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From designing diets for animals to designing food of animal origin – overview

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From designing diets for animals to designing food of animal origin – overview

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Abstract. In recent times, food is not only observed from the point of view of the required intake for growth, development and regeneration of the body, but also has a leading role in the quality of human life. Therefore, the diet focuses on optimizing the daily intake of both nutrients and non-nutritive ingredients of food, all in order to preserve health and, above all, reduce the risk of chronic non-communicable diseases. Functional food can be considered food that has been scientifically proven to have a positive effect on certain body functions (in addition to the usual nutritional value) that contribute to human health and reduce the risk of disease. At the same time, it is important that the food has a standard form and that the positive effect on health is manifested by consuming the usual amount of food. The functionality of food is achieved by the presence in it of bioactive components (one or more) which have been scientifically proven to have positive effects on human health in the quantities in which they are present in food. The nutritional value of foods of animal origin depends on many factors, but certainly animal diet has the greatest impact. In human nutrition the so-called designed products of animal origin (meat, milk, eggs) are used, which are due to the specific animal diets enriched with n-3 fatty acids, vitamins, carotenoids or trace elements. Today, there are nutritional strategies by which we can access functional foods for the purpose of health promotion.

1. Functional food

The beginning of the 21st century still presents food science with new challenges. Food is no longer viewed only from the aspect of the need for adequate intake, primarily for the purpose of proper growth, development and regeneration of the body. Food today has one of the leading roles in the quality of human life. For that reason, the previous so-called balanced diets (a term used in human medicine) have grown into the level of optimally balanced diets (also a term used in human medicine), which are focused on optimizing the daily intake of both nutrients and non-nutritive food components in order to promote health and reduce the risk of occurrence of chronic non-communicable diseases [1].

The term “functional food” was first used in Japan in the mid-1980s, and referred to food that, in addition to being nutritious, also contains ingredients useful for supporting certain bodily functions. Nutrition science is no longer just about ensuring proper nutrition and avoiding malnutrition and nutrient deficiencies, but also about discovering biologically active substances in food that have the ability to improve health and reduce the risk of disease [2,3]. In 1988, the Japanese government set up a project to investigate potential positive food functions in order to reduce treatment costs. The category of foods with potential positive health effects, which is the result of these studies, is known as “foods for specific health needs” (foods for specific health use - FOSHU food). This category of food appeared in 1991 and represents food that is expected to exhibit a certain, beneficial health effect, as a result of the presence of specific components.

Functional food is not easy to cover with a single definition, since this food is primarily a concept, not a well-defined group of food products. There are several working definitions of functional foods. In 1998, the European Union, in coordination with the International Life Science Institute Europe (ILSI Europe), adopted the following definition "a food can be considered functional if it has been satisfactorily shown to have a beneficial effect on one or more functions of the organism, outside the usual nutritional effects and in a way that is important for general health or to reduce the risk of disease" [2,4,5].

Functional foods, due to their specific and modified composition in relation to classic foods of the same type, have positive effects on human health and are most often used to preserve optimal gastrointestinal functions, raise levels of antioxidant defenses, reduce risk factors involved in the etiology of cardiovascular disease and cancer. The listed effects of functional food often show due to the presence of one or more bioactive components in their composition, which scientific research has determined that, in the quantities in which they are present in food, have positive effects on certain physiological or biochemical processes in the body. The biologically active compound can be a macronutrient (resistant starch or n-3 fatty acid), a micronutrient (vitamin or mineral), or a non-essential food ingredient that has a certain energy value (oligosaccharides, conjugated linoleic acid, plant sterol).

A functional ingredient can also be a phytochemical (isoflavones, phytoestrogens) or a living microorganism (probiotics). After consuming a functional food, a biologically active compound is released in the digestive tract, which acts at the site of release (dietary fiber, probiotic) or is resorbed and distributed to target tissues, where it will have a beneficial effect [4,5,7]. In recent years, there has been increasing talk about the application of nanotechnologies in the production of functional food, and its advantages, challenges and possible disadvantages [8].

The development and production of functional food requires a multidisciplinary approach and is a long and complex process [9]. The most common functional ingredients used in the enrichment of foods of animal origin are: selenium, omega-3 fatty acids and vitamin E. These ingredients are attractive primarily because for many years in the development of functional foods they have been used to modify a number of products to preserve heart health and to reduce overweight, since these are the biggest problems of the modern way of life [10].

