



EFFECT OF REARING TECHNOLOGY ON PRODUCTION PERFORMANCE, SELECTED AND BLOOD PARAMETERS AND WELFARE LEVELS OF BROILER CHICKENS DURING THE SUMMER PRODUCTION CYCLE*

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Abstract

The aim of the present study was to determine the effect of rearing technology (rearing system and dietary supplementation with a mixed herbal extract) on the production results, selected physiological and blood parameters, and welfare of broiler chickens during the summer production cycle. In the CON and HE groups, broiler chickens were kept on litter without access to free range; additionally, in the HE group, birds from 22 to 42 days of rearing received a mixed herbal extract (50% *Melissa officinalis* L. and 50% *Urtica dioica* L.) in the amount of 2 ml/l of water to drinkers with water. In the AP group, birds were reared on litter with access to pasture. During the experiment, production performance and body temperature of the birds were monitored. Blood was also taken from birds in each group and the H:L ratio, levels of corticosterone, glucose and thyroid hormones were determined. The application of 2 ml/l of mixed herbal extract to the drinking water did not improve the production results, nor did it affect the physiological indices of the birds studied. The addition of 2 ml/l of mixed herbal extract to the drinking water only resulted in lower corticosterone levels in the blood of the chickens on day 35 of the experiment. The free-range housing system had a negative effect on the slaughter performance of the broiler chickens. However, housing with access to the free range resulted in lower body temperature, lower mortality, as well as lower glucose, corticosterone and a narrower H:L ratio in the blood of the chickens during the period of increasing air temperature. It can therefore be concluded that housing with access to a free range reduces stress levels and thus improves the welfare of broiler chickens during the summer production cycle compared to confined housing. Comparing the rearing technologies used in the study, it was found that the free-range housing system contributed more to improving the comfort of broiler chickens during the summer than dietary supplementation with the tested herbal mixture extract.

Key words: rearing system, mixed herbal extract, productivity, physiological indicators, welfare, broiler chickens

Nowadays, due to ongoing climate warming, more and more losses in the poultry industry are associated with hyperthermia in broiler chickens. Heat stress causes numerous adverse changes in the birds' body: behavioural, physiological, metabolic, as well as immune suppression and oxidative stress (Skomorucha et al., 2017; Abo Ghanima et al., 2020 a; Wasti et al., 2020; Khan et al., 2021; Oke et al., 2021; Skomorucha and Sosnówka-Czajka, 2021; Akinyemi and Adewole, 2022; Zhang et al., 2023). This results in reduced feed intake and weight gain (Khan et al., 2021; Oke et al., 2021; Akinyemi and Adewole, 2022; Zhang et al., 2023), reduced bird welfare (Oke et al., 2021; Zhang et al., 2023) and increased mortality (Skomorucha and Sosnówka-Czajka, 2017; Wasti et al., 2020; Sanchez-Casanova et al., 2021). Hence, heat stress is considered a serious problem in broiler chicken

production worldwide, and the search for practical methods to mitigate the negative effects of heat stress on birds is becoming a priority.

One of the key factors affecting the comfort, health and productivity of birds is the rearing system (Skomorucha et al., 2011; Dong et al., 2017; Skomorucha and Sosnówka-Czajka, 2017; Abo Ghanima et al., 2020 a, b; Sanchez-Casanova et al., 2021). Al-Aqil and Zulkifli (2009) report that birds reared in different systems are exposed to different levels of stress. Intensive rearing of broiler chickens involving maximized production is usually associated with a variety of environmental stressors that reduce the welfare of the birds (Skomorucha and Sosnówka-Czajka, 2013 a; Sugiharto and Ayasan, 2023). An alternative to this system of keeping chickens is housing with outdoor access. According to some authors, this

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housing system is potentially beneficial for the welfare of the birds as it allows them to exhibit natural behavioural patterns, increases their immunity and contributes to reducing the stresses that poultry face during rearing (Chen et al., 2013; Skomorucha and Sosnówka-Czajka, 2017). However, other studies indicate that also in housing with outdoor access, birds may be exposed to environmental factors that reduce their welfare (Hegelund et al., 2005; Campo et al., 2008; Muchacka et al., 2016). Olanrewaju et al. (2010) highlight that, among other things, the rearing system determines the highest and lowest air temperatures that are critical for optimal bird productivity. In contrast, Abo Ghanima et al. (2020 a) report that the use of an appropriate rearing system is often helpful in achieving a suitable thermal environment onsite. The authors demonstrated in their study the different effects of three rearing systems on stress indices and production performance of broiler chickens under heat stress conditions. Similarly, Dong et al. (2017) observed a significant effect of housing systems on laying performance and blood biochemical results of native Xianju hens during summer. Skomorucha and Sosnówka-Czajka (2017), on the other hand, found an improvement in the welfare of broiler chickens exposed to heat stress and maintained in a free-range system compared to a confined system.

Herbal plants and herbal preparations continue to be of great interest in the poultry industry. They can be used as single herbs or mixtures of appropriately selected herbs and administered with drinking water and/or as a feed additive (Hartoyo et al., 2018). They improve feed intake and utilization, stimulate the immune response, and have bacteriostatic and antiviral properties (Sugiharto and Ayasan, 2023). Herbs are also seen to have actions that reduce birds' vulnerability to stress (Skomorucha and Sosnówka-Czajka, 2013 a). A number of authors have also reported positive effects of the addition of herbs to the diet on the body of broiler chickens reared under conditions of elevated air temperatures (Attia and Bertu, 2018; Song et al., 2018; Skomorucha and Sosnówka-Czajka, 2021).

Commonly known and appreciated herbs include lemon balm and nettle. These herbs exhibit a variety of health-promoting properties, including a calming and anti-stress effect due to their essential oil content. In addition, these plants also show strong antioxidant properties (Bonetti et al., 2016; Kasapidou et al., 2014), so they may be helpful in reducing heat-induced stress. However, no information was found in the scientific literature regarding the use of an extract from a mixture of these herbs to alleviate the effects of rearing stress on the body of broiler chickens.

Hence, the aim of the present study was to determine the effect of rearing technology (rearing system and dietary addition of a mixed herbal extract) on production performance, selected physiological and blood parameters, and welfare of broiler chickens during the summer production cycle.

