Rocz. Nauk. Zool., 45, 2 (2018) 163–174

FACTORS AFFECTING IMMUNITY IN POULTRY*

Ewa Sosnówka-Czajka, Iwona Skomorucha

National Research Institute of Animal Production, Department of Poultry Breeding,
32-083 Balice near Kraków

In poultry breeding, many factors adversely affect the birds' immune system, leading among others to reduced weight of lymphoid organs and a decline in antibody or lymphocyte production. According to many authors, breeding work performed over recent years, in which the main focus was on improved growth parameters, is inversely correlated with some immunity parameters of broiler chickens. Both scientists and practical breeders increasingly report about declining immunity and the incidence of immune system defects in poultry. Modern breeding programmes should account for the body's natural immunity to disease; this is all the more important since poultry producers are phasing out antibiotics and synthetic additives, which reduce the quality of poultry products. Provision of birds with rearing conditions that do not reduce immune system efficiency and, on the contrary, contribute to improved health, is a vital element of poultry production. The immune system in poultry, just as in other animals, is dependent on their origin and the origin by environment interaction. In recent years, modification of immune processes has attracted the interest of many centres around the world. Research was conducted on many modulators of immune response and substances enhancing the body's immunity to various infections. However, the best way of achieving immunoprophylaxis in poultry production is to select resistant breeds or lines and to use breeding practices aimed at creating strong immunity and preventing infections. This should be supported by the use of dietary immunostimulants, preferably of natural origin, in particular phytotherapy.

Key words: immunity, stress, genotype, poultry

In hens, states of decreased functions of the immune system occur quite frequently and may have various forms. Performance of the immune system may be reduced as a result of hereditary immune defects or develop in an acquired manner, under the influence of various immunosuppressive factors on animal organism. They may include microorganisms, independent factors, mainly chemical substances, improper nutrition and also unfavourable housing conditions of animals. This quite often contributes to the development of diseases evoked by conditionally pathogenic microorganisms (Rzedzicki and Kowalska, 1992; Trawińska et al., 2003).

The immune system in poultry, just as in other animals, is dependent on their origin and the interaction between the origin and the environment (Siegel, 1995).

* The study was financed from the statutory funds, task: 01-12-05-11.

In the last decades, many scientific research centres around the world have been conducting studies to obtain the in-depth knowledge on immune processes, factors that may interfere with immune reactions, and in particular on the modification of immunological processes. Many modulators of immune response and substances enhancing the organism's immunity to various infections were studied (Zulkifli et al., 2000; Koenen et al., 2002; Chen et al., 2003). Therefore, the aim of the present study is to review the factors affecting immunity in poultry and the applied methods of modification of the immune status in birds.

Bird genotype and immunity

According to many authors, breeding works that have been conducted in recent years and have been focused mainly on the improvement of production parameters, are inversely correlated with some immunity parameters of broiler chickens (Yunis et al., 2000; Cheema et al., 2003; Quinteiro-Filho et al., 2010; Soleimani et al., 2011; Jahanian and Rasouli, 2015). It should be remembered that the performance of the immune system significantly decides on the achieved economic effects of poultry rearing (Sivaraman et al., 2005).

Studies have shown that immune response in poultry, among others under stress conditions, is also genetically determined (Nestor et al., 2000; Sarker et al., 2000; Yang et al., 2000; Zulkifli et al., 2000; Cheng et al., 2001; Yonash et al., 2002; Soleimani et al., 2011; Ericsson et al., 2014; Fallahsharoudi et al., 2015, 2016; L0tvedt et al., 2017).

Numerous scientific studies have confirmed that bird origin decides on the immune response of the organism (Buitenhuis et al., 2004; Singh et al., 2004; Van den Brand et al., 2004; Van Eerden et al., 2004; Hangalapura et al., 2005; Cotter and Van Eerdent, 2006; Adriaansen-Tennekes et al., 2009). Nowadays, commercially used broiler chicken sets differ genetically in terms of cellular response, humoral and innate immune reaction (Cheema et al., 2003; Khajavi et al., 2003). Many studies confirmed the differences in the immune status of broiler chickens and laying hens (Yunis et al., 2000; Koenen et al., 2004). In spite of the fact that they belong to the same species, laying hens and meat-type hens differ not only in phenotypic features, but also in the rate of development of the immune system and final immunity level (Koenen et al., 2002). Chickens for fattening are characterized by lower general IgG concentration and weaker proliferation of the non-specific antibodies compared to laying hens kept under the same conditions. On the other hand, Al-Natour et al. (2004) demonstrated that the origin of laying hens from different flocks decides on the level of maternal antibodies contained in eggs and on the production of specific antibodies in chicks and on lymphoid organ weight. Also, Hamal et al. (2006) observed the effect of the origin of birds on IgY level in yolk and in new-hatched chicks. Leandro et al. (2011) reported as well that the transfer of maternal antibodies to the offspring and the development of spleen and bursa of Fabricius in the embryo depend on the line of laying hens. Campo et al. (2001) noted some differences in the number of heterophils and lymphocytes in blood in various trade lines of hens. Also, Cheng et al. (2001)

demonstrated differences in the concentration of IgG immunoglobulins and heterophils and lymphocytes in blood of hens of various origin.