Recently, there is an increasing trend of excluding pharmaceutical preparations from animal feed, so nutritional solutions are becoming an increasingly important alternative in existing production systems. All this is the reason why the concept of functional food should be built on solid scientific foundations, and at the same time recognized and accepted by both farmers and consumers of food of animal origin (meaning all of us) [4,6,7].

2. Animal nutrition

The science of nutrition is a relatively young science, and its importance lies in the fact that all living beings, plants and animals, including humans, intake food/feed regularly, that is, they bring energy and nutrients into the body, which is the material basis of life. Energy and nutrients ingested by food/feed ensure the development of basic biochemical processes and functions of individual tissues and organs, and thus the organism as a whole. Domesticated animals that intake feed every day do so to meet their needs for life support, growth, reproduction and work, as well as for the production of meat, milk and eggs. Appropriate animal nutrition, i.e. the optimal combination of nutrients, can increase production, but also improve the quality of food obtained for human consumption [11]. The fact that animal nutrition can affect the quality of food of animal origin is very important because the modern way of life of people indicates the need for quality food and prevention of chronic non-communicable diseases. With a proper diet, we can significantly control the oxidative status of the organism, and thus the overall health. The official expert recommendation is that you should take four important antioxidants every day and for life: vitamin C, beta-carotene (a precursor of vitamin A), vitamin E and selenium. For all of them, there is evidence that they have anticancer properties, and that they are important for the prevention of chronic non-communicable diseases [12,13].

3. Selenium

One of the ways to produce functional food, i.e. the "third generation of food with a positive aspect of health" is to enrich food with selenium (meat, eggs, milk), which has been confirmed by numerous studies [4,10,14,15,26]. Selenium is an essential element for humans and animals and as such is necessary in a certain amount in animal feed. Its most important function is that, together with vitamin E, it forms a multicomponent system of protection of biological membranes from oxidative degeneration. Selenium is the active ingredient of the enzyme glutathione peroxidase (GSH-Px) in which about 40% of the total selenium in the body is present. The reaction of free radicals, especially present in tissues with intensive oxygen circulation, causes peroxidation of phospholipids and damage to the structure of membranes, and thus the function of cell membranes. Selenium, together with vitamin E, has a protective role when it comes to heavy metals and some drugs and chemicals. In addition, it has other important functions in the body because it is an integral part of many selenoproteins. The creation of geo-botanical maps of selenium has been carried out in several regions of the world and indicates the existence of numerous selenium-deficient areas. Given this fact and all known functions of selenium in the body, there is a need for the production of selenium-enriched products (meat, eggs). In animal diets, selenium has been present as an essential element for decades in inorganic form in the amount of 0.15-0.30 ppm. Numerous researchers around the world have confirmed that the amount of selenium deposited in tissues depends on the levels and forms of selenium (organic, inorganic) used in the diet, i.e. that using increased amounts of organic selenium (0.5 ppm and more) allows its content in tissues to increase [7,14,15].

Studies [7,16,17] show the results of the influence of different amounts and sources of selenium from animal feed on its content in tissues and organs of poultry, i.e. the possibility of increasing the amount of organic selenium in the blood to achieve higher GSH-Px activity in the blood, but also a larger amount of selenium in muscles and organs, which is important from the aspect of consuming food of animal origin.
One of the experiments [7,14] was organized on a total of 150 one-day-old broilers of Hubbard provenance divided into three groups and the animals were fed complete mixtures for fattening broilers, with standard raw materials and chemical composition. The groups differed only in the amount of added organic form of selenium (selenized yeast) in the feed, namely 0.3, 0.6 and 0.9 ppm. All three groups of broilers also received an increased amount of vitamin E (100 IU) through feed. At the end of the experiment, in addition to better production results (body weight, body weight gain, conversion in the group with 0.6 ppm of added organic selenium) but without statistical significance ($p>0.05$), a significant result of this experiment was the higher ($p <0.01$) content of deposited selenium (in the group with 0.9 ppm vs. 0.3 pp), namely 0.61 mg/kg (breast meat), 0.54 mg/kg (drumstick with thigh), 0.96 mg/kg (liver) and 0.48 mg/kg (heart). The content of vitamin E was significantly higher ($p <0.01$) in the liver (4.49 mg/kg) with supplementation with 0.6 and 0.9 ppm

selenium vs. 0.3 ppm. In addition, in the experimental groups with increased content of selenium and vitamin E, there was significantly ($p <0.01$) less fat in meat, and a more favorable fatty acid composition (atherogenic index) [14].