It was hypothesized that an appropriate housing system or the addition of mixed herb extract to the diet could reduce stress levels and improve the production performance of summer-reared broiler chickens.

Material and methods

Experimental site

The experiment was conducted at a poultry farm of the National Research Institute of Animal Production in Aleksandrowice.

Birds and experimental design

The experiment was conducted during the summer production cycle (June/July). The experimental material consisted of 600 one-day-old Ross 308 broiler chicks from the Poultry Hatchery in Łęzkowice. On the first day of life, the chicks, after being weighed and marked with chick tags, were allocated to three groups (200 birds per group), each consisting of five subgroups (40 birds per subgroup). In groups I (CON) and II (HE), broiler chickens were kept on litter without outdoor access; additionally, in group II, birds from days 22 to 42 of rearing were given a liquid alcoholic extract of a mixture of herbs (50% *Melissa officinalis* L. and 50% *Urtica dioica* L.) in water drinkers at 2 ml/l water (Skomorucha and Sosnówka-Czajka, 2021). In group III (AP), birds were reared on litter with free-range access from day 1 of rearing (Table 1).

The experimental herbs were selected mainly for their content of antioxidant substances (essential oils, flavonoids, polyphenolic acids, β -carotenoids, chlorophyll (a and b), xanthophylls and vitamins C and E). The stocking density of chickens in the groups did not exceed 33 kg/m² (Regulation of the Ministry of Agriculture and Rural Development, Journal of Laws 2010.56.344, as amended), while the area of the free range per bird was 1 m². The free range was equipped with drinkers and overhead shelters to protect the chickens from the sun. The birds used the free range between 7:00 and 20:00 hours.

The birds were kept for a period of 42 days. The temperature inside the broiler house was 33°C in the first few days and was then lowered gradually to 20–18°C in the 5th and 6th weeks of rearing.

Table 1. Experimental design

Group		
CON	HE	AP
Rearing of broiler chickens without free-range access	Broiler chicken rearing without free-range access, from 22 to 42 days of the study, a liquid alcohol extract from a mixture of herbs was added to the water drinkers at a rate of 2 ml/l of water	Rearing of broiler chickens with free-range access

Table 2. Ingredient composition (%) and nutritive value of the diets

Item	Diet	
	Starter ¹ 1–21 days	Grower ² – Finisher ³ 22–42 days
Maize	55.35	47.21
Soybean meal	37.5	33.75
Wheat	–	10.00
Rapeseed oil	2.90	4.80
Ground limestone	1.10	1.15
Dicalcium phosphate	2.10	2.00
Sodium chloride	0.30	0.30
Vitamin-mineral premix	0.50	0.50
L-Lysine	0.03	0.09
DL-Methionine	0.22	0.20
Nutritive value per 1 kg		
Crude protein (%)	22.00	20.5
Metabolizable energy (MJ)	12.5	13.0
Lysine (g)	12.0	11.5
Methionine (g)	5.50	5.20
Calcium (g)	9.50	9.30
Phosphorus (g)	4.30	4.10

¹Supplements per kg starter diet: vit. A 13 500 IU; vit. D₃ 3 600 IU; vit. E 45 mg; vit. B₁ 3.25 mg; vit. B₂ 7.5 mg; vit. B₆ 5 mg; vit. B₁₂ 32.5 mcg; vit. K₃ 3 mg; biotin 150 mcg; nicotinic acid 45 mg; calcium pantothenate 15 mg; folic acid 1.5 mg; choline chloride 447.6 mg; Mn 100 mg; Cu 1.75 mg; Fe 76.5 mg; Se 0.275 mg; I 1 mg; Zn 75 mg; Co 0.4 mg; Seldox HM (antioxidant) 25 mg; Clinacox 0.5% 1 mg.

²Supplements per kg grower diet: vit. A 12 000 IU; vit. D₃ 3 250 IU; vit. E 40 mg; vit. B₁ 2 mg; vit. B₂ 7.3 mg; vit. B₆ 4.25 mg; vit. B₁₂ 30 mcg; vit. K₃ 2.25 mg; biotin 100 mcg; nicotinic acid 40 mg; calcium pantothenate 12 mg; folic acid 1.0 mg; choline chloride 335.7 mg; Mn 100 mg; Cu 1.5 mg; Fe 65 mg; Se 0.25 mg; I 0.9 mg; Zn 65 mg; Co 0.4 mg; Seldox HM (antioxidant) 25 mg; Coxidin 200 100 mg.

³Supplements per kg finisher diet: vit. A 10 500 IU; vit. D₃ 2 500 IU; vit. E 40 mg; vit. B₁ 1.5 mg; vit. B₂ 5.5 mg; vit. B₆ 3.25 mg; vit. B₁₂ 25 mcg; vit. K₃ 2 mg; biotin 100 mcg; nicotinic acid 35 mg; calcium pantothenate 12 mg; folic acid 1.0 mg; choline chloride 298.4 mg; Mn 80 mg; Cu 8 mg; Fe 60 mg; Se 0.2 mg; I 0.8 mg; Zn 50 mg; Co 0.4 mg; Seldox HM (antioxidant) 25 mg.

The light program used was: 23 h of light/day to the 7th day, from the 8th day 20 h of light/day. The chickens were fed freely with mixtures prepared on the basis of concentrates (Table 2). Feed and water were manually delivered to feed hoppers and bell drinkers, respectively. Throughout the rearing period, the broiler chickens had free access to feed and water drinkers.

The ethanol herb extract was made at a professional herbal company and had a certificate of compliance with the quality standard developed at this company (ZN-08/NX/545).

The experiment was approved by the Second Local Ethics Committee for Animal Experiments in Kraków (no. 1205/2015).

Data, sample collection and laboratory analyses

During the experiment, temperature and humidity data were collected outside and inside the broiler house. Macroclimate measurements were taken using a Techno-line Ltd weather station model WS-3650-IT. Inside the broiler house, temperature and humidity were recorded on a PL-9000 “poultry computer” from STIENEN BE. Microclimate sensors were placed in the broiler chicken area. In addition, at 13:00 hours, air temperature and

humidity were measured with a Testo 435 apparatus at 3 points on the diagonal of each compartment (subgroup) and at 3 points on the diagonal of the free range at the birds’ height. The climatic data given are an average calculated from the results read from all measuring devices at 13:00 hours.