Native breeds of hens that are characterized by high resistance to unfavourable environmental conditions and pathogenic factors are basic material of animal origin that is used for ecological production (Cywa-Benko, 2002). These breeds are very well adapted to local, varying and often extreme environmental conditions. In opinion of Cywa-Benko (2002), roosters and hens of yellow-legged partridge breed are characterized by high immunity to diseases and high survival rate both in rearing and laying period, that clearly indicates their high immunity which is genetically determined. Carlander et al. (2003) compared IgY level in yolk of eggs laid by hens of different origin. The level of IgY in eggs laid by the Swedish line white leghorn amounted to 2.21 mg/ml, in yolks of the Swedish line of RIR hens – 1.68 mg/ml, whereas in the commercial trade lines of eggs – 1.95 mg/ml. Those authors also demonstrated a very distinct individual variation in the IgY level in egg yolks. Campo et al. (2008) showed the effect of origin on the formation of H:L ratio during their studies on Spanish native breeds of laying hens, highly productive hens from trade set and white leghorn hens.

Environmental stress and immunity

Environmental conditions in which the birds stay are responsible for the development of their immune system (Yunis et al., 2000; Nazar et al., 2015). Such factors include, for example, nutrition (Whitehead and Keller, 2003; El Hadri et al., 2004; Panda et al., 2012; Perween et al., 2016), stock (Heckert et al., 2002) or equipment of the henhouse (Heckert et al., 2002). Poultry maintenance system has the effect on the reactions of the immune system. According to Campo et al. (2008), keeping hens on the bedding is associated with higher H:L ratio, whereas providing them with access to green runs decreases H:L ratio. The same authors, Campo et al. (2005), also observed that hens kept in the henhouse fitted with roosts were characterized by lower H:L ratio compared to the hens kept without the access to roosts.

Numerous studies indicate that stress significantly affects immunity in animals (Puvadolpirod and Thaxton, 2000b; Odihambo et al., 2006). Stress has harmful effect on the organism's immune system: among others decreases the activity of the NK cells (Natural Killer Cell), reduces the level and proliferation of lymphocytes, production of antibodies and reactivates the occult viral infections. Such influence on the immune system has serious consequences for health that include, among others, delayed wound healing, impairment of the response to vaccination etc. (Webster and Glaser, 2008).

Chronic stress associated with the applied rearing system (it is worth noting that each poultry rearing system evokes stress stimuli of various intensity and duration) may disturb the production of antibodies and cellular immune response, which lead to increased susceptibility to viral infections. According to many authors, immunosuppression of the humoral immune response is an indicator of physiological reaction of organism to stress (Puvadolpirod and Thaxton, 2000a,

b; Jahanian and Rasouli, 2015; Nazar et al., 2015). Thus, particular emphasis is made on studying the development of immunity in poultry under various stressful conditions. Among others, an adverse effect of transport stress on the immune response (Wójcik et al., 2011) was observed, and social stress had a similar effect. Disturbance of social hierarchy in poultry flock decreases the immunity to bacterial and viral infections (Fitko et al., 1990). Stress factors affecting the immune system also include manipulation stress in the form of scaring and immobilization (Fitko et al., 1990; Wiśniewski et al., 1995; Lechowski et al., 1998). Chronic social stress evoked by a sequential change in the appearance of some birds in the flock affected the immune status of hens causing, among others, changes in leukocyte level and H:L ratio (Nazar et al., 2017). During the production process, poultry is permanently exposed to stress factors, among others associated with the applied rearing system. Hangalapura et al. (2004a, b) claimed that during chronic stress, activation of the immune cellular response occurs. In laying hens, the effect of stress was a decrease in the number white blood cells (Mashaly et al., 2004). In the opinion of Campo et al. (2007), light stress (24L:0D) impairs the function of the immune system, which exhibits, among others, in the increase in H:L ratio. Results of studies conducted by Leandro et al. (2011) demonstrated that the stocking density of birds in a battery of cages has the effect on the transfer of maternal antibodies to the offspring and the development of spleen and bursa of Fabricius in the embryo.

Thermal stress is one of the strongest stress factors and may even lead to falls (Quinteiro-Filho et al., 2010; Bartlett and Smith, 2003). Exposure to thermal stress inhibits the immune reactions in poultry, which may increase the susceptibility to infectious diseases and thus enhance the negative effects of overheating the organism in the aspect of poultry welfare and performance (Monson et al., 2018). However, the studies have indicated that thermal stress in poultry, depending on the type of stressor and its action, has had exciting or inhibiting effect on immune reactivity (Sosnówka-Czajka, 2000; Sosnówka-Czajka and Herbut, 2001; Heckert et al., 2002; Sosnówka-Czajka et al., 2003). On the other hand, it was demonstrated that thermal stress increases the heterophil to lymphocyte ratio, due to a decreased number of circulating lymphocytes and increased number of heterophils (Prieto and Campo, 2010; Felver-Gant et al., 2012). Bozkurt et al. (2012) subjected laying hens to thermal stress and observed a decrease in humoral immune response. However, Ghazi et al. (2012) demonstrated that in laying hens thermal stress decreased thymus and spleen weight. Soleimani et al. (2011) stated that heat stress affecting Cobb 500 broiler chicks resulted in, among others, an increase in H:L ratio. Also, Prieto and Campo (2010) demonstrated the effect of heat stress on the formation of H:L ratio. Niu et al. (2009b) and Quinteiro-Filho et al. (2010), subjected broiler chickens to heat stresses and then observed a reduction in the weight of lymphoid organs in these birds. Bartlett and Smith (2003) also noted that broilers subjected to heat stress were characterized by a decreased weight of thymus, bursa of Fabricius and spleen as well as lower IgM and IgG level and reduced macrophage ability to phagocytosis. However,

