THE IMPORTANCE OF NUTRITION IN ALLEVIATING HIGH STOCKING DENSITY STRESS IN POULTRY – A REVIEW

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Abstract

In recent decades, the number of birds reared per unit area has dramatically spiked to increase profitability in egg and meat production. However, nowadays, the increase in sensitivity to animal welfare and consumer demands brings along with it a raised interest in stocking density. Stocking density is defined either as the number of animals or body weight per unit area or as the area per animal. High stocking density, which is a stress factor, can be defined as an increase in the number of animals per unit area or a decrease in the area per animal. Stress caused by high stocking density negatively affects the bird's physiology and performance as well as the quality of the product obtained. The ideal stocking density should be 9 laying hens, 35 kilograms for broilers, and 45 quails per square metre. Otherwise, one will observe stress indicators in birds reared in more than the recommended stocking density per unit area and, consequently, a decrease in bird growth, egg production, feed efficiency, and egg or meat quality. Apart from increasing the concentrations of amino acids such as lysine, methionine, tryptophan and arginine, minerals such as selenium and chromium, and vitamins such as C and E in the diet, the addition of additives such as probiotics, humates, phytochemical compounds, and propolis is also effective in reducing or eliminating these negative effects caused by high stocking density. As a result, regulations in the nutrition of animals are effective in reducing/preventing such negative effects, thus improving animal welfare and ensuring the maintenance of optimum yield.

Key words: stocking density, stress, nutrition, laying hen, broiler

Today, the demand for food of animal origin for adequate and balanced nutrition is constantly increasing. In parallel with this, the issue of producing animal proteins in the cheapest way and in the shortest time takes an important place. Poultry production is placed near the top in this respect. To increase profitability in the poultry industry, which is continuously developing in terms of both the amount of product and productivity in the world, one should aim to rear more birds per unit area as well as optimise the genetic structure and feeding and raising conditions.

Stocking density, which is defined as the number of animals per unit area or body weight (Estevez, 2007), is a very important issue in poultry production as it is closely related to performance and animal welfare problems (Zhang et al., 2013). With the rapid development of the poultry industry, many breeders aim to obtain more products per unit area with the highest possible stocking density to achieve more economic benefits. However, since high stocking density causes stress in poultry and hence negatively affects the welfare, health, and performance of the birds, it has become a remarkable issue in recent years (Yin et al., 2017; Sapsuha et al., 2021).

A characteristic feature of living organisms is their ability to try to maintain physiological and biochemical homeostasis. Pawlak and Kontecka (1995) defined

all factors that disrupt this stability (homeostasis) as stressors and the response to them as stress. According to Sugiharto et al. (2017), 'stress' is a term that describes the organism's responses to abnormal circumstances that potentially disrupt homeostasis or normal physiological balance. Therefore, stress represents the organism's response (a biological response) to stimuli that disrupt normal physiological balance or homeostasis. In industrial poultry production, the birds are exposed to a series of stress factors. Stress, depending on the factor and its density, can create positive effects by initiating high adaptation and increasing the general immunity of the organism. All that being said, the extent and consequences of metabolic events are determined by the type, prevalence, and duration of stress, and exposure to very immense and long-term stress factors can cause impaired immunity, decreased production performance, the increased incidence of pathological symptoms, and even death (Fitko et al., 1992; Pijarska et al., 2006).

With regard to animal welfare, high stocking density should be avoided, and a sufficient range should be left for the birds to exhibit natural behaviour. However, feeding strategies are important in preventing the loss of yield and product quality as a result of the stress caused by high stocking density if more birds are housed in the unit area than recommended. For this purpose, it was reported that

increasing amino acid (Srinongkote et al., 2004; Toghyani et al., 2016), vitamin (Desoky and Kamel, 2018; Wang et al., 2021), and mineral (Sohail et al., 2001; Jahanian and Mirfendereski, 2015) concentrations in the diet and the supplementation of additives (Ma et al., 2020; Wu et al., 2020 a) are effective in reducing/preventing high stocking density stress. In light of the above information, this review aims to briefly provide information about the ideal stocking density and the negative effects of high stocking density stress as well as to evaluate the prevention of these adverse effects on poultry by nutrition.