The production results monitored were body weight of the broiler chickens, feed conversion, and mortality. Feed intake from each replicate and chick mortality were monitored daily. The body weight of the chickens was monitored once a week. Birds were weighed individually on a WPT/F-30C scale. Feed conversion efficiency (kg per kg weight gain) was calculated by measuring the feed consumption and body weight. Bird mortality was presented as a percentage. On day 42 of rearing, 20 birds (10 females and 10 males) whose body weights were similar to the group and sex average were selected from each group. The selected birds were slaughtered by decapitation, after prior stunning with an STZ 6 electric stunner. The carcasses (with neck and giblets) were placed in a cold store at 4°C. After 24 hours, chilled carcasses were subjected to simple carcass analysis according to the method described by Ziółcki and Doruchowski (1989).

In the 4th, 5th and 6th week of rearing (28, 35, and 39 days of rearing, respectively), blood was collected by decapitation from 10 birds per group, after prior stunning with an STZ 6 electric stunner. Blood was collected into tubes with EDTA (ethylenediaminetetraacetic acid salts) anticoagulant and lithium heparin. From the blood collected on EDTA, smears were manually made using two glass slides, one with cut edges (smear slide). After preparation and drying of the smears, May-Grünwald-Giemsa staining (Alpha Diagnostics Warsaw, Poland, Cat. No LO 001, LO 002) was applied. The stained leucocytes were counted under a Nikon YS 100 microscope using the Schilling differential method (differential white blood cell count). Cells were counted using a hematology cell counter (SH 12/12, Poland). Based on the number of isolated white blood cells, the ratio of heterophils to lymphocytes (H:L) was calculated.

Blood collected into lithium heparin tubes was centrifuged (MPW-52 centrifuge) and plasma separated by centrifugation was pipetted into Eppendorf tubes. Plasma levels were determined for corticosterone, glucose and thyroid hormones (T_3 and T_4). Corticosterone and thyroid hormones were determined in plasma by radioimmunoassay in an automatic gamma counter (LKB Wallace) using rCorticosterone [125 I] (REF: RK-548), T_3 [125 I] (REF: RK-6CT1) and T_4 [125 I] (REF: RK-11CT1) RIA KIT by Institute of Isotopes Co. Ltd, Budapest. Analysis of blood glucose levels in birds was performed with a Mindray BS-120 biochemical analyzer using Glucose Standard reagent (cat. no. 239015) from Alpha Diagnostics, Poland.

On the same dates (days 28, 35 and 39), rectal and radiation temperature of feathered (back) and nonfeathered parts (shanks) was measured in 10 birds per group. Rectal temperature was measured with a veterinary thermometer accurate to 0.1°C , while radiation temperature using a Cole-Parmer pyrometer. The pyrometer was placed 15 cm from the bird's skin.

Physiological examinations and blood sampling were performed between 13:00 and 15:00 hours.

Statistical analyses

The results were statistically analyzed by one-way analysis of variance (ANOVA). The experimental units were the individual bird and subgroup (compartment with 40 birds) for feed conversion. Significant differences for the means between the experimental groups were determined with Duncan's multiple range test. Effects were considered significant at a probability of $P < 0.05$ and $P < 0.01$. The statistical calculations were made with Statistica 12 software.

Results

Figures 1 and 2 show the following parameters measured at 13:00 hrs: mean daily outdoor temperatures, the air temperatures measured inside the building in each experimental group at the level of the birds, and the results of the humidity measurement, respectively.