Aengwanich (2008) observed only a decrease in the weight of bursa of Fabricius in broiler chickens subjected to heat stress with a concomitant decrease in lymphocyte count. According to Niu et al. (2009a), heat stress applied to broiler chickens caused a significant decrease in the weight of lymphoid organs, level of antibodies and the phagocytic ability of macrophages. These results indicate that thermal stress significantly decreases the immunocompetence of birds. Cold stress also affects the immune system of birds causing, among others, an increase in H:L ratio (Campo et al., 2008).

According to Cheema et al. (2003), stress generally decreases the immune performance of broiler chickens, but organism immunity jest genetically determined, so the origin and genotype of birds and also the type and intensity of the stressor are crucial in the immune system reaction to stress.

Nutritive modification of bird immunity

Subject literature has reported that the addition of immunostimulants to feed or water for animals improves the immune status of the organism and thus may contribute to the improvement of performance results (Nasir and Grashorn, 2009, Gurbuz et al., 2010).

Diet modification can affect the immune response of the organism in broiler chickens (Cheema et al., 2003, Khajavi et al., 2003). Numerous feed additives stimulating the immune system are known – e.g. vitamins, fatty acids, oils, microelements or herbs (Swain et al., 2000, Wang et al., 2000). As it has been shown, in poultry farming many factors have an adverse effect on the immune system of birds, leading among others to a reduction in the weight of lymphoid organs (Ravindran et al., 2006). Singh et al. (2006), stimulated the immune system of broiler chickens with feed additives and found an increase in the weight of lymphoid organs; similar results were also obtained by other authors (Swain and Johri, 2000, Wang et al., 2000).

An increase in the level of unsaturated fatty acids in feed both in pure form and in the form of vegetable oils contributes to the improvement of performance of the immune system in birds (Puthpongsiriporn and Scheideler, 2005; Sosnówka-Czajka et al., 2005). Wang et al. (2004) administered LA and LNA to the laying hens of single comb white leghorn breed in feed in various proportions and obtained serum IgG concentration at the level of 5.6–11.8 mg/ml and IgY concentration in egg yolks ranging from 14.1 to 16.7 mg/ml.

A perennial plant called Eastern purple coneflower *(Echinacea purpurea)* is a very good immunostimulant that has been used in folk medicine for many years. Eastern purple coneflower is also used for the stimulation of immunity in animals (Allen, 2003). Coneflower stimulates the activity of the immune system and reduces the sensitivity to viral and bacterial infections (Świerczewska et al., 2003). Truchliński et al. (2006) successfully used coneflower juice to improve the general immunity in turkeys. Also, *Yucca schidigera* extract administered to laying hens at the amount of 100 mg/kg of feed may be used as the effective agent increasing blood serum IgG level (Alagawany et al., 2016).

Results of studies conducted by Salim et al. (2013) indicated that diet supplementation with *Lactobacillus reuteri* or a mixture of *Lactobacillus reuteri, Bacillus subtilis* and *Saccharomyces cerevisiae* increased the growth performance of birds at the early age and stimulated the immune response. Both the applied additives increased the general level of IgG, IgM and IgA in serum, whereas the mixture of *Lactobacillus reuteri, Bacillus subtilis and Saccharomyces cerevisiae increased the level of leukocytes and monocytes as well.*

Lipiński et al. (2009) administered broiler chickens with mixtures containing a prebiotic formulation with mannan oligosaccharides and observed an immediate activation of mechanisms of non-specific immune response to infections. Singh et al. (2006) found that the immunoglobulin complex in broiler chickens amounted to on average 2.46 g/dl, and if the immune system was stimulated by the addition of vitamin E and selenium to feed, it increased to the level of 2.99 g/dl. As it was shown by Saeed et al. (2018), L-theanine supplementation at the amount of 200 mg/kg of feed affected the increase in the weight of spleen and bursa of Fabricius in broiler chickens. However, higher L-theanine levels (300 mg/kg) may have a negative effect on chicken health.

Many research centres have conducted studies on methods for reducing the negative impact of heat stress on poultry immunity (Sahin et al., 2009, Hasheimi et al., 2013, Sarica et al., 2015). Wang et al. (2018) administered a probiotic formulation of *Bacillus subtilis* to broiler chickens exposed to heat stress. These authors demonstrated that under heat stress conditions, broiler chickens fed with the probiotic formulation containing *Bacillus subtilis* were able to effectively prevent decreases in immunity by the regulation of immunity modulated by microflora. On the other hand, Deng et al. (2012) showed the positive effect of a probiotic containing *Bacillus licheniformis* administered with feed on the improvement in the immune status of laying hens subjected to heat stress.

