KRMIVA

NUTRITIONAL FACTORS SUPPORTING THE IMMUNE RESPONSE IN ANIMALS

HRANIDBENI ČIMBENICI KAO PODRŠKA IMUNOM ODGOVORU U ŽIVOTINJA

D. Jamroz

Scientific paper - Pregledno znanstveni članak
UDC: 636.085.33.
Received - Primljeno: 15. august - kolovoz 2005.

SUMMARY

The immune system in animals and in humans as well, is a "*specific network of specialized organs, tissues and cells*" and different intrinsic biochemical substances that protect the host organism against invasions and unfavourable effects of pathogenic microorganisms. It plays the essential role in maintaining the resistance to disease. It is also known that some groups of specific nutrients can affect, positively or negatively the immune response of animals. In present review some connections between nutrition and immune response will be discussed.

Key words: imune system, resistance, nutrition protect

INTRODUCTION

In the organism of animals there are two immune systems. The innate (native or natural) is an non-specific system and provides protection in early stages of life; it includes mainly physical barriers - surfaces of skin and mucosa, which have a contact with the environment, but also phagocytic cells (neutrophils, macrophages), killer-cells, some proteins and cytokines. The second part of the immune system is highly specific and increases in the defense capability with exposure to different harmful factors.

It is well recognized that the functionality of the immunological barriers (regeneration of epithelium, activity of T- and B- lymphocytes) are closely linked with nutrition e.g. Zn level in the diet, vit. A. Because of the complexity of the immune system it is very difficult to describe this problem in a short communication. Possibilities of some groups of nutrients in the modification of immunological functions are really wide. For instance, the spare or limited feeding during a long period and nutrient deficiencies can affect in a negative manner the immune response, decrease the hormone synthesis, attenuate the cellular immunity (Macdonald,1995; Kan,2002; Cordain et al.,2005; Goddeeris, 2005; Lowenthal et al., 2005). The hormonal regulation system (insulin, insulin–like growth factor, glucagon, thyroxin, catecholamines, corticosterones) may be controlled by Zn, I, Se and other microelements, also by protein content in the diet. Well known and confirmed in many investigations is the antioxidative role of vitamins E and C. The synthesis of eicosenoids is dependent on PUFA C20, n–3 concentration in the received food. Some

Prof. dr hab. Dorota Jamroz, Department of Animal Nutrition and Feed Quality, Agricultural University, ul. Chełmońskiego 38C; 51-630 Wrocław, Poland - Poljska.

amino acids are responsible for IgG activity and humoral response. Cystine and cysteine are necessary for glutation synthesis, too low methionine level can decrease the level of antibodies.

Carbohydrates perform a basal function in fat metabolism, in biosynthesis of triacylglicerols and cholesterol but are also the agents which have a stimulatory function in the immune response to the antigens.

The immune system is constantly affected by several nutrients.

NUTRIENTS IMMUNE STIMULATORY FUNCTIONS

VITAMINS

Adequate feeding and nutritional state of animal organism can to a important extent stimulate the power of immunological response. The vitamins help the body fighting infections, promote white blood cells functions and are essential for antibodies production (Wolter,1995; Noguchi,1998; Whitehead, 1999).

Vitamin C – ascorbic acid improves the cellular immunity, cytotoxicity, kill-ability of neutrophils, humoral (circulating) resistance, influences the expression of lymphocyte receptors. It also increases the level of substances that protect the cells against viruses e.g. interferon.

Vitamin A - decreases the atrophy of lymphoidal organs and tissues, improves regeneration of mucosa epithelium, limit the possibilities of infections. **Beta-carotene**, besides being a precursor to vitamin A, has unique immune-stimulating properties (Burton,1989; Krinsky,1989). As a powerful antioxidant, it increases the power of infection-fighting cells as well as improves the activity of both killer- and T-cells. It also stimulates the macrophages that protect the organism against “foreign” cells.

Vitamin E – is a potent antioxidant and protects the cells of the immune response from peroxidative damage and also has an ability to modulate many other host immune functions. It increases humoral and cell-mediated immunity - improves proliferation of splenocytes, activates the killer-cells, production of antibodies, phagocytes and neutrophils. This vitamin alters cell membrane functions and cell-cell interactions, but the most pronounced effect of vitamin E is on immune phagocytosis. So, it improves the animal organism disease resistance. It also reduces the cholesterol level in the blood, is anti-inflamatory, antithrombosic and acts against the cancer cells proliferation (Abbey,1995; Hylands a. Poulev,1995).

Vitamin D - is useful for promoting immunity and blood cell formation. By promoting differentiation and inhibiting proliferation, it may become an important factor in cancer prevention. Another role of calcitriol involves activation of kinase C and controls the production of immune factors known as lymphokines (e.g. IL-1, IL-6, TNF-α, IL-2, IFγ), which affect cell-mediated immunity functions (Chen et al.,2003).

B-vitamins - constitute a complex of closely connected substances occuring together in vegetable and animal tissues. They can not be stored in the organism and should be taken from feeds. Their biological role depends, among others, on the activity as enzyme’ constituents that make active some compounds of the immune system, such as white blood cells or antibodies. For instance folic acid and vitamin B6 - decrease the atrophy of spleen and thymus, increase both the number and activity of cytotoxic lymphocytes and improve proliferation of interleukines – 2;

Carnitine – vitamin-like substance, is important for lipid metabolism; butylobetaine can affect the activation of corticoprogenic receptors.

MICROELEMENTS

Some minerals are essential to the animal health. The most important of them are zinc and selenium but also copper and iron play a significant role in the functionality of the immune system. These trace minerals prevent infections by strengthening the immune system (Franchini a. Bertuzzi,1991; Nys,1999).

Zinc (Zn) - The role of this valuable mineral is very important. It acts widely in the organism - activates about 200 metal-enzymes, influences the thymus functions and their hormones, increases the pancreas enzymatic activity (disaccharase, peptidase), acts as an insulin activator, stimulates the helper lymphocytes TH1, increases the IgF activity in serum; Zinc is known as a trace element that increases the white blood cells production and improves the release of antibodies, decreases infections, shows antimicrobial activity, decreases the diarrhea frequency; increases the enzymatic activity of brush border and improves the absorption of water, electrolytes (Na), glucose and other saccharides, amino acids and lipids. Ions of zinc are the blockers of the opiate agonists linkages on the synaptic receptors of membranes;

Copper (Cu) - The role of copper in functioning of the immune system is not yet fully understood. This metal supports the cell resistance and is necessary for the maintenance of white blood cells phagocytic activity.