High stocking density stress and optimum stocking density

Increasing the number of birds reared per unit area is a factor that reduces housing and equipment costs. More animals being housed in a unit area can cause the birds' skeletal and muscle development and performance to be adversely affected because of the reduction of feeders and drinkers per bird and the limitation of movement (Cengiz et al., 2015). Along with the decrease in body weight, feed intake, and feed efficiency (López-López et al., 2021; Guardia et al., 2011; Zuowei et al., 2011; Tong et al., 2012; Sun et al., 2013; Cengiz et al., 2015) in broilers with increasing stocking density, footpad dermatitis, foot swelling, hyperkeratosis, and leg weakness increase (Sørensen et al., 2000; Dozier et al., 2005; Lay et al., 2011), small intestinal villi structures deteriorate, and nutrient absorption diminishes (Shakeri et al., 2014; Li et al., 2017). However, high stocking density decreases lymphocytes and increases heterophiles among the immune components (thus an augmented heterophile:lymphocyte ratio) (Astaneh et al., 2018), reducing the immune response (Mustafa et al., 2010; Turkyilmaz, 2008). In addition, high stocking density can increase the incidence of footpad and hock problems as a result of such density negatively affecting litter quality (Kang et al., 2016). As well, more than the recommended stocking density can cause adverse environmental conditions such as heat stress and a decrease in airflow, in which case individual deaths can be observed (Feddes et al., 2002).

The optimum values suggested in some studies in the literature on the stocking density considerably affecting the health and welfare of poultry are as follows. The European Union Council Directive 1999/74/EC determined the maximum stocking density for laying hens as 9 hens/m² (750 cm²/hen, minimum) after 1 January 2012. The United Egg Producers (UEP, 2008) on the other hand, suggested the optimum stocking density for white and brown strains as 432 and 555 cm²/hen, respectively. Other studies noted that the optimum stocking density for laying hens is 375 cm²/hen until 45 weeks of age and 450 cm²/hen after 45 weeks of age (Rios et al., 2009), 733 cm²/hen (Benyi et al., 2006) or 7–9 hens/m² (Zimmerman et al., 2006) in semi-arid regions, and 1,000–2,000 cm²/hen (Saki et al., 2012) or 5 hens/m² (Kang et al., 2016) depending on the financial condition of the enterprise. EU 2007/43/EC stated that the stocking density for broil-

ers should be 33 kg/m², which could be 39 kg/m² under more proper housing conditions, and 42 kg/m² if herd management and viability can be guaranteed (European Union, 2007). Nasr et al. (2021) reported that the optimum stocking density in broiler chicks is 18 birds/m² in terms of both performance and animal welfare. Other values for the optimum stocking density for broilers include 17 birds/m² (Gholami et al., 2020), 14–18 birds/m² (Kryeziu et al., 2018), 14.3 birds/m² (Feddes et al., 2002) in arid regions, and 30 chicks/m² depending on age (Qaid et al., 2016). Some researchers reported that the stocking density could be increased up to 50 kg/m² in coops with litter (Shanawany, 1988; Grashorn and Kutritz, 1991; Thaxton et al., 2006). For laying quails, the stocking density was indicated as 45 quails/m² (Ratriyanto et al., 2020). The research results explained above demonstrate that the optimum stocking density differs at different ages and under different environments, or production systems.

The stress mechanism consists of three phases: alarm, adaptation, and exhaustion. In these phases, glucocorticoids (Ravindran et al., 2006) as well as blood glucose (Puvadolpirod and Thaxton, 2000) and cholesterol (Dozier et al., 2006) levels increase, an imbalance in the heterophil:lymphocyte is observed because of a decrease in lymphocytes, and some changes such as an increase in pulsation, blood pressure and respiratory rate are experienced. Adrenal insufficiency seen in the exhaustion phase causes pathological changes, and ultimately death occurs (Öziş Altınçekiç and Koyuncu, 2012). To reduce stress in poultry, methods such as the enrichment and improvement of environmental conditions and breeding practices are used. Along with the management methods applied in previous years, interest in diet manipulation has increased in recent years (Taşkın et al., 2015). For this reason, this review focuses on this issue.