Mehaisen et al. (2017) observed that propolis improved the immune status of Japanese quails exposed to heat stress. According to Prieto and Cam, the (2010) dietary supplementation with capsaicin or allicin in broiler chickens treated with high temperatures caused a reduction in the H:L ratio. Monson et al. (2018) applied subcutaneous immunostimulation with lipopolysaccharide in two lines of chickens in order to reduce the negative effect of heat stress on the immune system. These authors showed a positive effect of the above-mentioned injection applied for the improvement of immunity, but the intensity of the organism reaction was largely dependent on the broiler chicken line.

Dietary supplementation of broiler chickens, both with organic and inorganic chromium under heat stress conditions, significantly increased the level of antibodies ($P < 0.01$), improved H:L ratio ($P < 0.05$) and also relative weight of thymus ($P < 0.05$) and spleen ($P < 0.01$). These results suggest that enriching broiler chicken diet with chromium, especially in the organic form, increases the level of immunocompetence in broiler chickens that used to be decreased due to heat stress (Ghazi et al., 2012). Niu et al. (2009a) attempted to assess the influence of selenium in diet on the immunocompetence of broiler chickens subjected to heat

stress conditions. These authors showed an increase in the level of phagocytic macrophages and specific antibodies after selenium administration to birds exposed to high temperatures, which indicates a stimulating effect of selenium on the immune system of birds under heat stress.

Summary

Summing up, in poultry breeding the birds are constantly exposed to factors that may significantly interfere with both the development and the functioning of the immune system. Immunity disturbances can be very detrimental to health and performance of hens, and thus lead to a decrease in the profitability of production. The selection of poultry breeds or lines characterized by high immunity and the use of natural additives that have a positive effect on the immune system of birds are the basic principles on which poultry production should be based, leading to the improvement of poultry production efficiency in the aspect of bird health. Therefore, the primary objective of a poultry producer should be to apply such practices that do not expose the birds to a decrease in immunity, but on the contrary – that improve their immune status. There are many known additives that improve the immunity of poultry, but there is still a need for further research in this field.

References

Adriaansen-Tennekes R., Decuypere E., Parmentier H.K., Savelkoul H.F.J. (2009). Chicken lines selected for their primary antibody response to sheep red blood cells show differential hypothalamic-pituitary-adrenal axis responsiveness to mild stressors. Poultry Sci., 88: 1879-1882.

Aengwanich W. (2008). Pathological changes and the effects of ascorbic acid on lesion scores of bursa of Fabricius in broilers under chronic heat stress. Res. J. Vet. Sci., 1: 62-66.

Alagawany M., Abd El-Hack M.E., El-Kholy M.S. (2016). Productive performance, egg quality, blood constituents, immune functions, and antioxidant parameters in laying hens fed diets with different levels of *Yucca schidigera* extract. Environ Sci. Pollut. Res. 23: 6774-6782.

Allen P.C. (2003). Dietary supplementation with *Echinacea* and development of immunity to challenge infection with coccidia. Parasitol. Res., 91, 1: 74-78.

Al-Natour M.Q., Ward L.A., Saif Y.M., Stewart-Brown B., Keck L.D. (2004). Effect of different levels of maternally derived antibodies on protection against infectious bursal disease virus. Avian Dis., 48, 1: 177-182.

Bartlett J.R., Smith M.O. (2003). Effects of different levels of zinc on the performance and immunocompetence of broilers under heat stress. Poultry Sci., 82: 1580-1588.

Bozkurt M., Kucukvilmaz K. Catli A.U., Cinar M., Bintas E., Coven F. (2012). Performance, egg quality, and immune response of laying hens fed diets supplemented with mannan-oligosaccharide or an essential oil mixture under moderate and hot environmental conditions. Poultry Sci., 91: 1379-1386.

Buitenhuis A.J., Rodenburg T.B., Wissink P.H., Visscher J., Koene P., Bovenhuis H., Ducro B.J., van der Poel J.J. (2004). Genetic and phenotypic correlations between feather pecking behavior, stress response, immune response, and egg quality traits in laying hens. Poultry Sci., 83, 7: 1077-1082.

Campo J.L., Gil M.G., Torres O., Davila S.G. (2001). Association between plumage condition and fear and stress levels in five breeds of chickens. Poultry Sci., 80: 549-555.

Campo J.L., Gil M.G, Dávila S.G., Muñoz I. (2005). Influence of perches and footpad dermatitis on tonic immobility and heterophil to lymphocyte ratio of chickens, Poultry Sci., 84, 7: 1004-1009.

Campo J.L., Gil M.G., Dávila S.G., Muñoz I. (2007). Effect of lighting stress on fluctuating asymmetry, heterophil-to-lymphocyte ratio, and tonic immobility duration in eleven breeds of