Iron (Fe) - supports the "killing" activity of neutrophils and lymphatic tissues of ileal and respiratory tract mucosa. Iron deficiency make the immune response weak. Iron plays a very important role within the immune system in the specific immune defense substance called lactoferrin.

Selenium (Se) – acts as an immunostimulant in both mono- and poligastric animals. It plays a role similar to that of vitamin E; Se supports the killer-cells activity and increases the Ig circulation; however its role in fighting infections is still unclear.

Magnesium (Mg) – this macroelement is necessary for the activation of many biochemical reactions and for boosting the immune system in the organism. It enhances natural killer-cells and the activity of macrophages.

CARBOHYDRATES

Oligosaccharides

The oligosaccharides - derivatives of fructose and galactose play a specific, prebiotical role in immune supporting. They are not degraded by the endogenous enzymes secreted by the host organism. Undigested and unabsorbed they decrease the energy supply inside the intestine and decrease the insulin secretion; however, they are easily fermented by the *Bifidobacteria* settled in the GI-tract with short-chain fatty acids (SCFA) synthesis as a result of their activity. Products of microbial fermentation of oligosaccharides (SCFA) have beneficial effect on proliferation of cells of the intestinal wall mucosa, show antiinflamatory and antitumour activity and improve the motoric activity of the intestine. In this way the population of Gram-negative bacteria (anaerobe bacterioides) could be lowered (Mitsuoka et al.,1987; Oyofo et al.,1989; Bayley et al.,1991; Waldroup et al.,1993; Iji a. Tivey,1998,1999).

Oligosaccharides also perform the prebiotic function in the intestine. By the acidification of the environment inside the gastrointestinal tract they improve the anti-pathogens barrier (S*almonella*), decrease adhesion of fimbrial (type 1 – fimbrie) pathogens to the epithelium of caeca and the large intestine (fimbria are linked to the mannose instead of to the mannose-like sugars from enterocytes). *E. coli* agglutinates fastly and to a great extent (about 80 %) with the mannans which are present in the cells of yeast. It results in limitation of their adhesion to the intestinal walls.

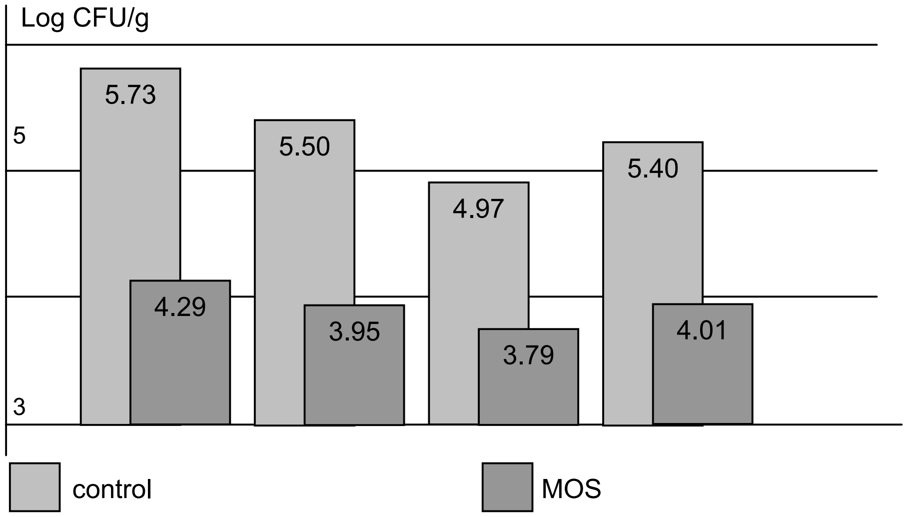
The main source of oligosaccharides are leguminose seeds (Table 1).

The most effective in prebiotic function are the mannans. The mode of action of these substances depends on preferential linking of pathogenic microorganisms to the alternate attachment sites on the surface of molecules present in the digesta instead of linking to the specific sugars of epithelial cells; linking of fimbria with mannans decrease possibilities of colonization of intestine walls with pathogens (*S. typhimurium* even up to 90 %) and subsequent enteric infections (Bailey et al.,1991). Mannan oligosaccharides are not degraded by the edogenous digestive enzymes and are not a source of energy needed for development of pathogens; in presence of mannan oligosaccharides the saprophytic intestinal microflora grows. Mannan oligosaccharides stimulate the formulation of antibodies and the process of phagocytosis and mannose may block the epithelial cells receptors, inhibit agglutination of bacteria (type-1 fimbria) with erythrocytes.

The results of investigations of Oyofo et al.(1989), Connoly (2002) and Zduńczyk et al.(2003) (Figure 1) show the effect of mannan-oligosaccharides on *Salmonella typhimurium*

Table 1. The indigestible oligosaccharides content in feeds (g/kg DM) (Mosenthin, 2001)
Tablica 1. Sadržaj neprobavljivih oligosaharida u hrani (g/kg DM) (Mosenthin, 2001)

	Soya bean Sojino zrno	Soya bean meal Sojino brašno	Lupine Lupina (vučika)	Peas Grašak	Horse bean Bob	Wheat Pšenica	Barley Ječam	Maize Kukuruz
α-Galactooligosaccharides a-Galaktooligosaharidi	29–59	42–73	101–123	30–113	-	5	2	3
Stachyose - Stahioza	30-52	47	42–55	23	16	1–2	0–1	1
Raffinose - Rafinoza	7–19	10	10–11	5	4	4–5	2–5	2
Verbascose - Verbaskoza	-	3	23–40	22	34	-	-	-
Saccharose - Saharoza	-	70	14-39	30	27	8-11	12-4	13
Fructooligosaccharides Fruktooligosaharidi	-	-	-	1	-	1-8	2-7	-



CFU – colony forming units

CFU - jedinice koje stvaraju koloniju

Figure 1. Effect of mannano-oligosaccharides on the *Salmonella typhimurium* 29e number in caeca (Connoly, 2002)
Slika 1. Djelovanje manano-oligosaharida na Salmonellu typhimarium broj 29e u cecumu (Connoly, 2002)

Other different foods and feedstuffs are also a source of oligosaccharides – in them alpha – galactooligosaccharides. Topinambur and chicory contain inuline, the yeast are the basic source of mannans; fructo-oligosaccharides are present in lupines, peas, lentil, honey, yeast, garlic, rye, bananas; raffinose (melitriose) is an ingredient of molasses, phaseolus, horse bean, peas; lupines also contain other important group of prebiotical substances – lectins (complex of protein and carbohydrates).