Prevention of stocking density stress by nutrition

Importance of protein and amino acids in diet

Protein synthesised in poultry plays an important role in the structure of products such as meat and eggs as well as in the formation of feathers that protect the skin against wounds and infections (Lopez-Coello, 2003), improving immunity (Swain and Johri, 2000; Attia et al., 2005). The effects of some essential amino acids, which are important in the synthesis of proteins, in animals exposed to stress are summarised below.

Methionine is the first limiting amino acid because the vegetable protein sources used in the diet are insufficient in terms of this amino acid, and it is necessary for feather growth and protein synthesis. Foot and hock wounds are related to each other, and these are caused by high stocking density and high litter moisture (Mayne, 2005; Dozier et al., 2005). Toghyani et al. (2016) reported that foot and hock injuries increased in broilers reared at high stocking densities (16 or 18 chicks/m²) and that these problems were reduced with the use of high levels of sulphurous amino acids (120% of need) in the diet. Miao et al. (2021) stated that the negative effects

of high stocking density (20 birds/m²) on the immunity of broilers could be prevented by adding methionine to the diet (0.40%–0.45%), but this positive effect was not observed in the performance, and while a 0.40% dietary methionine level was sufficient in optimum density (14 birds/m²), this should be 0.45% in high stocking density (20 birds/m²).

Lysine (Chang et al., 1993) and arginine (McCracken and Stewart, 2001; Obled et al., 2002) are two amino acids that can reduce the adverse effects of stress. However, the effects of stress factors on the mentioned amino acids differ because of the antagonism between them (Han and Baker, 1993; Brake et al., 1998). The addition of lysine and arginine double the recommended level to the diets of broilers reared at high stocking density (12 broilers/m²) increases body weight and lymphocytes, but this positive effect is not observed in carcass yield and neutrophil and monocyte counts (Srinongkote et al., 2004).

Tryptophan is an essential amino acid in monogastric animals since it cannot be synthesised. Rech et al. (2010) stated that the negative effects of high stocking density on laying hens housed at densities of 563, 450, or 375 cm²/hen were not affected by different levels of tryptophan (0.175%, 0.195%, 0.392%, or 0.591%) in the diet. In another study, 0.18% tryptophan was effective in improving feed efficiency, and 0.27% tryptophan was effective in increasing plasma glucose levels in broilers under high stocking density (11 and 15.4 chicks/m²) stress (Wang et al., 2014).

It can be said that individual essential amino acid needs, which can vary according to yield aspect and period, are higher when the birds are exposed to high stress. Therefore, the positive effect of increasing the amounts of methionine, lysine, and other essential amino acids in the diet can be attributed to this.

Importance of energy level of diet

Sarıözkan et al. (2009) stated that the stocking density (285.7 and 500 cm²/hen) did not affect performance in laying hens, but for hens fed with diets containing high energy (2,850 kcal/kg), feed intake decreased, and feed efficiency improved compared with hens fed with diets containing low energy (2,650 kcal/kg).

Importance of vitamins

It was reported that the supplementation of 25-hydroxycholecalciferol to the diet increased body weight gain (Bello et al., 2013), improved the meat quality of broilers, and diminished tibial dysplasia (Ledwaba and Roberson 2003; Świątkiewicz et al., 2006), while hatchability, immunity (Saunders-Blades and Korver, 2015), and eggshell quality (Keshavarz, 2003) in chickens improved. In laying hens aged 45 weeks, reared at low (506 cm²/hen) and high (338 cm²/hen) stocking densities, egg production, egg weight, feed intake, eggshell quality, tibia (Wang et al., 2020) and duodenal crypt depth, short-chain fatty acids (propionic and butyric acid) in the cecum, and serum levels of superoxide dismutase, catalase,

and malondialdehyde (Wang et al., 2021) were adversely affected from high stocking density, but the addition of 69 µg/kg of vitamin D₃ to the diet was effective in eliminating these negative effects (Wang et al., 2020, 2021).