chickens. Poultry Sci., 86, 1: 37-45.
Campo J.L., Prieto M.T., Dávila S.G. (2008). Effects of housing system and cold stress on heterophil-to-lymphocyte ratio, fluctuating asymmetry, and tonic immobility duration of chickens. Poultry Sci., 87, 4: 621-626.
Carlander D., Wilhelmson M., Larsson A. (2003). Immunoglobulin Y levels in egg yolk from three chicken genotypes. Food Agric. Immunol., 15: 35-40.
Cheema M.A., Qureshi M.A., Havenstein G.B. (2003). A comparison of the immune response of a 2001 commercial broiler with a 1957 randombred broiler strain when fed representative 1957 and 2001 broiler diets. Poultry Sci., 82, 10: 1519-1529.
Chen H.L., Li D.F., Chang B.Y., Gong L.M., Dai J.G., Yi G.F. (2003). Effects of Chinese herbal polysaccharides on the immunity and growth performance of young broilers. Poultry Sci., 82: 364-370.
Cheng H.W., Eicher S.D., Chen Y., Singleton P., Muir W.M. (2001). Effect of genetic selection for group productivity and longevity on immunological and hematological parameters of chickens. Poultry Sci., 80: 1079-1086.
Cotter P.F., Van Eerden E. (2006). Natural anti-Gal and Salmonella-specific antibodies in bile and plasma of hens differing in diet efficiency. Poultry Sci., 85, 3: 435-440.
Cywa-Benko K. (2002). Charakterystyka genetyczna i fenotypowa rodzimych rodów kur objętych programem ochrony bioróżnorodności. Rocz. Nauk. Zoot. Rozprawy Habilitacyjne, 15.
Deng W., Dong X.F., Tong J.M., Zhang Q. (2012). The probiotic *Bacillus licheniformis* ameliorates heat stress-induced impairment of egg production, gut morphology, and intestinal mucosal immunity in laying hens. Poultry Sci., 91, 3: 575-582.
El Hadri L., Garlich J.D., Qureshi M.A., Ferket P.R., Odetallah N.H. (2004). Glucose and electrolyte supplementation of drinking water improve the immune responses of poults with inanition. Poultry Sci., 83, 5: 803-809.
Ericsson M., Fallahsharoudi A., Bergquist J., Kushnir M.M., Jensen P. (2014). Domestication effects on behavioural and hormonal responses to acute stress in chickens. Physiol. Behav., 133: 161-169.
Fallahsharoudi A., de Kock N., Johnsson M., Ubhayasekera S.J., Bergquist J., Wright D., Jensen P. (2015). Domestication effects on stress induced steroid secretion and adrenal gene expression in chickens. Sci. Rep.,16: 15345.
Fallahsharoudi A., de Kock N., Johnsson M., Bektic L., Ubhayasekera S.J., Bergquist J., Wright D., Jensen P. (2016). Genetic and targeted eQTL mapping reveals strong candidate genes modulating the stress response during chicken domestication. G3 (Bethesda, Md.), 7: 497-504.
Felver-Gant J.N., Mack L.A., Dennis R.L., Eicher S.D., Cheng H.W. (2012). Genetic variations alter physiological responses following heat stress in 2 strains of laying hens. Poultry Sci., 91: 1542-1551.
Fitko R., Rotkierwicz Z., Brzezińska M. (1990). Reakcja immunologiczna kurcząt w stresie manipulacji. Med. Weter., 11: 652-654.
Ghazi S., Habibian M., Moeini M.M., Abdolmohammadi A.R. (2012). Effects of different levels of organic and inorganic chromium on growth performance and immunocompetence of broilers under heat stress. Biol. Trace Elem. Res., 146: 309-317.
Gurbuz E., Balevi T., Kurtoglu V., Coskun B., Oznurlu Y., Kan Y., Kartal M. (2010). Effects of Echinacea extract on performance, antibody titres, and intestinal histology of layer chicks. British Poultry Sci., 51, 6: 805-810.
Hamal K.R., Burgess S.C., Pevzner I.Y., Erf G.F. (2006). Maternal antibody transfer from dams to their egg yolks, egg whites, and chicks in meat lines of chickens. Poultry Sci., 85: 1364-1372.
Hangalapura B.N., Nieuwland M.G.B., Busse J., Kemp B., Parmentier H.K. (2004a). Effect of duration of cold stress on plasma adrenal and thyroid hormone levels and immune responses in chicken lines divergently selected for antibody responses. Poultry Sci., 83: 1644-1649.
Hangalapura B.N., Nieuwland M.G., de Vries Reilingh G., van den Brand H., Kemp B., Parmentier H.K. (2004b). Durations of cold stress modulates overall immunity of chicken lines divergently selected for antibody responses. Poultry Sci., 83: 765-775.
Hangalapura B.N., Kaiser M.G., Poel J.J., Parmentier H.K., Lamont S.J. (2005). Cold stress equally enhances *in vivo* pro-inflammatory cytokine gene expression in chicken lines divergently selected for antibody responses. Dev. Comp. Immunol., 30, 5: 503-511.

Hasheimi S.R., Zulkifli I., Somchit M.N., Zunita Z., Loh T.C., Soleimani A.F., Tang S.C. (2013). Dietary supplementation of *Zingiber officinale* and *Zingiber zerumbet* to heat- stressed broiler chickens and its effect on heat shock protein 70 expression, blood parameters and body temperature. J. Anim. Physiol. Anim. Nutr., 97: 632-638.

Heckert R.A., Estevez I. Russek-Cohen E., Pettit-Riley R. (2002). Effects of density and perch availability on the immune status of broilers. Poultry Sci., 81: 451-457.

Jahanian R., Rasouli E. (2015). Dietary chromium methionine supplementation could alleviate immunosuppressive effects of heat stress in broiler chicks. J. Anim. Sci., 93: 3355-3363.