Other polysaccharides, such as the NSP – β-1,3/1,6-glucans binds the glucans to the glucan particles receptors of leukocytes (monocytes, macrophages, granulocytes) and act as prebiotical substances. As distinct result of NSP activity the villi of intestine willto be shortened and intestinal crypts deeper and also the number of *E. coli* in digesta lower.

OTHER PREBIOTICAL SUBSTANCES

The **lectins** (protein + carbohydrates) constitute a large and diverse class of naturally occurring molecules. Many of these are found on the exterior walls or membranes of single cells. Multiple binding sites on the surfaces cause that they associate with large numbers of different cells, causing them to clump together or agglutinate. It is especially important in protection against harmful (pathogenic) bacteria (*Salmonella* and *Escherichia coli*), which typically attach to the receptors with lectin-like sugar specificity (Eshdat et al.,1978; Mirelman et al.,1980). Low doses of lectins (large doses show antinutritive acivity) accelerate the maturation of the intestinal epithelium. Lectins increase the volume of the bladders in pancreas, improves the level of cholecystokinine in blood.

Many other nutrients also play an important role in supporting the immune system in animals.

PROTEINS, PEPTIDES, AMINOACIDS

Protein and gut regulatory peptides level influences the synthesis of enzymes, hormones which regulate metabolism, and are important for the production of blood cells, lymphoidial tissues, proliferation of mucosa cells, for lysosyme and γ-globulins functions (Macdonalds, 1995).

Amino acids - taurin, arginine, glutamine, lysine, leucine – participate in the integration of the intestine wall cells, revival of the lymphotic cells; reduce the thymus atrophy; stimulate the lymphocytes proliferation; threonine is important in γ-globulins synthesis and tryptophan – participates in serotonine synthesis.

POLYUNSATURATED FATTY ACIDS

The numerous, beneficial properties of polyunsaturated fatty acids (PUFA), important in metabolism function have caused dynamical development of the number and field of investigations concerning the immune response of the organism to the kind of PUFA content in the feed and food (Kraft et al., 2001; Bodkowski et al., 2003). In the biosynthesis of PUFA in dose dependance to the level of basic acid in the components of the diet (Figure 2).

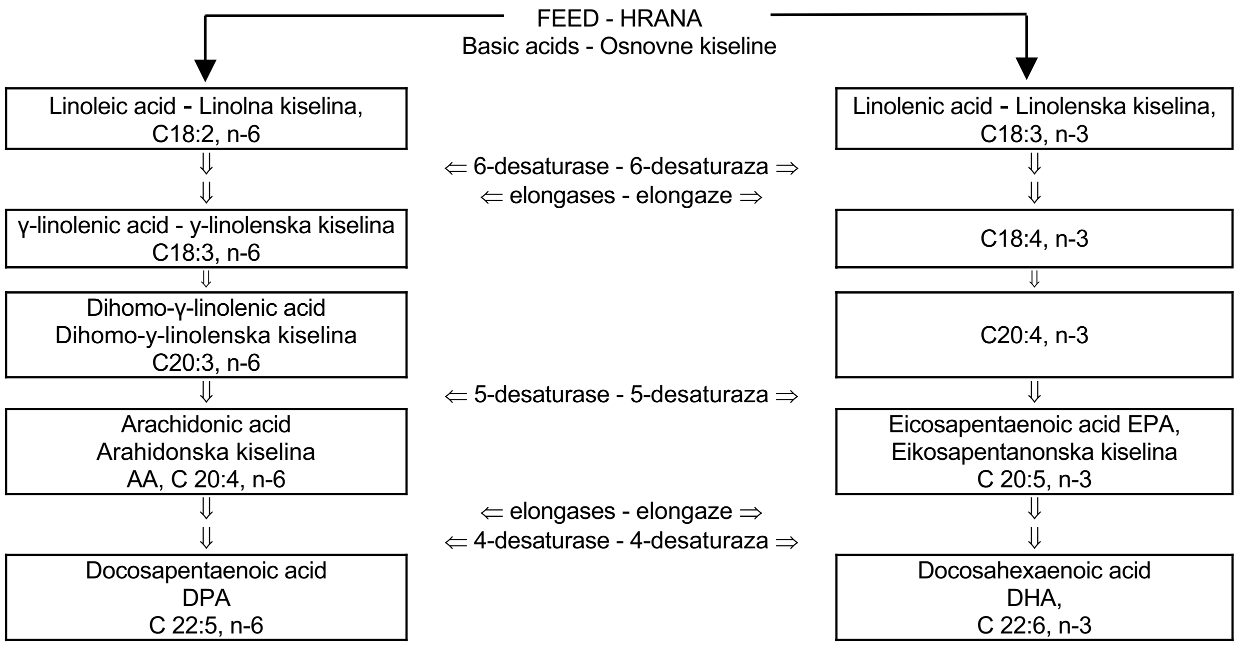


Figure 2. Biosynthesis of long chain polyunsaturated fatty acids in animal tissues
Slika 2. Biosinteza dugog lanca mnogostuko nezasićenih masnih kiselina u tkivu životinje

Synthesised in animal organism the **fatty acids n-3**, e.g. EPA, DHA (Table 2) are essential in antyinflammatory, antiatherogenic, anticancerogenic and other processes (Jahreis,1997; Stangl,1999). They act as immune boosters by increasing the intensity of phagocytosis and white blood cells activity. The best source of these FA is the fish oil. Among plant sources rich in n-3 PUFA are lineseed oil and rapeseed oil (Lopez-Ferrer et al.,1999).