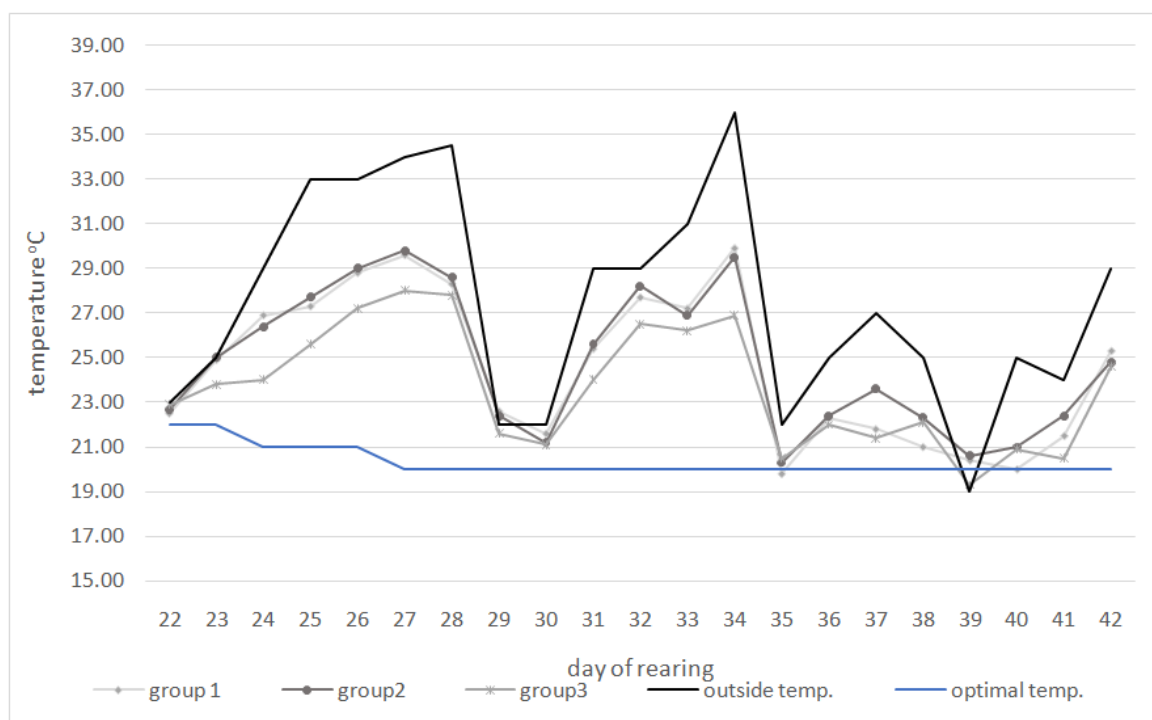


Figure 1. Daily external and indoor temperatures at 13:00 hrs

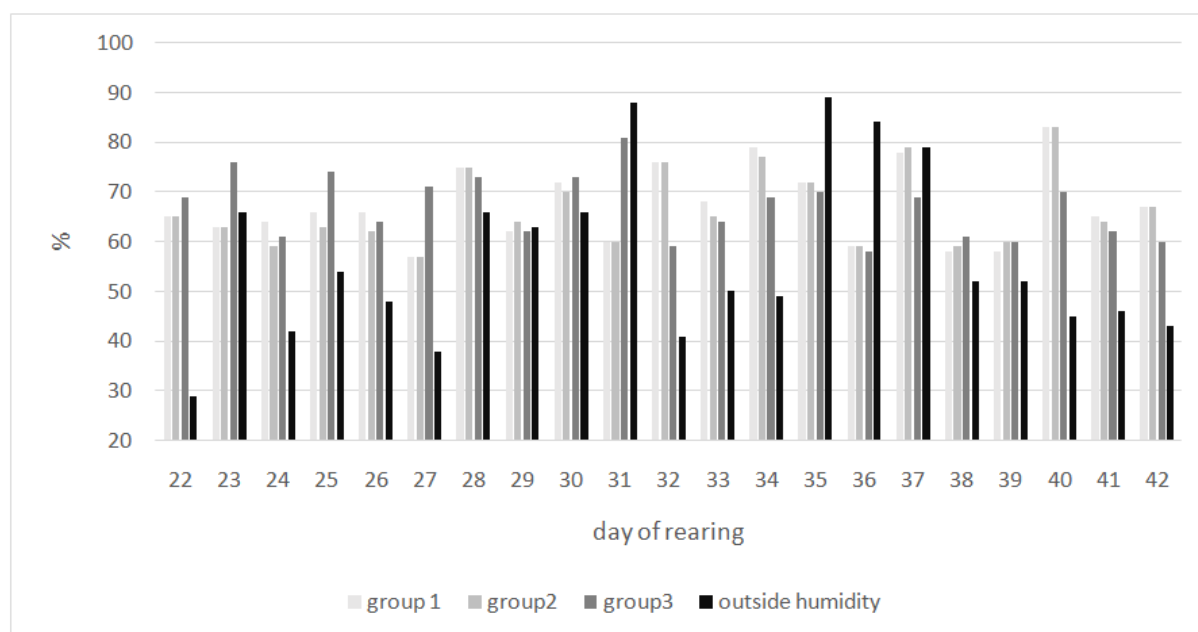


Figure 2. Humidity (%) inside and outside the broiler house at 13:00 hrs

Table 3. Production results and dissection analysis of 42-day-old broiler chickens

Item	Group			SEM
	CON	HE	AP	
¹ Body weight (g)	2731.28	2754.80	2726.15	35.01
² Feed conversion (kg) per kg weight gain	1.64	1.63	1.72	0.04
Mortality (%)	3.80	4.40	2.00	–
³ Dressing percentage with giblets (%)	79.95 A	79.28 AB	78.56 B	0.31
³ Dressing percentage without giblets (%)	77.02 a	76.35 ab	75.69 b	0.32

a, b – values in rows with different letters differ significantly ($P < 0.05$).

A, B – values in rows with different letters differ highly significantly ($P < 0.01$).

Pooled SEM – Pooled standard error of mean.

CON – control group – kept on litter without herbal extract and without access to pasture.

HE – kept on litter with herbal extract and without access to pasture.

AP – access to pasture without herbal extract.

¹n = 200 per group.

²n = 5 per group.

³n = 20 per group.

Table 3 shows the production results of 42-day-old broiler chickens. Birds in the AP group had poorer slaughter performance both with and without offal compared to birds in the CON group at $P < 0.01$ and $P < 0.05$, respectively. There were no differences between groups in other production parameters.

Radiated and rectal temperature values are shown in Table 4. On the 35th and 39th day of the experiment, there was a difference in the radiated temperature of the feathered parts between the AP group and the HE and CON groups ($P < 0.01$, $P < 0.05$). For the unfeathered parts, the difference in radiated temperature was recorded: on day 28 of rearing between the AP and CON group ($P < 0.05$) and on days 35 and 39 of the experiment between the

AP and CON and HE groups at $P < 0.01$ and $P < 0.05$, respectively. For rectal temperature, the difference was observed between the AP and CON group on day 28 of the experiment at $P < 0.01$ (Table 4).

Broiler chickens from the AP group had lower corticosterone concentrations ($P < 0.05$) on day 28 compared to the HE and CON groups and on day 35 of the experiment compared to the CON group (Table 5). On day 35 of rearing, lower corticosterone levels were also found in the blood of broiler chickens from the HE group compared to the CON group. On day 28 of rearing, there was also a difference in glucose levels between the AP and CON groups and the magnitude of the H:L ratio in blood between the AP and CON and HE groups at $P < 0.05$.

Table 4. Body temperature (°C) of broiler chickens (mean, n = 10)

Days of rearing	Group			Pooled SEM
	CON	HE	AP	
Radiated temperature of feathered parts				
28	35.33	35.38	34.28	0.36
35	29.76 A	28.81 a	27.41 Bb	0.48
39	27.28 A	27.34 A	24.07 B	0.62
Radiated temperature of unfeathered parts				
28	38.55 a	38.08 ab	37.13 b	0.40
35	37.21 A	37.81 A	34.03 B	0.39
39	34.99 a	34.88 a	32.84 b	0.54
Rectal temperature				
28	41.95 A	41.79 AB	41.58 B	0.08
35	41.21	41.26	41.15	0.10
39	41.06	41.32	41.20	0.12

a, b – values in rows with different letters differ significantly ($P < 0.05$).

A, B – values in rows with different letters differ highly significantly ($P < 0.01$).

Pooled SEM – Pooled standard error of mean.

CON – control group – kept on litter without herbal extract and without access to pasture.

HE – kept on litter with herbal extract and without access to pasture.

AP – access to pasture without herbal extract.