Khajavi M., Rahimi S., Hassan Z.M., Kamali M.A., Mousavi T. (2003). Effect of feed restriction early in life on humoral and cellular immunity of two commercial broiler strains under heat stress conditions. Br. Poultry Sci., 44, 3: 490-497.

Koenen M.E., Boonstra-Blom A.G., Jeurissen S.H. (2002). Immunological differences between layer- and broiler-type chickens. Vet. Immunol. Immunopathol., 8, 89: 47-56.

Koenen M.E., Kramer J. van der Hulst R., Heres L., Jeurissen S.H., Boersma WJ. (2004). Immunomodulation by probiotic lactobacilli in layer- and meat-type chickens. Brit. Poultry Sci., 45, 3: 355-366.

Leandro N.M., Ali R., Koci M., Moraes V., Eusebio-Balcazar P.E., Jornigan J., Malheiros M.J., Wineland R.D., Brake J., Oviedo-Rondón E.O. (2011). Maternal antibody transfer to broiler progeny varies among strains and is affected by grain source and cage density. Poultry Sci., 90, 12: 2730-2739.

Lechowski R., Sawosz E., Kluciński W., Chachułowa J., Siwicki A.K. (1998). Wpływ różnych rodzajów stresu na stężenie białek ostrej fazy, gamma globulin, białka całkowitego i aktywności lizozymu w surowicy świń. Med. Weter., 54, 9: 619-621.

Lipiński K., Tywończuk J., Siwicki A. (2009). Wpływ mannanoligosacharydów na status zdrowotny i jakość mięsa kurcząt brojlerów. Żywn. Nauk. Technol. Ja., 65: 26-33.

Løtvedt P., Fallahshahroudi A., Bektic L., Altimiras J., Jensen P. (2017). Chicken domestication changes expression of stress-related genes in brain, pituitary and adrenals. Neurobiology of stress, 7: 113-121.

Mashaly M.M., Hendricks G.L., Kalama M.A., Gehad A.E., Abbas A.O., Patterson P.H. (2004). Effect of heat stress on production parameters and immune responses of commercial laying hens. Poultry Sci., 83: 889-894.

Mehaisen G., Ibrahim R.M., Desoky A. A., Safaa H.M., El-Sayed O.A., Abass A.O. (2017). The importance of propolis in alleviating the negative physiological effects of heat stress in quail chicks. PloS one, 12, 10, doi:10.1371/journal.pone.0186907.

Monson M.S., Van Goor A.G., Ashwell C.M., Persia M.E., Rothschild M.F., Schmidt C.J., Lamont S.J. (2018). Immunomodulatory effects of heat stress and lipopolysaccharide on the bursal transcriptome in two distinct chicken lines. BMC genomics, 19, 1: 643.

Nasir Z., Grashorn M.A. (2009). *Echinacea:* A potential feed and water additive in poultry and swine production. Arch. Geflugelk., 73, 4: 227-236.

Nazar F.N., Marin R.H., Liste G., Campderrich I., Estevez I. (2015). Manipulation of the phenotypic appearance of individuals in groups of laying hens: effects on stress and immune-related variables. Stress, 18: 710-717.

Nazar F.N., Estevez I., Correa S.G., Marin R.H. (2017). Stress induced polarization of immune-neuroendocrine phenotypes in *Gallus gallus.* Sci. Rep., 7, 1: 8102.

Nestor K.E., Anderson J.W., Patterson R.A. (2000). Genetics of growth and reproduction in the turkey. 14. Changes in genetic parameters over thirty generations of selection for increased body weight. Poultry Sci., 79, 4: 445-452.

Niu Z., Liu F., Yan Q., Li L. (2009a). Effects of different levels of selenium on growth performance and immunocompetence of broilers under heat stress. Arch. Anim. Nutr., 63, 1: 56-65.

Niu Z.Y., Liu F.Z., Yan Q.L., Li W.C. (2009b). Effects of different levels of vitamin E on growth performance and immune responses of broilers under heat stress. Poultry Sci., 88: 2101-2107.

Odihambo M.J., Thaxton J.P., Vizzier-Thaxton Y., Dodson W.L. (2006). Physiological stress in laying hens. Poultry Sci., 85: 761-769.

Panda A.K., Rao S.V., Raju M.V., Niranjan M., Reddy M.R. (2012). Effect of nutrient density on production performance, egg quality and humoral immune response of brown laying (Dahlem Red) hens in the tropics. Trop. Anim. Health Prod., 44: 293-299.