Table 2. Fatty acids contents in oils (% of total FA) (Kulasek and Ostaszewski, 1997)
Tablica 2. Sadržaj masnih kiselina u ulju (% ukupnih MK) (Kulasek and Ostaszewski, 1997)

	Acids - Kiseline								
	Saturated FA - Zasićene MK		MUFA	PUFA					
	16:0	18:0	18:1 n-9	18:2 n-6 LA	18:3 n-6 GLA	20:4 n-6 AA	18:3 n-3 ALA	20:5 n-3 EPA	22:6 n-3 DHA
Olive - Maslina	14.5	2.3	71.5	10.2	0.03	-	0.17	-	-
Rapeseed Sjeme repice	4.8	1.5	53.2	22.0	-	-	11.1!	-	-
Maize - Kukuruz	10.7	1.7	24.6	57.3	-	-	0.8	-	-
Soya - Soja	10.7	3.9	22.8	51.0	-	-	6.8	-	-
Sunflower Suncokret	5.8	4.1	21.7	66.4	-	-	0.3	-	-
Oenanthera Bjelorepka	6.1	1.6	8.9	73.2	9.3	-	-	-	-
Flax - Lan	12.4	4.4	19.6	36.6	25.2	-	0.16	-	-
Line - Laneno vlakno	8.2	1.2	20.2	17.0	-	-	**53.3!**	-	-
Fish (sea) Riba (morska)	**16.0**	**2.8**	**10.5**	**1.2**	**1.0**	**0.6**	**-**	**16.9**	**12.0**

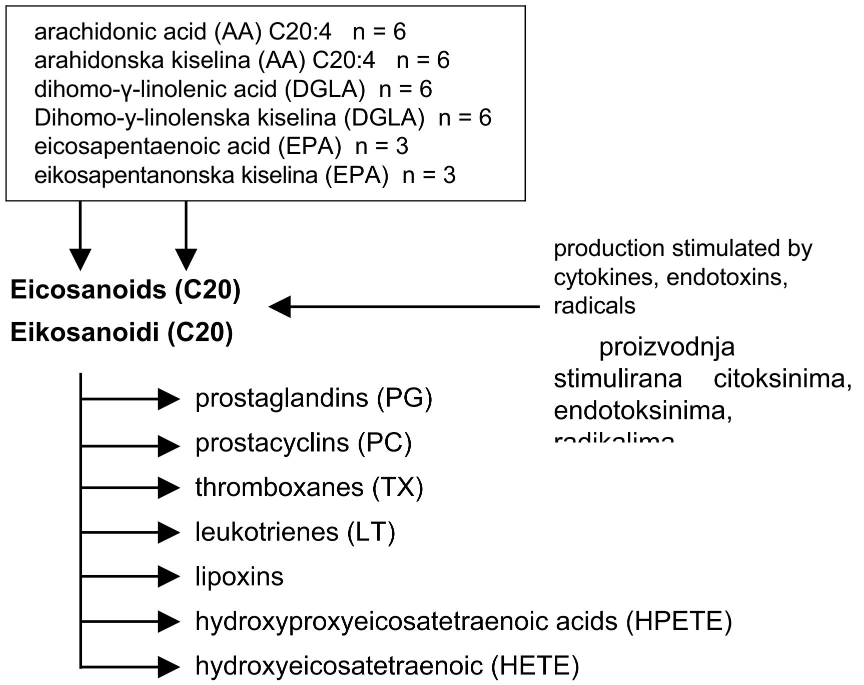


Figure 3. Sources of eicosanoids
Slika 3. Izvori eikosanoiđa

The research has shown that some acids, which were relatively little known in their function are important because of their antibacterial activity, e.g.: caprylic acid, C8 – anti *E. coli, Salmonella*; capryl acid, C10 **-** anti *E. coli, Clostridium*; lauric acid, C12 – anti C*lostridium.*

PUFA n-6 are the precursor of different eicosdanoids (Figure 3 and 4) characterised by numerous nonbeneficial biological functions in the organism e.g. proinflamatory, proaggregation of blood cells actions (Slomma et al., 2001).