Table 5. Blood parameter levels of broiler chickens (mean, n = 10)

Days of rearing	Group			Pooled SEM
	CON	HE	AP	
	T ₃ (nmol/l)			
28	9.82	9.27	8.75	0.60
35	11.19	10.88	10.35	0.52
39	11.35	10.37	9.65	0.50
	T ₄ (nmol/l)			
28	57.13	60.72	49.48	4.76
35	59.04	63.91	64.26	3.94
39	74.24	74.20	72.61	2.92
	Corticosterone (ng/ml)			
28	3.68 a	3.80 a	1.71 b	0.51
35	5.75 a	4.09 b	3.94 b	0.47
39	2.31	2.08	2.13	0.48
	Glucose (nmol/l)			
28	14.60 a	13.79 ab	12.82 b	0.40
35	13.95	13.40	13.29	0.48
39	13.47	12.38	13.13	0.72
	H:L			
28	0.55 a	0.74 A	0.35 Bb	0.04
35	0.64	0.77	0.58	0.08
39	0.55	0.80	0.80	0.07

a, b – values in rows with different letters differ significantly ($P < 0.05$).

A, B – values in rows with different letters differ highly significantly ($P < 0.01$).

Pooled SEM – Pooled standard error of mean.

CON – control group – kept on litter without herbal extract and without access to pasture.

HE – kept on litter with herbal extract and without access to pasture.

AP – access to pasture without herbal extract.

Discussion

In our study, free-range access did not affect the final body weight of broiler chickens or feed conversion. Several studies have reported lower body weights and poorer feed conversion by birds having free-range access compared to those housed indoors (Castellini et al., 2002; Pavlovski et al., 2009; Skomorucha and Sosnówka-Czajka, 2017). Sanchez-Casanova et al. (2021), on the other hand, showed a trend towards higher body weights in chickens reared with free-range access during periods of high outdoor temperatures. In contrast, Santos et al. (2005) and Ponte et al. (2008) showed significantly higher body weights in broiler chickens that had free access to the free range.

In our study, lower mortality was observed in AP chickens compared to CON and HE chickens. According to Weitzenbürger et al. (2005), poultry mortality depends on a number of factors and therefore cannot be used to evaluate housing systems. May and Lott (2000), on the other hand, state that bird mortality is the best indicator of correct rearing temperature. An increase in air temperature above the thermoneutral zone leads to disturbances in body homeostasis resulting, among other things, from increased plasma corticosterone concentrations and consequent deterioration in bird health. Studies confirm the negative effects of elevated air temperatures on poultry survival (Sanchez-Casanova et al., 2021; Zhang et al., 2023). Therefore, it can be concluded that, in our study, the housing conditions, including thermal conditions, acting on birds with free-range access were more favorable, as evident in the lower proportion of chickens dying throughout the rearing period. Similar results were obtained by Skomorucha and Sosnówka-Czajka (2017). The authors observed a 2.2% lower mortality rate of broiler chickens with free-range access during the summer production cycle compared to chickens reared indoors.

In our study, chickens using the range area had lower slaughter performance compared to CON birds. Also Skomorucha et al. (2020) and Cömert et al. (2016) obtained poorer slaughter performance of broiler chickens kept with free-range access compared to the confined group. Different results were observed by Sanchez-Casanova et al. (2021). The free-range system contributed to the higher slaughter performance of the birds reared in it. In contrast, Sosnówka et al. (2017) reported no effect of housing systems on the slaughter performance of chickens.

Broiler chickens, especially in intensive rearing, are exposed to a variety of stress factors. During summer production cycles, higher than recommended air temperatures usually become a major problem. High temperatures in broiler chicken rearing cause, among other things, the development of oxidative stress, which is recognized as a primary factor that reduces production performance (Muchacka et al., 2016). This is confirmed by the study of Behboodi et al. (2021), who found the

emergence of oxidative stress in broiler chickens exposed to elevated temperatures and demonstrated its negative effects on feed intake, daily weight gain, percentage of legs and abdominal fat in the carcass. Phytonutrients are believed to enhance immunity and improve gastrointestinal function, hence there is increasing interest in the use of herbs and medicinal plants in poultry nutrition to improve the health and productivity of birds exposed to stress (Barbarestani et al., 2017). Improvements in the production performance of broiler chickens under the influence of diets supplemented with herbs were obtained by Kasapidou et al. (2014), Redoy et al. (2021), Rafeeq et al. (2021) and Akinyemi and Adewole (2022). However, in our study, the addition of an extract from a mixture of herbs considered to be potent antioxidants, i.e. lemon balm and common nettle, to the drinking water at a rate of 2 ml/l had no significant effect on body weight, feed conversion and survival. There was also no effect of this experimental factor on the slaughter performance of the chickens. Similarly, Skomorucha and Sosnówka-Czajka (2013 a) showed no statistically significant differences in final body weight and feed conversion between chickens in the control group and birds receiving the 2 ml/l addition of lemon balm extract to water. Also in the study by Skomorucha et al. (2020) the addition of a mixed herbal extract to the drinking water did not improve the slaughter performance of broiler chickens. On the other hand, in a study by Skomorucha and Sosnówka-Czajka (2014), depending on the herb mixture used, higher body weights, improved feed conversion or lower mortality in broiler chickens were obtained.

The literature points out that the rearing system affects the stress level of birds (Al-Aqil and Zulkifli, 2009). The bodily response of birds to the stress of elevated air temperature is an increase in body temperature (Akinyemi and Adewole, 2022). Skomorucha and Sosnówka-Czajka (2017) showed a lower radiated temperature of the unfeathered parts and lower rectal temperature of 41-day-old broiler chickens having access to the free range during the summer rearing cycle. In our study, birds with free-range access had a lower radiated temperature and, on day 28, when a high outside temperature was recorded, also a lower rectal temperature compared to birds kept indoors. This may indicate that the heat load of the indoor broiler chickens was higher than that of the free-range birds despite the fact that the outdoor air temperature to which the free-range birds were exposed on this day was 34°C. The lower rectal temperature of the AP birds was probably influenced by other environmental parameters such as air movement and associated cooling, as well as a different type of flooring and a relatively lower stocking rate per 1 m², which allowed for better heat exchange between the bird's body and the environment. The shading of the free range was also important to protect the broiler chickens from direct sunlight.