Vitamin E is considered an essential nutrient for the growth and health of all animal species (McDowell, 2012). One of the most important properties of vitamin E, which is very important in terms of nutritional myopathy, prostaglandin biosynthesis and immunity, is that it is a powerful antioxidant. Vitamin E protects cells and tissues from oxidative damage caused by free radicals (Lin et al., 1996). Adebisi (2011) examined the effects of supplementing 0, 50, 100, or 150 mg/kg of vitamin E (alpha-tocopherol acetate) to the diets of broilers at different stocking densities (10 and 20 chicks/m²) and announced that the broilers can be raised at 20 chicks/m² by adding 100 mg/kg of vitamin E to the diet. Desoky and Kamel (2018), on the other hand, showed that the body weight gain and feed efficiency of Japanese quail chicks reared at different stocking densities (80 and 100 chicks/m²) were adversely affected by the high density (100 chicks/m²), but the mentioned parameters as well as mineral accumulation improved with the addition of 200 mg/kg of vitamin E to the diet.

Vitamin C is a vitamin that is effective in stress circumstances (Naseem et al., 2005). Vitamin C concentration in the plasma, which plays a role in the synthesis of white blood cells alongside participating in mineral and amino acid metabolism, decreases under stress conditions, and its synthesised amount cannot satisfy this need (Khan et al., 2012; Attia et al., 2018). It was found that the decreased plasma vitamin C level in laying hens exposed to high stocking density (7 hens/0.18 m²) stress, ascended again with the addition of ascorbic acid to the diet, that plasma corticosterone concentration and malondialdehyde levels of plasma and yolk decreased again, and that feed efficiency improved considerably (Mirfendereski and Jahanian, 2015). Similarly, vitamin C can alleviate the harmful effects of stress by reducing the synthesis and secretion of corticosteroids (McDowell, 2000). Ratriyanto et al. (2020) stated that the supplementation of 250 mg/kg vitamin C to the diets of quails reared at 40, 45, and 50 quails/m² densities prevented the decrease in egg production of quails housed at high stocking density (50 quails/m²). The positive effect of vitamin C supplementation in stress circumstances is due to the insufficient amount of its synthesised form under these conditions; this situation causes protein catabolism and low protein biosynthesis given the increase of cytotoxic free radicals that damage the cell and cell membranes (İpek et al., 2007).

Importance of minerals

Articles on the use of minerals in eliminating the negative effects of high stocking density on poultry are quite few compared with those on vitamins and additives. These studies are summarised below. Sohail et al. (2001) indicated that egg production and feed intake linearly declined with the increase in stocking density

(300, 400 or 600 cm²/hen); egg production subsequently advanced with the increasing available phosphorus level (from 0.15% to 0.40%) in the diet, and this could be due to the decrease in feed and phosphorus intake caused by stocking density.

Copper is an essential element in the use of iron in the synthesis of haemoglobin and as a cofactor for enzymes such as cytochrome A, ascorbic acid oxidase, and superoxide dismutase (Wedekind et al., 1992; İpek et al., 2003). Olgun and Aygun (2017) reported that the stocking density (500, 417, and 357 cm²/hen) did not affect the perfor-

mance of aged laying hens, but interestingly, it advanced eggshell thickness, and the heterophile:lymphocyte ratio changed significantly with the addition of copper in the group with the highest stocking density. The supplementation of selenium at levels of 0.15 and 0.30 mg/kg to the diets of Japanese quail chicks reared at high stocking density (100 chicks/m²) was effective in eliminating the negative effects of stocking density stress on body weight and feed efficiency and also regulated calcium and phosphorus metabolism levels (Desoky and Kamel, 2018).