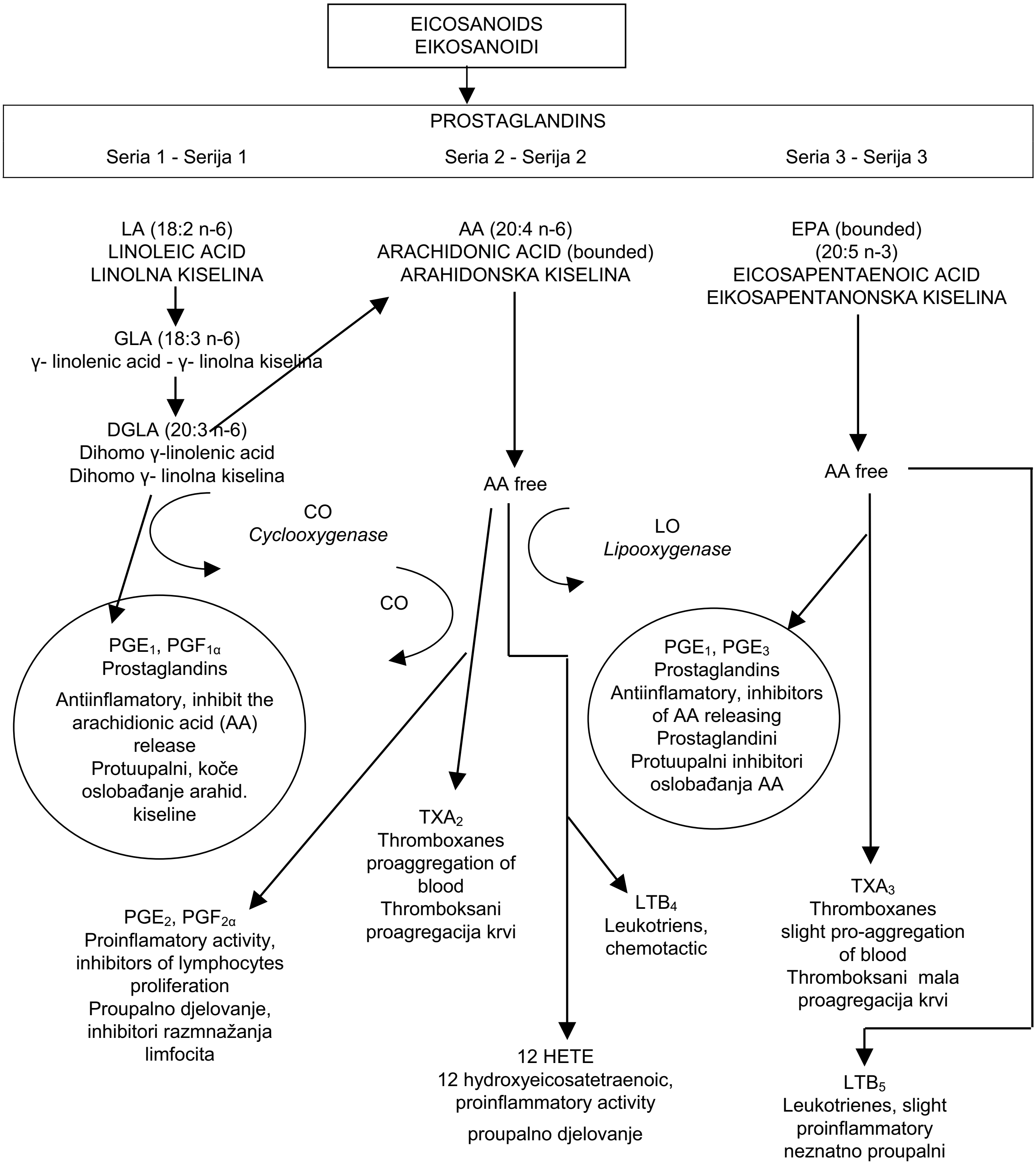


Figure 4. Some functions of eicosanoids in organism

Slika 4. Neke funkcije eikosanoida u organizmu

Conjugated linoleic acid

Specially important, biological functions in many processes in animal organism are those of the derivatives of linoleic acid (n-6) $C_{18:2}$ cis-9 cis-12 the isomers 9,11; 10,12 cis, trans. Isomers cis-9, trans-11 known as the “rumen acid” in effect of ruminal *Butyryvibrio fibrisolvens* and intestinal microflora activity are transformed through the biohydrogenation of linoleic acid to the CLA (conjugated linoleic acid) with the stearic acid as the end-product. Among the isomers of CLA the greatest activity was found to be that of bioactive isomers cis-9, trans-11 and cis-11, trans-9.

Immune support of CLA-dienes is expressed in numerous functions, such as

- antimutagenic
- antiinflammatory
- anticancerogenic (in cell cultures)
- antisclerotic (atherogenic)
- anti osteoporosis activity.

The role of CLA-dienes in supporting the glucose tolerance, reduction of the size of adipocites and fat deposition, reduction of obesity, antioxidative properties, reduction of prostaglandins synthesis (PGE2), antithrombosic, antivascular diseases, antiallergic activities – was confirmed in numerous investigations and studies (Jahreis, 1997; Jamroz et al., 2003a,b; 2004; Kraft a. Jahreis, 2004; Patkowska-Sokoła et al., 2004; Tischendorf et al., 200; Erdmann et al., 2005; Munday et al., 1999).

In human diet the main sources of CLA are milk and milk products (2.3 – 26. 0 mg/g of fat) and beef meat (3.1 – 8.5 mg/g of fat). The FA and CLA content (C_9t_{11}) in meat of young ruminants and in milk differs depending on animal species or products (Table 3).

MICROBIAL BALANCE

The balance of microflora in the intestine is very important for health and correct functioning of the gastrointestinal tract (GIT). The number of micro-organisms varies in particular parts of GIT from 10^8 up to 10^{11}-10^{12} and strictly depends on pH value of intestine content and the nutrition of animals (Pabst a. Rothkötter, 1998; Rodehutscord a. Kluth, 2002; Mead, 2002; Lan et al., 2005) (Table 4).

Table 3. Content of FA and CLA (C_9t_{11}) in meat of young animals and in milk (Jamroz et al., 2004; Sokoła et al., 2004)

Tablica 3. Sadržaj Mk i CLA u mesu i mlijeku mladih životinja (Jamroz i sur., 2004; Sokoła i sur., 2004)

	Species of animals - Životinje		
	Beef - Govedina	Lamb - Janjetina	Kid - Jaretina
Meat - Meso Share in total FA (%) - Udio u ukupnim MK (%)			
MUFA	45.4A	43.5B	40.6B
PUFA	7.4A	8.5AB	9.5B
CLA (C9t11)	0.62Aa	1.28B	0.98ABb
	Cow - Krava	Sheep - Ovca	Goat - Koza
Milk - Mlijeko Share in total FA (%) - Udio u ukupnim FA (%)			
MUFA	32.1B	27.2A	26.9A
PUFA	3.9b	4.7A	3.5Ba
CLA (C9t11)	0.83Bb	1.24A	0.67Ba

Table 4. pH value and number of microorganisms in the intestinal tract (Mead,1993)
Tablica 4. Vrijednost pH i broj mikroorganizama u probavnom traktu (Mead,1993)

Aesophagus, stomach - Jednjak, želudac *Lactobacillus* (Low *E. coli* CFU) (malo *E. coli*)	pH 0.5-2.5-4.0 10^8/g content - sadržaja
Duodenum, jejunum *Streptococcus (enterococcus), Staphylococcus, Sactobacillus, E. coli, eubacterium, propionibacterium, Clostridium, gemminger, fusobacterium*	pH 5.7-7.2-8.0 10^8-10^9/g content - sadržaja
Caeca, large intestine - Cekum, debelo crijevo Microorganisms	pH 7.0-8.0 10^8-10^{11}/g content - sadržaja

Table 5. Optimal pH value needed for growth of some pathogens (Brunell et al., 1988)
Tablica 5. Optimalna vrijednost pH potrebna za rast nekih patogena (Brunell i sur., 1988)

	Minimum	Optimum	Maximum
Clostridium perfringens	-	6.0 – 7.6	8.5
Clostridium botulinum	-	6.0 – 7.0	8.0 – 9.0
Pseudomonas aeruginosa	4.4 – 5.6	6.6 – 7.0	8.0 – 9.0
Salmonella spp.	4.0 – 5.0	6.0 – 7.5	9.0
Staphylococcus spp.	4.2	6.8 – 7.5	9.3

PROBIOTICS

The probiotic microorganisms have a significant influence on the population of regular intestinal microflora (400 species, 10^9 – 10^{14} /g). They produce toxins that kill closely related microorganisms (the strains within the same species), occupy the niches – receptors on the cells of intestinal epithelium, increase activity of some intestinal enzymes (such as saccharase, maltase), stimulate the organism resistance in the mucosa (activity of macrophages, level of antibodies), decreases the production of biogenic amines and NH_3, and produce vitamins (B_{12}, other from group B) (Wolter, 1995; Zimmermann et al., 2001; Kan, 2002; Mead, 2002; Rodehutscord a. Kluth, 2002; Cordain et al., 2005;).

ORGANIC ACIDS

The decrease of the intestinal pH content by supplementation of feed mixtures or diets with organic acids (and their salts) affects the pepsin activation (pepsinogen + HCl), improves the process of the protein digestion, stimulates both secretion and activity of GIT' enzymes, improves nutrients absorption, decreases the amount of secreted HCl, decreases the possibility of the intestine wall colonisation by pathogens (pH lower than 5.0 – 6.8) because of optimal pH for the development of different *Salmonella* spp. is 6.8 – 7.2 and *E. coli* 6.0 – 8.0. The optimal pH values for pathogens growth are presented in Table 5.