According to Tao et al. (2006), during summer production cycles broiler chickens are exposed to a cyclic

increase in air temperature, which leads to a decrease in the average daily concentration of T_3 in the blood, in turn the response of T_4 hormone to air temperature is slower. Gibson et al. (1986) showed lower blood T_3 levels in laying hens reared with access to the free range compared to caged birds. Skomorucha and Sosnówka-Czajka (2017) obtained lower triiodothyronine levels during periods of high outdoor temperatures in a group of chickens with free-range access. In our study, both T_3 and T_4 levels in the blood of the birds were at similar levels regardless of the rearing system. It is well known that thyroid hormones play a key role in the regulation of body temperature and the adaptation of thermal metabolism, hence heat stress induces changes in the concentration of these hormones (Sohail et al., 2010; Weitzel et al., 2017). In our study, the thermal conditions prevailing during the summer in the housing systems used did not alter the concentration of thyroid hormones, suggesting that the birds were not exposed to heat stress. However, according to Jiang et al. (2020), the effect of heat stress on thyroid hormone levels in broiler chickens depends on a number of factors, including the level and duration of stress and the age of the bird.

Important parameters in the assessment of stress and poultry welfare are the determination of corticosterone concentrations, biochemical parameters and the H:L ratio in the blood of birds (Dong et al., 2017; Abo Ghanima et al., 2020 a). Skomorucha et al. (2011) showed differences in corticosterone and plasma glucose in broiler chickens reared in different housing systems, but the authors found no differences in the H:L ratio in the blood of experimental birds. In contrast, Abo Ghanima et al. (2020 a) reported significant differences in the H:L ratio in the blood of birds reared in different systems and exposed to heat stress. Dong et al. (2017) and Rehmana et al. (2017) observed lower plasma glucose levels in birds with free-range access, which, according to the authors, is influenced by the higher activity of birds in this system than in confined housing. In contrast, Wasti et al. (2020) report that increased plasma glucose concentrations are associated with increased secretion of glucocorticoids during stress. In our study, higher levels of corticosterone (days 28 and 35 of rearing), glucose (day 28 of rearing) and a higher H:L ratio (day 28 of rearing) were found in the blood of confined birds compared to AP chickens, which may suggest that conventionally reared birds exhibited poorer living comfort on these days than chickens from the other housing system. Also, a previous study (Skomorucha and Sosnówka-Czajka, 2017) showed higher glucose and corticosterone concentrations in the blood of broiler chickens reared indoors than in birds with free-range access.

Some studies have shown that the addition of natural antioxidants to the diet of broiler chickens results in a slowing of basal metabolism and a significant decrease in body temperature (Ragab et al., 2013; Morovat et al., 2016; Skomorucha and Sosnówka-Czajka, 2021). How-

ever, in our study, the addition of 2 ml/l of mixed herbal extract to water had no effect on thyroid hormone levels and body temperature of broiler chickens. Similarly, Akinyemi and Adewole (2022) and Baghban et al. (2016) found no change in rectal temperature of broiler chickens receiving phytoadditives in feed and exposed to elevated air temperature.

Kannan et al. (1997) report that lower corticosterone levels in the blood usually mean that the organism is less susceptible to stressors acting on it. Skomorucha and Sosnówka-Czajka (2013 a, b) found lower levels of this hormone in broiler chickens receiving St John's wort extract and mixed herb extract in their water. Similarly, in our study, the addition of 2 ml/l of herbal mixture extract to the water contributed to lower corticosterone levels in the blood of HE birds on day 35 of the experiment compared to the CON control group. The diet of birds supplemented with herbs can also affect glucose levels (Skomorucha and Sosnówka-Czajka, 2014; Morovat et al., 2016) and the magnitude of the H:L ratio (Khafar et al., 2019; Skomorucha and Sosnówka-Czajka, 2021). However, in our study, no change in glucose levels or the magnitude of the H:L ratio was observed under the influence of dietary mixed herb extract.

In conclusion, the application of an oxidative herb mixture extract to the drinking water at 2 ml/l did not improve the production performance of summer-reared broiler chickens. Dietary supplementation with mixed herb extract in the form and concentration used also had no effect on the physiological indices of the birds studied. The addition of 2 ml/l of herbal mixture extract to the drinking water only resulted in lower corticosterone levels in the blood of the chickens on day 35 of the experiment, which could suggest that the inclusion of herbal mixture extract in the diet of broiler chickens could reduce the susceptibility of the organism to the stressors acting on it. However, further research is needed to select the appropriate dose and form of administration of the tested herbs, which could clearly improve the physiological status of broiler chickens during the summer production cycle.

The free-range housing system had a negative effect on the slaughter performance of broiler chickens. However, housing with free-range access resulted in lower body temperatures and lower mortality in the birds, as well as lower levels of glucose, corticosterone and a narrower H:L ratio in the blood of the chickens during periods of increased air temperature. It can therefore be concluded that housing with access to a sun-protected free range reduces stress levels and thus improves the welfare of broiler chickens during the summer production cycle compared to a confined system.

Comparing the rearing technologies used in the study, it was found that the free-range housing system contributed more to improving the "welfare" of broiler chickens during the summer period than dietary supplementation with the tested herbal mixture extract.