Table 1. The effect of some nutrients/additives on the prevention of high stocking density stress

Birds	Age	Stocking density	Nutrient/additive	Results	References
Nutrients					
Broilers	22 d	20 chicks/m ²	Methionine, 0.35, 0.40, 0.45 or 0.50%	Oxidative stress decreased	Miao et al. (2021)
Broilers	18 d	12 chicks/m ²	Lysine and arginine, twice as much of need	Animal welfare and feed efficiency improved	Srinongkote et al. (2004)
Broilers	25 d	15.4 chicks/m ²	Tryptophan, 0.27%	Animal welfare and feed efficiency improved	Wang et al. (2014)
Laying hens	45 wk	338 cm ² /hen	25-hydroxycholecalciferol, 69 µg/kg	Performance and bone quality traits improved	Wang et al. (2020)
Growing quails	8 d	100 quails/m ²	Vitamin E, 200 mg/kg Selenium, 0.30 mg/kg Vitamin E 50 + selenium 0.15 mg/kg	Body weight gain and feed efficiency increased	Desoky and Kamel (2018)
Laying hens	26 wk	7 hens/cage (40x45 cm)	Organic chromium, 500 and 1000 µg/kg Vitamin C 500 mg/kg	Chromium improved performance and antioxidant capacity, plasma MDA level decreased. Vitamin C diminished MDA of plasma and yolk	Jahanian and Mirfendereski (2015)
Additives					
Laying hens	54 wk	360 cm ² /hen	Probiotic, 0.15 and 0.30%	Performance and metabolic profile improved	Yörük et al. (2004)
Layer quails	10 wk	84 and 126 cm ² /quail	Humate and prebiotic, 0.2%	Egg production, egg weight and feed efficiency advanced when both were added	Yörük et al. (2008)
Broilers	22 d	18 chicks/m ²	Alpha-lipoic acid, 300 mg/kg	Performance improved, physiological response to stress increased	Ma et al. (2020)
Broilers	21 d	18 chicks/m ²	Nicotinamide, 50 and 100 mg/kg Sodium butyrate, 500 and 1000 mg/kg	Meat quality increased	Wu et al. (2020 b)
Laying hens	50 wk	580 cm ² /hen	Tarragon, 1.2, 6.0 or 12 mg/kg	Performance, immune system and intestinal microflora were positively affected	Kaya et al. (2021)
Growing quails	8 d	80 cm ² /quail	Propolis ethanol extract, 0.5, 1.0 or 1.5 mg/kg	Body weight, feed intake and feed efficiency improved	Arslan et al. (2014)
Growing quails	7 d	90 cm ² /quail	Thyme volatile oil, 200, 400 or 600 mg/kg	Intestinal microflora, performance and carcass advanced	Önel and Aksu (2020)
Broilers	15 d	10 and 16 birds/m ²	Encapsulated <i>Cosmos caudatus</i> leaf extract, 0.5 and 1.0 g/kg	Body weight increased	Agusetyaningsih et al. (2021)
Broilers	15 d	16 birds/m ²	Nutmeg flesh extract, 0.5, 1.0, 1.5 ml/kg	Improved performance parameters	Sapsuha et al. (2021)
Broilers	1 d	25, 30, 35, and 40 kg/m ²	Lemongrass essential oil and tea tree essential oil, 300 mg/kg	Better results were obtained from tea tree essential oil than lemongrass essential oil	Ghanima et al. (2021)

Chromium is essential for carbohydrate, fat, and protein metabolism (McCarty, 1991; Anderson, 1997). Stress and illness increase the urinary excretion of chromium (Anderson et al., 1988), and augmented chromium excretion can increase the need for this element and can create significant deficiency in stress circumstances (Starich and Blincoe, 1983). It was found that the addition of chromium (0, 500, or 1,000 µg/kg) to the diets of laying hens exposed to stocking density stress (5 and 7 hens/0.18 m²) was effective in eliminating the adverse effects of high stocking density on egg production, egg mass, and feed efficiency, and the serum vitamin C level and antioxidant capacity in the birds increased (Jahanian and Mirfendereski, 2015). The same researchers (Mirfendereski and Jahanian, 2015) clarified that the plasma insulin and glucose levels became concentrated as the stocking density increased and descended with the addition of chromium to the diet; also, high stocking density considerably increased the plasma corticosterone level, but the chromium and stocking density interaction did not significantly affect plasma corticosterone.