The proliferation and the development of the moulds in feeds, can be to a great extent, inhibited by organic acids supplement. The acidification also decreases the threat of the unprofitable degradation of nutrients in feeds.

PLANT EXTRACTS

Among the feed supplements which can affect the immune response of animal organism of substantial importances are the essential plant oils and different plant extracts.

In the mode of action of the plant active substances the most important activities (Table 6) are: improvement of the endogenous enzymes secretion, stimulation of appetite, digestibility and nutrients absorption, improvement of the microflora balance, decrease of *E. coli* and C*lostridium* population and stimulation of the *Lactobacillus* spp. proliferation, intestinal villi layer protection, antibacterial, antiviral and anti diarrheal activity and stimulation of the immune system.

Table 6. Active principles and preservative properties of herbs and spices (Narahari,2005)
Tablica 6. Djelatne tvari i svojstva mirisnih trava i začina (Narahari,2005)

Herb - Trave	Active principles - Djelatne tvari	Functions - Funkcije
Fenugreek seeds Sjeme grozdaste piskavice *(Trigonella foenum graecum)*	Quercitin, luteolin, diosgenin, citogenin	Antioxidant, antimicrobial Antioksidantna, antimikrobska
Curry/Bay leaves Kari/lovor *(Murrya koenigii)*	Carbazole alkaloids – koenimbine, mehanimbine, O-methyl-murrayamine, murryanol, bismahine, bismurryafoline	Antioxidant, antimicrobial hypoglycaemic, aromatic Antioksidantna, antimikrobska, hipoglikemijska, aromatična
Mustard seeds Sjeme gorušice *(Brassica junacea)*	Glucosinolates, myrosinase enzymes, isothiocyanates	Antioxidant, hypoglycaemic, preservative - Antioksidantna, antimikrobska, konzervans
Coriander seeds and leaves Sjeme i listovi korijandara	Volatile oils and glycosides Hlapljiva ulja i glikozidi	Antioxidant, minimises water activity and preservatives Antioksidantna, smanjuje djelovanje vode i konzervansa
Turmeric powder Prašak turmerika *(Curcuma longa)*	Curcumin	Antimicrobial, antioxidant, preservative and colouring agent Antimikrobska, antioksidantna, konzervans i sredstvo za bojanje
Garlic Češnjak *(Allium sativum)*	Allicin, allin, ajoene	Antibacterial, antiviral and flavouring agent Antibaktirijska, antivirusna i aromatično sredstvo
Basil leaves Listovi bosiljka *(Ocimum basilicum)*	Flavonoids orientin, vicenin, estragole, linalool, cineol, eugenol, limonene, sabinene	Antibacterial, immunostimulant, antiviral and preservative Antibakterijska, imunostimulativna, antivirusna i konzervans
Black pepper Crni papar *(Piper nigrum)*	-	Carminative, antioxidative, antibacterial Protiv nadutosti, antioksidantna, antibakterijska
Chili pepper, red Crvena čili paprika *(Capsicum family)*	Capsacin	Preservative and colouring agent Konzervans i sredstvo za bojanje
Cinnamon Cimet *(Cinnamonum verum)*	Cinnamaldehyde, cinnamylacetate, cinnayl alcohol	Antioxidant, antimicrobial, Antioksidantna, antimikrobska
Cloves Klinčić *(Eugenia caryophyllus)*	Eugenol, kaempferol, rhamnetin, volatile oils - Hlapiva ulja	Antioxidant, antimicrobial, flavouring agent Antioksidantna, antimikrobska, sredstvo za bojanje
Ginger Đumbir *(Zingiber officinale)*	Gingerols	Antioxidant, antimicrobial Antioksidantna, antimikrobska
Rosemary, sage, thyme, oregano, mint, aniseed, onion, cumin, ajwain, caraway Ružmarin, žalfija, majčina dušica, origano, metvica, anis, luk, kim, ajwain, obični kim	Plant phenolics, ellagic acids, essential oils ansd volatile oils Biljni fenoli, elagične kiseline, esencijalna ulja i hlapiva ulja	Antioxidant, antimicrobial, flavouring agent Antioksidantna, antimikrobska, sredstvo za bojanje
Oils and fats Ulja i masti	-	Reduces water activity, preservative Smanjuju djelovanje vode, konzervansi
Common salt, sugar, jaggery and molasses Obična sol, šećer, tamni šećer, melase	-	Reduces water and microbial activity, preservative Smanjuju djelovanje vode i mikroba, konzervans

Some phytochemicals, such as polyphenolics (fruits, vegetables, different herbs, spices etc.) hydroxybenzoic acids, hydroxycinnanic acids, flavonoids, and in them catechins, anthocyanidins, proontocyanidins, isoflavones and tocopherols play the basic role in supporting the cellular antioxidative mechanisms (Hertog et al., 1992; Franke et al., 1994; Hu et al., 1995; Aruoma et al., 1996; Wartanowicz a. Ziemlański,1999; Horbowicz, 2000; Jamroz et al., 2004a,b) (Table 6).

CONCLUSION

In recapitulation of numerous biological possibilities for supporting immunity by the management of quality of animal products and also by introducing additives into animal feed mixtures or using diets supplemented to create functional feed it could be said that mentioned substances: vitamin A, carotenoids, vit. E, D_3, C, Mg, Zn, Se, dietary fibre, antioxidative substances (plant extracts), n-3 fatty acids, EPA, DHA, CLA, phytoestrogenes, probiotics, prebiotics and some other, such as folic acid, Ca, Fe, Cr, I offer great chance for modification of feed or food quality and health status of animals and humans – consumers of animal products.