References

- Abo Ghanima M.M., Abd El-Hack M.E., Othman S.I., Taha A.E., Allam A.A., Abdel-Moneim E. (2020 a). Impact of different rearing systems on growth, carcass traits, oxidative stress biomarkers, and humoral immunity of broilers exposed to heat stress. *Poultry Sci.*, 99: 3070–3078.
- Abo Ghanima M.M., Alagawany M., Abd El-Hack M.E., Taha A., Elnesr S.S., Ajarem J., Allam A.A., Mahmoud A.M. (2020 b). Consequences of various housing systems and dietary supplementation of thymol, carvacrol, and euganol on performance, egg quality, blood chemistry, and antioxidant parameters. *Poultry Sci.*, 99: 4384–4397.
- Akinyemi F., Adewole D. (2022). Effects of brown seaweed products on growth performance, plasma biochemistry, immune response, and antioxidant capacity of broiler chickens challenged with heat stress. *Poultry Sci.*, 101: 102215.
- Al-Aqil A., Zulkifli I. (2009). Changes in heat shock protein 70 expression and blood characteristics in transported broiler chickens as affected by housing and early age feed restriction. *Poultry Sci.*, 88: 1358–1364.
- Attia Y.A., Bertu N.K. (2018). Utilisation of thyme powder (*Thyme vulgaris* L.) as a growth promoter alternative to antibiotics for broiler chickens raised in a hot climate. *Europ. Poult. Sci.*, 82.
- Baghban P., Daneshyar M., Najafi R. (2016). Effects of cinnamon (*Cinnamomum zeylanicum*) and turmeric (*Curcuma longa*) powders on performance, enzyme activity, and blood parameters of broiler chickens under heat stress. *Poultry Sci. J.*, 4: 47–53.
- Barbarestani S.Y., Samadi F., Hassani S., Asadi G. (2017). Effects of encapsulated nano- and microparticles of peppermint (*Mentha piperita*) alcoholic extract on the growth performance, blood parameters and immune function of broilers under heat stress condition. *Iranian J. Appl. Anim. Sci.*, 7: 669–677.
- Behboodi H.R., Sedaghat A., Baradaran A., Nazarpak H.H. (2021). The effects of the mixture of betaine, vitamin C, St John's wort (*Hypericum perforatum* L.), lavender, and *Melissa officinalis* on performance and some physiological parameters in broiler chickens exposed to heat stress. *Poultry Sci.*, 100: 101344.
- Bonetti G., Tedeschi P., Meca G., Bertelli D., Mañes J., Barandolini V., Maietti A. (2016). *In vitro* bioaccessibility, transepithelial transport and antioxidant activity of *Urtica dioica* L. phenolic compounds in nettle based food products. *Food Funct.*, 7: 4222–4230.
- 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: 621–626.
- Castellini C., Mugnai C., Dal Bosco A. (2002). Effect of organic production system on broiler carcass and meat quality. *Meat Sci.*, 60: 219–225.
- Chen X., Jiang W., Tan H. Z., Xu G. F., Zhang X. B., Wei S., Wang X. Q. (2013). Effects of outdoor access on growth performance, carcass composition, and meat characteristics of broiler chickens. *Poultry Sci.*, 92: 435–443.
- Cömert M., Şayan Y., Kirkpınar F., Bayraktar Ö.H., Mert S. (2016). Comparison of carcass characteristics, meat quality, and blood parameters of slow and fast grown female broiler chickens raised in organic or conventional production system. *Asian-Australas J. Anim. Sci.*, 29: 987–997.
- Dong X.Y., Yin Z.Z., Ma Y.Z., Cao H.Y., Dong D.J. (2017). Effects of rearing systems on laying performance, egg quality, and serum biochemistry of Xianju chickens in summer. *Poultry Sci.*, 96: 3896–3900.
- Gibson S.W., Hughes B.O., Harvey S., Dun P. (1986). Plasma concentrations of corticosterone and thyroid hormones in laying fowls from different housing systems. *Br. Poult. Sci.*, 27: 621–628.
- Hartoyo B., Iriyanti N., Rimbawanto E.A. (2018). The use of “Fermherbafit” (mixed herbs) in broiler chicken feed on performance and cholesterol profile. *Anim. Prod.*, 20: 139–146.
- Hegelund L.S., Ørensen J.T., Kjer J.B. and Kristensen I.S. (2005). Use of the range area in organic egg production systems: effect of climatic factors, flock size, age and artificial cover. *Br. Poult. Sci.*, 46: 1–8.
- Jiang S., Mohammed A.A., Jacobs J.A., Cramer T.A., Cheng H.W. (2020). Effect of synbiotics on thyroid hormones, intestinal histomorphology, and heat shock protein 70 expression in broiler chickens reared under cyclic heat stress. *Poultry Sci.*, 99: 142–150.
- Kannan G., Heath J.L., Wabeck C.J., Souza M.C.P., Howe J.C., Mench J.A. (1997). Effects of crating and transport on stress and meat quality characteristics in broilers. *Poultry Sci.*, 76: 523–529.
- Kasapidou E., Giannenas I., Mitlianga P., Sinapis E., Bouloumpasi E., Petrotos K., Manouras A., Kyriazakis I. (2014). Effect of *Melissa officinalis* supplementation on growth performance and meat quality characteristics in organically produced broilers. *Br. Poult. Sci.*, 55: 774–784.
- Khafar K.R., Mojtahedin A., Rastegar N., Neytali K.M., Olfati A. (2019). Dietary inclusion of thyme essential oil alleviative effects of heat stress on growth performance and immune system of broiler chicks. *Iranian J. Appl. Anim. Sci.*, 9: 509–517.
- Khan R.U., Naz S., Ullah H., Ullah Q., Laudadio V., Qudratullah G., Tufarelli B.V. (2021). Physiological dynamics in broiler chickens under heat stress and possible mitigation strategies. *Anim. Biotechnol.*, 2: 1–10.
- May J.D., Lott B.D. (2000). The effect of environmental temperature on growth and feed conversion of broilers to 21 days of age. *Poultry Sci.*, 79: 669–671.
- Morovat M., Chamani M., Zarei A., Sadeghi A.A. (2016). Dietary but not *in ovo* feeding of *Silybum marianum* extract resulted in an improvement in performance, immunity and carcass characteristics and decreased the adverse effects of high temperatures in broilers. *Br. Poult. Sci.*, 57: 105–113.
- Muchacka R., Kapusta E., Skomorucha I., Sosnowka-Czajka E. (2016). Antioxidant enzymes activity and level of GSH and MDA in serum, liver, kidney and spleen of broiler chickens reared in different systems and exposed to high ambient temperature (in Polish). *Rocz. Nauk. Zoot.*, 43: 245–255.
- Oke O.E., Uyanga V.A., Iyasere O.S., Oke F.O., Majekodunmi B.C., Logunleko M.O., Onagbesan O.M. (2021). Environmental stress and livestock productivity in hot-humid tropics: alleviation and future perspectives. *J. Therm. Biol.*, 100: 103077.
- Olanrewaju H.A., Purswell J.L., Collier S.D., Branton S.L. (2010). Effect of ambient temperature and light intensity on physiological reactions of heavy broiler chickens. *Poultry Sci.*, 89: 2668–2677.
- Pavlovski Z., Škrabić Z., Lukić M., Petričević V.L., Trenkovski S. (2009). The effect of genotype and housing system on production results of fattening chickens. *Biotechnol. Anim. Husb.*, 25: 221–229.
- Ponte P.I., Rosado C.M., Crespo J.P., Crespo D.G., Mourão J.L., Chaveiro-Soares M.A., Brás J.L., Mendes I., Gama L.T., Prates J.A., Ferreira L.M., Fontes C.M. (2008). Pasture intake improves the performance and meat sensory attributes of free-range broilers. *Poultry Sci.*, 87: 71–79.
- Rafeeq M., Rashid N., Tariq M.M., Sheikh I.S., Mustafa M.Z., Shafee M., Mehmood K., Bilal R.M., Asmat T. (2021). Effect of herbal extract on the growth performance, serum biochemical composition, ileal histo-morphology and immune response of broiler chickens. *Pakistan J. Zool.*, 53: 1793–1801.
- Ragab M.S., Namra M.M.M., Aly M.M.M., Fathi M.A. (2013). Impact of inclusion fennel seeds and thyme dried leaves in broiler diets on some productive and physiological performance during summer season. *Egypt. Poult. Sci.*, 33: 197–219.
- Redoy M.R.A., Rahman M.A., Atikuzzaman M., Shuvo A.A.S., Hosain E., Khan M.J., Al-Mamun M. (2021). Dose titration of plantain herb (*Plantago lanceolata* L.) supplementation on growth performance, serum antioxidants status, liver enzymatic activity and meat quality in broiler chickens. *Ital. J. Anim. Sci.*, 20: 1244–1255.
- Rehman M.S., Mahmud A., Mehmood S., Pasha T.N., Hussain J., Khan M.T. (2017). Blood biochemistry and immune response in Aseel chicken under free range, semi-intensive, and confinement rearing systems. *Poultry Sci.*, 96: 226–233.
- Sanchez-Casanova R., Sarmiento-Franco L., Phillips C. (2021). The effects of outdoor access and stocking density on the performance