From the obtained results, it can be concluded that by increasing the content of organic selenium in feed mixtures, the content of selenium in meat and organs also significantly increased ($p <0.01$). Since it is known that the soil of Serbia is poor in selenium, and that the body absorbs it best when it is ingested through meat, milk and eggs, it is certainly necessary to include it in the diets of animals that excrete it in their products [18,19]. Since pork and chicken meat are consumed in large quantities, it is considered to be one of the best ways to get selenium, although there is increasing talk about milk and eggs enriched with this microelement. In countries with developed biotechnologies, products of animal origin have been used for many years, by which this important microelement is introduced into the body in the most natural way.

4. Improving the fatty acid composition of meat

Today, numerous studies in the world refer to the impact of fats on human health and the appearance of chronic mass non-communicable diseases. Fats are of multiple importance to human health, being energy source, carriers of fat-soluble vitamins, participants in important physiological processes in the body and are indispensable in many biological functions, including growth and development of the body. However, few studies can consistently show a link between the intake of fats or certain fatty acids and health, so that in scientific circles, there is no complete consensus on the relationship between fat intake and health, which can be seen from the differences in the recommendations on the intake of fats and fatty acids [20]. The importance of the use of n-3 and n-6 fatty acids and their ratio is especially emphasized (Tables 1 and 2).

Table 1. Ratio of n-6 PUFA to n-3 PUFA in human nutrition

Period-area	**n-6/n-3**
Paleolithic	0.79
Greece prior to 1960	1.00 - 2.00
Current Japan	4.00
Current India, rural	5 - 6.1
Current UK and Northern Europe	15.00
Current US	16.74
Current India, urban	38-50

Source [21]

The human body does not have the ability to synthesize essential fatty acids, namely linoleic acid (LA) and alpha-linolenic acid (ALA). Deficiency of these fatty acids can be the cause of human diseases, so they must be taken with food. By extending the chain, LA and ALA can be converted into components that play the role of hormones and participate in protection against inflammation. As such, essential fatty acids are involved in a number of physiological processes, such as blood clotting, wound healing and protection against inflammation.

Also, the importance of conjugated linoleic acid (CLA) for human health is increasingly being discussed. CLA is a mixture of positional and geometric isomers of C18: 2n-6 linoleic acid (LA). A number of CLA isomers have been isolated, but all physiological effects known so far are related to the two isomers cis-9, trans-11 (c9t11CLA) and trans-10, cis-12 (t10c12CLA) isomer. Most of the studies related to the health effects of CLA have examined the effects on the occurrence of cancer, cardiovascular disease, diabetes, obesity, and on the immune system and lipid metabolism.

Table 2. Fatty acid content in platelet phospholipids and mortality rate from cardiovascular diseases

Parameter	Europe and the US	Japan	Greenlandic Inuit
C20:4, n-6 (%)	26	21	8.3
C20:5, n-3 (%)	0.5	1.6	8.0
n-6/n-3 ratio	50	12	1
CVD mortality (%)	45	12	7

Source [22]; CVD - cardiovascular diseases

In accordance with the previous facts, but also the constant demands of some consumers for food of high quality, food production systems of animal origin try to produce food with as many positive effects on human health as possible. Unsaturated fatty acids are currently a hot topic in the food industry, and therefore, increasing their amount in the food is attracting ever more attention from both the public and the food industry [23].

To make the content and ratio of fatty acids in pig meat more favorable, it can be influenced by the optimal choice of nutrients for pig nutrition. The aim of the study in two experiments [24, 25] on pigs was to examine the effect of commercial flax preparation, i.e. commercial CLA preparation, added to pig feed on the fatty acid composition of pig meat. Since flaxseed has a desirable fatty acid composition, many producers are interested in improving the fatty acid composition of adipose tissue and pig meat by including it in the final fattening diet of pigs [24,25]. The basis of these and similar studies is the fact that the fatty acid composition of human foods reflects the fatty acid composition of tissues - that is, foods of animal origin that we get from animals in intensive breeding.