Perween S., Kumar K.C., Kumar S., Singh P.K., Kumar M., Dey A. (2016). Effect of

feeding different dietary levels of energy and protein on growth performance and immune status of Vanaraja chicken in the tropic. Veterinary World, 9, 8: 893-899.
Prieto M.T., Campo J.L. (2010). Effect of heat and several additives related to stress levels on fluctuating asymmetry, heterophil:lymphocyte ratio, and tonic immobility duration in White Leghorn chicks. Poultry Sci., 89: 2071-2077.
Puthpongsiriporn U., Scheideler S.E. (2005). Effects of dietary ratio of linoleic to linolenic acid on performance, antibody production, and *in vitro* lymphocyte proliferation in two strains of leghorn pullet chicks. Poultry Sci., 84, 6: 846-857.
Puvadolpirod S., Thaxton J.P. (2000a). Model of physiological stress in chickens. 2. Dosimetry of adrenocorticotropin. Poultry Sci., 79: 370-376.
Puvadolpirod S., Thaxton J.P. (2000b). Model of physiological stress in chickens. 3. Temporal patterns of response. Poultry Sci., 79: 377-382.
Quinteiro-Filho W.M., Ribeiro A., Ferraz-de-Paula V., Pinheiro M.L., Sakai M., As L.R., Ferreira A.J., Palermo-Neto J. (2010). Heat stress impairs performance parameters, induces intestinal injury, and decreases macrophage activity in broiler chickens. Poultry Sci., 89: 1905-1914.
Ravindran V., Thomas D.V., Thomas D.G., Morel P.C.H. (2006). Performance and welfare of broilers as affected by stocking density and zinc bacitracin supplementation. Anim. Sci. J., 77: 110-116.
Rzedzicki J., Kowalska M. (1992). Immunosupresyjne działanie niektórych leków u zwierząt. Med. Weter., 48, 7: 291-293.
Saeed M., Yatao X., Hassan F.U., Arain M.A., Abd El-Hack M.E., Noreldin A.E., Sun C. (2018). Influence of graded levels of L-theanine dietary supplementation on growth performance, carcass traits, meat quality, organs histomorphometry, blood chemistry and immune response of broiler chickens. Int. J. Mol. Sci., 19, 2: 462.
Sahin N., Tuzcu M., Orhan C., Onderci M., Eroksuz Y., Dr Sahin K. (2009). The effects of vitamin C and E supplementation on heat shock protein 70 response of ovary and brain in heat- stressed quail. Brit. Poultry Sci., 50, 2: 259-265.
Salim H.M., Kang H.K., Akter N., Kim D.W., Kim J.H., Kim M.J., Na J.C., Jong H.B., Choi H.C., Suh O.S., Kim W.K. (2013). Supplementation of direct-fed microbials as an alternative to antibiotic on growth performance, immune response, cecal microbial population, and ileal morphology of broiler chickens. Poultry Sci., 92, 8: 2084-2090.
Sarica S., Özdemir D., Öztürk H. (2015). The effects of dietary oleuropein and organic selenium supplementation on performance and heat shock protein 70 response of brain in heat-stressed quail. Ital. J. Anim. Sci., 14:2, DOI: 10.4081/ijas.2015.3737.
Sarker N., Tsudzuki M., Nishibori M., Yasue H., Yamamoto Y. (2000). Cell-mediated and humoral immunity and phagocytic ability in chicken lines divergently selected for serum immunoglobulin M and G levels. Poultry Sci., 79: 1705-1709.
Siegel H.S. (1995). Gordon Memorial Lecture. Stress, strains and resistance. Brit. Poultry Sci., 36: 3-22.
Singh H., Sodhi S., Kaur R. (2006). Effects of dietary supplements of selenium, vitamin E or combinations of the two on antibody responses of broilers. Brit. Poultry Sci., 47: 714-719.
Singh N.S., Kumar S., Majumdar S., Sivaraman G.K., Shivakumar B.M. (2004). Studies on immunocompetence status in two turkey varieties in India. Brit. Poultry Sci., 45, 5: 619-623.
Sivaraman G.K., Kumar S., Saxena V.K., Singh N.S., Shivakumar B.M. (2005). Genetics of immunocompetent traits in a synthetic broiler dam line. Brit. Poultry Sci., 46: 169-174.
Soleimani A.F., Zulkifli I., Omar A.R., Raha A.R. (2011). Physiological responses of 3 chicken breeds to acute heat stress. Poultry Sci., 90: 1435-1440.
Sosnówka-Czajka E. (2000). Wpływ krótkotrwałych zmian temperatury na produkcyjność i wskaźniki fizjologiczne kurcząt brojlerów. Zesz. Nauk. PTZ, 49: 90-91.
Sosnówka-Czajka E., Herbut E. (2001). Effect of short-term thermal stress early in rearing on performance and physiological indicators of broiler chickens. Ann. Anim. Sci., 1, 2: 187-197.
Sosnówka-Czajka E., Herbut E., Pietras M. (2003). Effect of thermal stress on physiological indicators of broiler chickens. XI International Congress in Animal Hygiene, 23-27.02.2003, Mexico City, 837.
Sosnówka-Czajka E., Skomorucha I., Herbut E., Muchacka R. (2005). Effect of

free fatty acids and heat stress on productivity and yolk sac resorption in broiler chickens. Scientific Messenger of Lviv National Academy of Veterinary Medicine, 7, 2: 200-204.

Swain B.K., Johri T.S. (2000). Effect of supplementation of different levels of selenium and vitamin E on the relative weight of some organs and serum enzyme level in broilers. Indian Journal of Poultry Science, 35: 66-69.

Swain B.K., Johri T.S., Majumdar S. (2000). Effect of supplementation of vitamin E, selenium and their different combinations on the performance and immune response of broilers. Brit. Poultry Sci., 41: 287-292.

Świerczewska E., Niemiec J., Noworyta-Głowacka J. (2003). A note on the effect of immunostimulation of laying hens on the lysosyme activity in egg white. Anim. Sci. Pap. Rep., 21, 1: 63-68.

