the markets worldwide under different names, such as Columbus eggs, Plus eggs, enriched in docosahexaenoic acid (DHA), omega-3 eggs, Bio-omega-3 eggs, Greek eggs, children eggs, Achyrona omega eggs, EUROU (Agricola Bucharest, Romania) (Surai and Sparks, 2001). The egg industry responded positively to the search of new methods which to alleviate the adverse perceptions of the consumers regarding the problems concerning the eggs and egg products, particularly the cholesterol level (Alagawany et al., 2018).

The egg market in the European Union

The European Union (EU) is an important producer, exporter and consumer of eggs. Both the demand and consumption of eggs increased steadily in the EU being, in average, of 14.4 kg eggs per inhabitant, in 2009, 6.6% more than in 2000 (Pirvutoiu and Popescu, 2012). At the same time, egg consumption in the EU is higher compared to the world average of about 10 kg/capita. In 2009, the EU egg balance was positive, with 149 thousand tons of exports, 4.96 times more than the imports, compared to 2000, with 201 thousand tons of exports and 27 thousand tons of imports (Van Horne, 2010). The higher demand for eggs leads to a permanent increase of the egg production, so than in 2009, the EU produced 6,980 thousand tons of eggs, 22.45% more than in 2000 (5,700 thousand tons). The egg market shows several trends for the future, such as the increase of egg consumption, the constant advancement of the small producers, a slight increase of the egg trade, mainly in the countries with low costs (Pirvutoiu and Popescu, 2012).

The trends that need attention concern layer rearing for a good production of eggs: a) provision of layer welfare by improving the rearing conditions, replacement of the old digestibility cages (550 cm^2) with new cages (750 cm^2), but at the expense of 8% increase of the egg production cost; b) longer shelf life of the eggs and lower transportation costs; c) development of animal and environmental friendly poultry rearing systems;

d) ensuring food safety, to produce and market high quality eggs accompanied by all necessary information of egg origin, quality, farming system, shelf life, producer brand and trade mark (Pirvutoiu and Popescu, 2012).

In Romania, there are many technological systems for poultry production. The laying hens are reared in rearing halls, on the floor, free range, ecological systems, and 17% are reared in enriched cages. There is an important connection between the farming system and egg quality, as the organic and ecologic farming systems produce eggs of higher quality. The industrial farming systems feed the layers with compound feeds, whose formulation includes cereal grains (wheat, barley, corn), sunflower cakes proteins, fats such as soybean oil, vitamins and minerals, according to EU legislation (Pirvutoiu and Popescu, 2012). In 2007, in Romania there were 3,228,920 poultry farms, 3.69% less than in 2002, when there were 3,352,542 (National Institute of Statistics, 2010). Among these, most are small producers; only about 150-200 are industrial egg producing systems, of these, only 35-55 might be considered as the biggest egg producers, holding 85% of the total egg production (Van, 2011).

Pirvutoiu and Popescu, (2012) conducted a study to evaluate the dynamics of the Romanian egg market in 1990-2009 (INS data), aiming to determine its trend. They monitored the following aspects: number of producing farms, modern household poultry rearing technologies, stock of live layers, production and distribution of eggs, consumption of eggs, price and commerce with eggs. In 2009, the production of eggs amounted to 6,211 million items, of which 95.73% hen eggs, 25% less than in 1990, because of the lower stock of household layers and of the average production of eggs. Therefore, in 2009, the production was of only 289 eggs per capita, compared to 347 eggs in 1990. Consequently, the demand/offer ratio was imbalanced and just 50% of the domestic production covered market demand. The egg producers will have to give more attention to the increase and diversification of the production, to egg quality, to egg packing and distribution and to the export possibilities.

The market segment for omega-3 eggs is segmented based on the size, colour, final destination and distribution channel. The omega-3 eggs are classified by size (large and small) and by colour (white and brown), for retail trade and for commercial use (food industry, hotels, restaurants, etc.). The omega-3 eggs are classified by region in seven world regions, North America, Latin America, Western Europe, Eastern Europe, Asia-Pacific, Japan, Middle East and Africa. Currently, the highest demand for omega-3 eggs is in USA, Germany, France, Great Britain and other Western Europe countries. The demand for omega-3 eggs is expected to increase because of the shift towards a healthy lifestyle. Eggland's Best, LLC, CMC Food Inc., Wilcox Farms, Cal-Maine Foods, Inc., Horizon Organic, Organic Valley,

Burnbrae Farms Limited, Phils Fresh Eggs, Inc., Golden Irish, Rose Acre Farms, are among the largest omega-3 eggs producers (https://www.transparencymarketresearch.com/omega-3-eggs-market.html). In Romania, S.C. Agricola Bucharest produces eggs enriched in ALA, while S.C. Avicola Lumina produces eggs (INIMOASE) enriched in PUFA.

Conclusions

The quality of human diets can be improved by the consumption of functional foods, with no modification of the dietary habits, and an affordable price. The promotion of functional foods must be done following standard clinical studies. The omega-3 eggs play an important role in the human diet because of their specific health benefits: modulation of the immune functions of the organism, treatment of specific diseases and health disorders, such as cancer and diabetes; blood pressure regulation, decrease g the blood cholesterol; alleviation of the cardiac disorders and allergies. The clinical studies showed that the functional foods can be a useful vehicle to increase the consumption of important nutrients for human health. Among the most important achievements is the improvement of the blood biochemical profile and increase of polyunsaturated fatty acids concentrations, such as the eicosapentaenoic acid (EPA) and the docosahexaenoic acid (DHA), associated to a lower risk of cardiac diseases and prevention of myocardia infarct.

Consumer perception of omega-3 eggs relies on the motivation for a healthy diet and life, on the background of sound education for healthy dietary habits, of the preference for natural food additives, rather than for synthetic ones.

The pressure created by the increasing demand for healthy foods led to the necessity to identify new alternative solutions which to respond consumer preferences. The food industry innovations of the recent years refer mainly to new scientific and technical approaches for the production, processing and introduction of new foods. Thus, the global market for functional foods expanded dramatically during the past decade and it is estimated to grown steadily, reaching 255.10 billion USD by 2024. This trend will not only provide an excellent manner for the customers to protect their health but will also be a new way out for the producers to improve their competitiveness and image in the sector of healthy foods.

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