The aim of one study was to examine the influence of different fat sources (sunflower, flax and soy) in the diet of fattening pigs on the fatty acid composition and meat quality [25]. The study was performed on 30 pig crossbreeds (Yorkshire × Landrace), with an initial weight of 60 kg. The pigs were divided into three groups and the experiment lasted 46 days to a mean pig weight of about 100 kg. They were fed a standard mixture for pigs in the last stage of fattening (finisher), and the groups differed only in that the first experimental group (EI) received sunflower grain in the meal as a source of fat and fatty acids, while the second experimental group (E-II) had a commercial preparation of flax (Vitalan ®, Vitalac, France) in the recommended amount of 2.5% in the mixture, and the third experimental group (E-III) received full-fat soybean meal in the diet. The composition of fatty acids in feed and meat, i.e. the content of n-3 and n-6 fatty acids, as well as their mutual relationship (n-6/n-3) were examined. Similar studies, i.e. examination of the influence of nutrients (fats, flax or their mixtures) on the fatty acid composition of meat have been performed on poultry [27].

The aim of a second study was to investigate the effects of adding conjugated linoleic acid (CLA) preparations to the diet of fattening pigs, on the fatty acid composition in the meat of these pigs. Sixty crossbreeds of pigs (Yorkshire × Landrace), with an initial body weight of 60 kg were used in this experiment. Pigs were divided into two groups (control and experimental), with 30 pigs in each and were fed with a standard mixture (NRC, 1998), for fattening pigs from 60 to 110 kg (fattening period of 60 days). The meal differed between the groups only in that the experimental pigs received feed with added commercial preparation of conjugated linoleic acid 60% CLA (Lutalin®, BASF, Germany), at the recommended amount of 2.0%. The mixtures were balanced and fully met the needs of the animals at this stage of production.

The meat of pigs fed with these supplements had a significantly more favorable ratio of n-6/n-3 fatty acids, compared to the meat of pigs fed without the addition of flax, i.e. CLA [25,28]. Similar results were obtained when examining the effect of adding CLA to a poultry diet [29].

The results of testing the content of specific saturated, monounsaturated and polyunsaturated fatty acids in the muscle tissue of pigs show that the content of saturated fatty acids was higher, and monounsaturated and polyunsaturated fatty acids were lower in the experimental group of pigs. The differences in the content of n-3 and n-6 fatty acids of the experimental and control groups of pigs were not statistically significant, but the ratio of n-6/n-3 was more favorable in the experimental group of pigs. The presence of both isomers of this preparation has been proven in the meat of pigs fed with the addition of CLA. The presence of these isomers has not been demonstrated in the meat of pigs fed without the addition of CLA [28].

In these studies, two isomers of CLA were used, namely c9t11CLA and t10c12CLA as a feed additive for pigs. Both of these acids were also found in pig meat at the end of fattening, with the content of c9t11CLA being almost twice as high as the content of t10c12CLA. It is noticeable here that the same degree of uptake and incorporation of both isomers of conjugated linoleic acid observed in feed is not the same. The c9t11 isomer is much more suitable for incorporation into intramuscular fat depots [28].

5. Conclusion

Animal meat can be enriched with functional ingredients through diet i.e. meal design. The relationship between organic selenium ingested with feed, and selenium content in animal tissues and products is not linear. By ingesting the organic form of selenium in feed, the selenium content in fresh tissues reaches the level of 0.3 to 0.4 mg/kg. Organs, liver and heart, contain higher concentrations of selenium, liver up to four times in relation to skeletal muscles. The addition of flax, i.e. CLA, to pig feed improves the value of pig meat from both the nutritional and health aspects. The above facts unequivocally indicate that functional foods, primarily meat enriched with the mentioned bioactive additives, will increasingly be an indispensable part of the human daily diet. Food production exceeds the need to survive and satisfy hunger. The development and creation of functional food is a scientific temptation that must be ahead of the economic temptation, and which must be founded on scientifically based facts.

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