Boron is very important for various metabolic and physiological systems, although its biochemical mechanism in humans and animals has not been fully determined (Hunt, 2003). On the other hand, Özdemir et al. (2016) – by adding 0, 25, 50, or 75 mg/kg of boron to the diets of quails with stocking densities of 70, 65, and 50 cm²/quail – reported no interaction between the stocking density and boron when the performance parameters were examined cumulatively; however, the positive effects of boron addition increased as the stocking density decreased on the thymus weight and the size of the bursa of Fabricius.

Importance of additives

First of all, additives, which do not have harmful effects on human or animal health, are added to the diet and positively affect the performance and product quality of the animals, and these are widely used in poultry nutrition today. Additives can also have beneficial effects in reducing the stress caused by high stocking density (Table 1).

Probiotics and prebiotics

Stress factors negatively affect intestinal microflora balance and cause decreases in product quantity and quality (Lan et al., 2004). Probiotics and prebiotics are additives that increase the number of lactic acid bacteria in the intestinal microflora, suppress the increase of intestinal pathogens, and strengthen immunity (Jadamus et al., 2001; Ehrmann et al., 2002; Ghareeb et al., 2008). Given these positive effects on the intestinal microflora, probiotics and prebiotics can be added to the diets of birds as stress reducers. It was explained that the supplementation of 0.15% and 0.30% probiotics to the diets of hens housed in 540–360 cm²/bird stocking densities improves feed intake and feed efficiency, which are negatively affected by stocking density (Hayirli et al., 2005). Also, the

addition of 2 and 1 g/kg of prebiotics to the starter and finisher diets, respectively, did not considerably affect performance, lymphoid organ weight, and blood glucose, cholesterol, and corticosterone concentrations as well as the heterophile:lymphocyte ratio in broilers raised at high stocking density (16 birds/m²) (Houshmand et al., 2012). In contrast, Yörük et al. (2008) reported that the increased stocking density (84, 126, and 252 cm²/quail) of quails affected their performance and blood parameters negatively, but these negative effects were reduced with the supplementation of 0.2% prebiotics (dextran oligosaccharide) to the diet.

Humates

Humates are composed of humic acids and salts originated from humus formed by some substances such as carbohydrates, amino acids, and phenols, which are the decomposition products of organic substances in the soil. Furthermore, humic acids are composed of humic, fulvic, and ulmic acids as well as salts and minerals from humus. It was clarified that humate compounds prevent the growth of pathogenic microorganisms by providing optimum pH formation in the digestive tract, increasing the bioavailability of calcium and various trace minerals (İslam et al., 2005); humic and fulvic acids also play a role in the detoxification of pathogenic bacterial toxins by chelating with heavy metals such as lead and mercury (Klocking, 1980). Çetin et al. (2011) found that the lymphocyte count descended in hens housed at two different densities (287 and 500 cm²/bird) given the increase in stocking density, and when 0.15% humate was added to the diet, the lymphocyte count became concentrated. According to research conducted with quails reared at different stocking densities (252, 126, or 84 cm²/quail), as the stocking density increased, the body weight changed, and egg production, egg weight, feed efficiency, and blood traits were adversely affected; this negative effect of stocking density was reduced by adding 0.2% humate to the diet (Yörük et al., 2008).

Herbal products

Zhang et al. (2013) reported that the supplementation of 100 mg/kg of *Forsythia suspensa*, 100 mg/kg of berberine, and 100 mg/kg of *Forsythia suspensa* + 100 mg/kg of berberine to the diets of 6 (28 kg/m²) or 10 (46 kg/m²) broilers raised in 0.54 m² positively affected the birds' performance by increasing immunity, reducing oxidative stress, and improving digestive system microflora at high stocking density. Another study reported that the administration of 0.5 and 1.0 g/kg of encapsulated *Cosmos caudatus* leaf extract to broiler diets had a positive effect on body weight at high stocking density (10 and 16 birds/m², respectively) (Agusetyaningsih et al., 2021). By adding 0, 1.2, 6, or 12 g/kg of tarragon (*Artemisia dracuncululus* L.) to the diets of laying hens housed at different densities (5 or 7 hens/cage), serum corticosterone, total immunoglobulin and total oxidant concentrations, malondialdehyde levels of the serum, liver, and egg, and