- of broilers reared under tropical conditions. *Brit. Poultry Sci.*, 62.
- Santos A.L., Sakomura N.K., Freitas E.R., Fortes C.M.S., Carrilho N.V.M. (2005). Comparison of free range broiler chicken strains raised in confined and semi-confined systems. *Braz. J. Poult. Sci.*, 7: 85–92.
- Skomorucha I., Sosnowka-Czajka E. (2013 a). Effect of water supplementation with herbal extracts on broiler chicken welfare. *Ann. Anim. Sci.*, 13: 849–857.
- Skomorucha I., Sosnowka-Czajka E. (2013 b). Effect of adding mixed herb extracts to drinking water on stress hormone levels in broiler chickens (in Polish). *Wiad. Zoot.*, LI, 4: 14–18.
- Skomorucha I., Sosnowka-Czajka E. (2014). Effect of adding herb extracts to water on production results and some blood biochemical parameters of broiler (in Polish). *Wiad. Zoot.*, R. LII, 2: 17–24.
- Skomorucha I., Sosnowka-Czajka E. (2017). Physiological parameters in broiler chickens reared under different housing systems during a period of high temperatures. *Acta Sci. Pol. Zootechnica*, 16: 25–34.
- Skomorucha I., Sosnowka-Czajka E. (2021). The effect of adding herbal extracts to drinking water on body temperature, level of thyroid hormones and H:L ratio in the blood of broiler chickens exposed to elevated ambient temperature. *Ann. Anim. Sci.*, 21: 1511–1522.
- Skomorucha I., Sosnowka-Czajka E., Muchacka R. (2011). Effect of rearing system on production results and some stress indicators in the blood of broiler chickens of different origin (in Polish). *Rocz. Nauk. Zoot.*, 38: 269–278.
- Skomorucha I., Sosnowka-Czajka E., Muchacka R. (2020). Effects of supplementing drinking water with mixed herb extract or outdoor access on meat quality characteristics in broiler chickens. *Ann. Anim. Sci.*, 20: 647–660.
- Sohail M.U., Ijaz A., Yousaf M.S., Ashraf K., Zaneb H., Aleem M., Rehman H. (2010). Alleviation of cyclic heat stress in broilers by dietary supplementation of mannan-oligosaccharide and *Lactobacillus*-based probiotic: dynamics of cortisol, thyroid hormones, cholesterol, C-reactive protein, and humoral immunity. *Poultry Sci.*, 89: 1934–1938.
- Song Z.H., Cheng K., Zheng X.C., Ahmad H., Zhang L.L., Wang T. (2018). Effects of dietary supplementation with enzymatically treated *Artemisia annua* on growth performance, intestinal morphology, digestive enzyme activities, immunity, and antioxidant capacity of heat-stressed broilers. *Poultry Sci.*, 97: 430–437.
- Sosnowka-Czajka E., Skomorucha I., Muchacka R. (2017). Effect of organic productions system on the performance and meat and meat quality of two purebred slow-growing chicken breeds. *Ann. Anim. Sci.*, 17: 119–1213.
- Sugiharto S., Ayasan T. (2023). Encapsulation as a way to improve the phytogetic effects of herbal additives in broilers – an overview. *Ann. Anim. Sci.*, 23: 53–68.
- Tao X., Zhang Z.Y., Dong H., Zhang H., Xin H. (2006). Responses of thyroid hormones of market-size broilers to thermoneutral constant and warm cyclic temperatures. *Poultry Sci.*, 85: 1520–1528.
- Wasti S., Sah N., Mishra B. (2020). Impact of heat stress on poultry health and performances, and potential mitigation strategies. *Animals*, 10: 1266.
- Weitzel J.M., Viergutz T., Albrecht D., Bruckmaier R., Schmicke M., Tuchscherer A., Koch F., Kuhla B. (2017). Hepatic thyroid signaling of heat-stressed late pregnant and early lactating cows. *J. Endocrinol.*, 234.
- Weitzenb rger D., Vits A., Hamann H., Distl O. (2005). Effect of furnished small group housing systems and furnished cages on mortality and causes of death in two layers strains. *Br. Poult. Sci.*, 46: 553–559.
- Zhang H., Majdeddin M., Degroote J., Van Liefferinge E., Van Noten N., Van Kerschaver C., Vandaele M., De Paula Dorigam J.C., Michiels J. (2023). Effect of supplemental methyl sulfonyl methane on performance, carcass and meat quality and oxidative status in chronic cyclic heat-stressed finishing broilers. *Poultry Sci.*, 102: 102321.
- Ziolecki J., Doruchowski W. (1989). Evaluation methods of slaughter value (in Polish). COBRD Poznań, Poland, pp. 1–22.

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