REFERENCES

1. Abbey, M. (1995.): The importance of vitamin E in reducing cardiovascular risk. Nutr. Rev. 53:9-13.
2. Aruoma, O. I., J. P. Spencer, R. Rossi, R. Aeshbach, A. Khan, N. Mahmod, A. Murcia, J. Butler, B. Halliwell (1996.): An evaluation of the antioxidant and antiviral action of extracts of rosemary and Provencal herbs. Food Chem. Tox. 34:449-456.
3. Bailey, J. S., L. C. Blankenship, N. A. Cox (1991.): Effect of fructooligosaccharide on Salmonella colonisation of the chicken intestine. Poult. Sci., 70:2433-2438.
4. Bodkowski, R., B. Patkowska-Sokoła, D. Jamroz, T. Wertelecki, A. Ćwikła, W. Walisiewicz-Niedbalska (2003.): Influence of feeding upon the profile of fatty acids and the content of conjugated dienes of linoleic acid c9t11 in sheep milk. Chemistry for Agriculture, 4:250-256.
5. Burton, G. W. (1989.): Antioxidant action of carotenoids. J. Nutr. 119:109-111.
6. Chen, H. L., D. F. Li, R. Y. Chang, L. M. Gong, X. S. Piao, G. F. Yi, J. X. Zhangs (2003.): Effects of Lentinan on broiler splenocyte proliferation, interleukin-2, production and signal transduction. Poultry Sci., 82:760-766.
7. Connolly, A. (2002.): Rising to the challenge of removing antibiotic growth promoters from feeds and how specific oligosaccharides haveled the way. (Information from Author, Alltech, Ireland).
8. Cordain, L., B. Eaton, A. Sebastian, N. Mann, S. Lindberg, B. A. Watkins, J. H. O'Keefe (2005.): Origins and evolution of the Western diet: health implications for the 21st Century. Am. J. Clin. Nutr., 81:341-354.
9. Erdmann, K., P. Lebzien, L. Hüther, G. Flachowsky, P. Möckel, G. Jahreis (2005.): Influence of polyunsaturated fatty acids (PUFA) and the rumen milieu on ruminal production of trans fatty acids and conjugated linoleic acid (CLA), their flow into the duodenum and their content in the milk fat. Proc. Soc. Nutr. Physiol., 14:109.
10. Eshdat, Y., I. Ofek, Y. Yashouv-Gan, N. Sharon, D. Mirelman (1978.): Isolation of a mannose – specific lectin from Escherichia coli and its role in the adherence of the bacteria to epithelial cells. Biochem. a. Biophysic. Res. Comm., 85, 4:1551-1559.
11. Franchini, A., S. Bertuzzi (1991.): Micronutrients and immune functions. Proceed. 8th Europ. Symp. Poultyr Nutr., Venezia-Mestre, Italy, 63-80.
12. Franke, A. A., L. J. Custer, C. M. Cerna, K. K. Narala (1994.): Quantitation of phytoestrogens in legumes. J. Agric. Food Chem., 42:1905-1913.
13. Goddeeris, B. M. (2005.): Crosstalk between nutrition and immunity. Proc. Soc. Nutr. Physiol., 14:15-20.
14. Hertog, M. G., P. C. H. Hollman, M. B. Katan (1992.): Content of potentially anticancerogenic flavonoids of 28 vegetables and 9 fruits commonly consumed in the Netherlands. J. Agric. Food Chem., 40:2379-2383.
15. Horbowicz, M. (2000.): Występowanie, biosynteza, właściwości biochemiczne flawonoli. Post. Nauk Rol., 2:3-17.
16. Hu, J. P., M. Calomme, T. Lasure, V. Bruyne de, A. Pieters, A. Vlietinck, D. A. Vanden Berghe (1995.): Structure-activity relationships of flavonoids with superoxide scavenging activity. Biol. Trace Elem. Res., 47:327-331.
17. Hylands, P. J., A. A. Poulev (1995.): Immuno-stimulants: maximizing the health and efficiency of

animals through plant-derived biomolecules. Biotechnology in the Feed Industry. Proceed. Alltech's Eleventh Ann. Symp., Nottingham Univ. Press, 117-139.

18. Iji, P. A., D. R. Tivey (1998.): Natural and synthetic oligosaccharides in broiler chicken diets. World's Poultry Sci. J., 54, 129-143.
19. Iji, P. A., D. R. Tivey (1999.): The use of oligosaccharides in broiler diets. Proceed. 12th Europ. Symp. on Poultry Nutr., Veldhoven, The Netherlands, 193-201.
20. Jahreis, G. (1997.): Krebshemmende Fettsäuren in Milch und Rindfleisch. Ernährungs- Umschau, 44, 5, 168-172.
21. Jamroz, D. (2004a.): Plant extracts – biologic active substances in animal nutrition. Polskie Drobiarstwo, 6:27-30 (in Polish).
22. Jamroz, D., R. Bodkowski, B. Patkowska-Sokoła, A. Ćwikła, T. Wertelecki (2004.): Influence of species and nutrition on fatty acids profile and CLA content in meat fat of ruminants. Krmiva, 46, 4, 175-187.
23. Jamroz, D., J. Orda, C. Kamel, A. Wiliczkiewicz, T. Wertelecki, J. Skorupińska (2003a.): The influence of phytogenic extracts on performance, nutrients digestibility, carcass characteristics and gut microbial status in broiler chickens. J. Anim. a. Feed Sci., 12:583-596.
24. Jamroz, D., B. Patkowska-Sokoła, R. Bodkowski, A. Ćwikła, T. Wertelecki, W. Walisiewicz-Niedbalska (2003b.): The influence of sheep race upon composition of fatty acids and content of conjugated dienes of linoleic acid c9t11 in meat fat. Chemistry for Agriculture, 4, 195-199
25. Jamroz, D., T. Wertelecki, M. Houszka (2004b.): Influence of kind of grain and plant origin active substances on morphological and histochemical pattern of stomach and jejunum walls in chicken (in printing; J. Anim. Phys a. Nutr.).
26. Kan, C. A. (2002.): Prevention and control of contaminants of industrial processes and pesticides in the poultry production chain. World's Poultry. Sci. Assoc., 159-167.
27. Kraft, J., J. M. Grunari, P. Möckel, G. Jahreis (2001.): Effects of CLA calcium salts on CLA content in milk lipids. Proceed. 8 Symp. Vitamine und Zusatzstoffe in der Ernährung von Mensch und Tier. Jena, 217-223.
28. Kraft, J., G. Jahreis (2004.): Physiologische Wirkungen von konjugierten Linolsäuren. Schriftreiche Int. f. Nutztierwissenschaften, ETH Zürich, 25:81-98.
29. Krinsky, N. J. (1989.): Antioxidant function of carotenoids. Free Rad. Biol. Med., 7:617-621.
30. Kulasek, G., P. Ostaszewski (1997.): Necessary, unsaturated fatty acids in diet-prophylactic and diet therapy in dogs and cats. Proceed. IV Symp. Żywienie psów i kotów i innych zwierząt amatorskich, AR Wrocław, 13-36 (in Polish).
31. Lan, Y., M. W. A. Versteegen, S. Tamminga, B. A. Williams (2005.): The role of the commensal gut microbial community in broiler chickens. World's Poultry Sci. J., 61:95-104.
32. Lòpez-Ferrer, S., M. D. Baucells, A. C. Barroeta, M. A. Grashorn (1999.): n-3 enrichment of chicken meat using fish oil: alternative substitution with rapeseed and linseed oils. Poultry Sci., 78, 356-365.
33. Lowenthal, J. W., M. A. Johnson, S. G. Tyack, L. S. Hilton, A. G. D. Bean (2005.): Oral delivery of novel therapeutics: development of a fowl adenovirus vector expressing chicken IL-2 and MGF. World's Poultry Sci. J., 61:87-94.
34. Macdonald, F., (1995.): Use of immunostimulants in agricultural applications. Proceed. Alltech' 11th Ann. Symp., Nottingham Univ. Press:97-103.
35. Mead, G. C. (2002.): Factors affecting intestinal colonisation of poultry by Campylobacter and role of microflora in control. World's Poultry Sci. Assoc., 169-178.
36. Mead, G. (1993.): Microorganisms in the digestive tract of poultry. Proceed. 9th Europ. Symp. Poult. Nutrit., Jelenia Góra:138-147.
37. Mirelman, D., G. Altmann, Y. Eshdat (1980.): Screening of bacterial isolates for mannose specific lectin activity by agglutination of yeast. J. Clin. Microb, 11, 4:328-331.
38. Mitsuoka, T., H. Hidaka, T. Toshiaki (1987.): Effect of fructooligosaccharides on intestinal microflora. Die Nährung, 31, 5-6:427-436.
39. Mosenthin, R., (2001.): Digestion-resistant oligosaccharides in swine nutrition. Przegl. Hodowl., 2:2-6 (in Polish).
40. Munday, J. S., K. G. Thompson, K. A. C. James (1999.): Dietary conjugated linoleic acids promote fatty streak formation in the C57 BL/6 mouse atherosclerosis model. Br. J. Nutr., 81:251-255.
41. Narahari, D. (2005.): Preservation of chicken fast foods at room temperature using multi-hurdle technology. Poultry Internat., August, 22-30.
42. Noguchi, N. (1998.): Action of vitamins as antioxidant against oxidative modification of low density lipoprotein. Biofactors, 7, 1-2:41-51.
43. Nys, Y. (1999.): Trace elements as related to health and environment in chickens. Proceed. 12th Europ. Symp. on Poultry Nutr., Veldhoven, The Netherlands:91-105.