Trawińska B., Saba L., Tymczyna L. (2003). Status immunologiczny kur reprodukcyjnych w fermie. Med. Weter., 59: 243-246.

Truchliński J., Krauze M., Cendrowska-Pinkosz M., Modzelewska-Banachiewicz B. (2006). Influence of garlic, synthetic 1,2,4-triasole derivative and herbal preparation Echinovit C on selected indices of turkey-hens non-specific immunity. Pol. J. Veter. Sci., 9, 1: 51-55.

Van den Brand H., Parmentier H.K., Kemp B. (2004). Selection for antibody response against sheep red blood cells and layer age affect egg quality. Brit. Poultry Sci., 45, 6: 787-792.

Van Eerden E. Van Den Brand H., Parmentier H.K., De Jong M.C., Kemp B. (2004). Phenotypic selection for residual feed intake and its effect on humoral immune responses in growing layer hens. Poultry Sci., 83, 9: 1602-1609.

Wang W.C., Yan F.F., Hu J.Y., Amen O.A., Cheng H.W. (2018). Supplementation of *Bacillus* subtilis-based probiotic reduces heat stress-related behaviors and inflammatory response in broiler chickens, J. Anim. Sci., 96, 5: 1654-1666.

Wang Y.W., Field C.J., Sim J.S. (2000). Dietary polyunsaturated fatty acids alter lymphocyte subset proportion and proliferation, serum immunoglobulin G concentration, and immune tissue development in chicks. Poultry Sci., 79: 1741-1748.

Wang Y.W., Sunwoo H., Cherian G., Sim J.S. (2004). Maternal dietary ratio of linoleic acid to a-linolenic acid affects the passive immunity of hatching chicks. Poultry Sci., 83: 2039-2043.

Webster M.J.I., Glaser R. (2008). Stress hormones and immune function. Cell. Immun., 252: 16-26.

Whitehead C.C., Keller T. (2003). An update on ascorbic acid in poultry. World's Poultry Sci. J., 59: 161-184.

Wiśniewski J., Grabowska G., Rotkiewicz Z., Fitko R. (1995). Pierwotna i wtórna odpowiedź immunologiczna kurcząt w stanie stresu wywołanego długotrwałym unieruchomieniem. Med. Weter., 1: 31-33.

Wójcik A., Sowińska J., Witkowska D., Kamińska B., Mazur-Lech B., Stenzel T., Mielcarek S., Mituniewicz T., Pomianowski J. F. (2011). Możliwości wykorzystania ziół w celu poprawy dobrostanu kurcząt brojlerów w czasie obrotu przedubojowego ocenianego na podstawie wybranych parametrów krwi. Zesz. Nauk. UP Wroc., Biol. Hod. Zwierz., LXIII, 583: 355-362.

Yang N., Larsen C.T., Dunnington T.E.A., Geraert P.A., Picard P.M., Siegel P.B. (2000). Immune competence of chicks from two lines divergently selected for antibody response to sheep red blood cells as affected by supplemental vitamin E. Poultry Sci., 79: 683-690.

Yonash N., Bacon L.D., Smith E.J. (2002). Concentration of immunoglobulin G in plasma varies among 6C.7 recombinant congenic strains of chickens. Poultry Sci., 81: 1104-1108.

Yunis R., Ben-David A., Heller E.D., Cahaner A. (2000). Immunocompetence and viability under commercial conditions of broiler groups differing in growth rate and in antibody response to *Escherichia coli* vaccine. Poultry Sci., 79: 810-816.

Zulkifli L., Abdullah N., Mohd. Azrin N., Ho Y.W. (2000). Growth performance and immune response of two commercial broiler strains fed diets containing *Lactobacillus* cultures and oxytetracycline under heat stress conditions. Brit. Poultry Sci., 41: 593-597.

Accepted for print on 11 January 2019

EWA SOSNÓWKA-CZAJKA, IWONA SKOMORUCHA

Factors affecting immunity in poultry

SUMMARY

In poultry breeding, many factors adversely affect the birds' immune system, leading among others to reduced weight of lymphoid organs and a decline in antibody or lymphocyte production. According to many authors, breeding work performed over recent years, in which the main focus was on improved growth parameters, is inversely correlated with some immunity parameters of broiler chickens.

Both scientists and practical breeders increasingly report about declining immunity and the incidence of immune system defects in poultry. Modern breeding programmes should account for the body's natural immunity to disease; this is all the more important since poultry producers are phasing out antibiotics and synthetic additives, which reduce the quality of poultry products. Provision of birds with rearing conditions that do not reduce immune system efficiency and, on the contrary, contribute to improved health, is a vital element of poultry production. The immune system in poultry, just as in other animals, is dependent on their origin and the origin by environment interaction. In recent years, modification of immune processes has attracted the interest of many centres around the world. Research was conducted on many modulators of immune response and substances enhancing the body's immunity to various infections. However, the best way of achieving immunoprophylaxis in poultry production is to select resistant breeds or lines and to use breeding practices aimed at creating strong immunity and preventing infections. This should be supported by the use of dietary immunostimulants, preferably of natural origin, in particular phytotherapy.

Key words: immunity, stress, genotype, poultry