intestinal *E. coli* decreased; on the contrary, serum IgG levels increased in hens at high stocking density (7 hens/m²) (Kaya et al., 2021). The addition of 200, 400, and 600 mg/kg of thyme essential oil to the diets of quails reared at high stocking density (90 cm²/quail) eliminated the negative effects of stocking density on performance, carcass, and small intestine microflora; it would also be beneficial to supplement a high level (600 mg/kg) of thyme essential oil to the diet so as to remove the negative effects of high stocking density (Önel and Aksu, 2020). In addition, Sapsuha et al. (2021) stated that the supplementation of 0.5, 1.0, and 1.5 ml/kg of nutmeg flesh extract to the diets of broiler chicks raised at high stocking density (16 birds/m²) improved performance parameters without affecting internal organ weight and carcass yield.

Apitherapy

Bee products are widely used in traditional medicine given their antioxidant, antimicrobial and anti-inflammatory properties (Aygun et al., 2012). It is reported that bee pollen, which contains almost all of the major and minor elements, is rich in protein, carbohydrates and lipids (Villanueva et al., 2002), has a protective effect against free radicals (Aliyazıcıoğlu et al., 2005) and contains polyphenol compounds with significant antioxidant potential (Campos et al., 1997; Schmidt, 1997). Some researchers declared that the supplementation of 1 g/kg of bee pollen (Seven et al., 2011) or 0.5 1.0 or 1.5 g/kg of propolis ether extract (Arslan et al., 2014) to quail chicks diets raised at different densities (80 and 160 cm²/chick) eliminated the negative effects of high stocking density on performance. In another study by the same researchers, the administration of royal jelly at 250 and 500 mg/kg of body weight to quails was effective in eliminating the negative effects of high stocking on body weight, body weight gain, and feed intake (Seven et al., 2014). This positive effect of bee products is because they contain compounds with antioxidant activity such as flavonoids (Arslan et al., 2014).

Other additives

Ghanima et al. (2021), in their research conducted by adding 300 mg/kg of tea tree essential oil and 300 mg/kg of lemon grass essential oil to the diets of broilers raised at 25, 30, 35, and 40 kg/m² stocking densities, stated that the supplementation of tea tree essential oil did positively affect performance, meat traits, and cellular immunity, and better results were obtained from tea tree essential oil than lemon grass essential oil at high settlement density. Wu et al. (2020 a) reported that the supplementation of 50 mg/kg of nicotinamide and 500 mg/kg of sodium butyrate to the diets of 21-day-old broilers raised at 14 and 18 birds/m² stocking densities did not affect feed intake, body weight, body weight gain, and feed efficiency; cooking loss was reduced, and pH and lactate dehydrogenase enzyme activity was optimised in birds with high stocking density with the addition of nicotinamide and sodium butyrate to the diet. Sarözkan et al. (2009) stated that the addition of L-carnitine at the level of 200 mg/

kg to the diets of hens reared at 285.7 and 500 cm²/hen stocking densities did not have an economic effect. Bone quality was adversely affected, with physiological and oxidative stress indicators augmented in broilers raised at high stocking density (18 birds/m²), but performance and physiological stress indicators improved with the addition of alpha-lipoic acid (300 mg/kg) to the diet (Ma et al., 2020). In another study, the addition of nicotinamide (50 and 100 mg/kg) and sodium butyrate (500 and 1,000 mg/kg) to the diets of broilers raised at high stocking density (18.6 birds/m²) improved the meat quality (Wu et al., 2020 b). Jeong et al. (2020) reported that the supplementation of 100 mg/kg of gamma-amino butyric acid to broiler diets housed at high stocking density (15 birds/m²) could not prevent poor performance, but it had positive effects on corticosterone and the heterophile:lymphocyte ratio.

Conclusion

Increasing the stocking density in poultry production is a method applied to obtain more products per unit area – in other words, to increase profitability. However, this technique could adversely affect product quantity and quality. It has been observed that increasing the level of antioxidant nutrients in the diet and adding additives are effective in reducing the stress caused by high stocking density to prevent the decrease in product quantity and quality.

Disclosure of potential conflicts of interest

No potential conflict of interest was reported by the author(s).

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