44. Oyofo, B. A., J. R. De Loach, D. E. Corrier, J. O. Norman, R. L. Ziprin, H. H. Mollenhauer (1989.): Effects of carbohydrates on Salmonella typhimurium colonisation in broiler chickens. Avian Diseases, 33:531-534.
45. Pabst, R., H-J. Rothkötter (1998.): The morphological and functional basis for the immune function of the intestinal wall: a barrier function in contrast to the absorption of nutrients. Proceed. Soc. Nutr. Physiol., 7:13-22.
46. Patkowska-Sokoła, B., D. Jamroz, T. Wertelecki, R. Bodkowski, A. Ćwikła (2004.): Fatty acids content and conjugated dienes of linoleic acid cis-9 trans-11 in the milk of ruminants. Krmiva, 46, 4:189-196.
47. Rodehutscord M., H. Kluth (2002.): Tierfütterung ohne antibiotisch wirkende Leistungförderer. Züchtungskunde, 74, 6:445-452.
48. Slomma, N., K. Becker, K. Eder (2001.): Wirkung konjugierter Linolsäuren auf die arachidonsäure-Kaskade von Hepatozyten. Proceed. 8 Symp. Vitamine und Zusatzstoffe in der Ernährung von Mensch und Tier. Jena:211-217.
49. Stangl, G. I. (1999.): Zur Wirkung des Nahrungs-fettes auf das Krebsgeschehen. Ernährungs-Umschlau, 46, 1:4-9.
50. Tischendorf, F., F. Schöne, U. Kirchheim, G. Jahreis (2002.): Influence of a conjugated linoleic acid mixture on growth, organ weights, carcass traits and meat quality in growing pigs. J. Anim. Physiol. a. Anim. Nutr., 86:117-128.
51. Waldroup, A. L., R. E. Skinner R. E. Hierholzer P. W. Waldroup (1993.): An evaluation of fructooligosaccharide in diets for broiler chickens and effects on Salmonellae contamination of carcass. Poult. Sci., 72:643-650.
52. Wartanowicz, M., Ś. Ziemlański, (1999.): Antioxidative stress and protective mechanisms. Żyw. Człow. Metab., 1:67-80.
53. Whitehead, C. C. (1999.): The impact of vitamins on health and performance in fowls. Proceed. 12th Europ. Symp. on Poultry Nutr., Veldhoven, The Netherlands, 73-82
54. Wolter, R. (1995.): Dietetic feeds and nutritional supplements. Proceed. Alltech's Eleventh Ann. Symp., Nottingham Univ. Press:143-150.
55. Zduńczyk, Z., J. Jankowski, J. Juśkiewicz, J. Stańczuk, M. Wróblewska (2003.): Selected parameters of functioning of gastrointestinal tract of turkeys fed diets containing flavomycin, mannan-oligosaccharide or inulin. Proceed. 14th Europ. Symp. Poultry Nutr., Lillehammer, Norway, 214-215.
56. Zimmermann, B., E. Bauer, R. Mosenthin (2001.): Pro- and prebiotics in pig nutrition – potential modulators of gut health. J. Anim. a. Feed Sci., 10, 47-56.

SAŽETAK

Imuni sustav u životinja kao i u ljudi je "specifična mreža specijaliziranih organa, tkiva i stanica" te različitih važnih biokemijskih tvari koje štite organizam domaćina od napada i nepovoljnog djelovanja patogenih mikroorganizama. On ima bitnu ulogu u održavanju otpornosti na bolesti. Isto tako je poznato da neke skupine hranjivih tvari mogu djelovati pozitivno ili negativno na imuni odgovor životinja. U ovom radu raspravlja se o povezanosti između hranjivih tvari i imunog odgovora.

Ključne riječi: imuni sustav, otpornost, hranidba.