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Effects of chicken feed herbal additives on the breeding performance, slaughter yield and mechanical and morphometric parameters of chicken tibia bones

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Summary

The analyses aimed at determining the effect of replacing the antibiotic in feed mixes with various herbal additives on the core chicken breeding parameters such as weight gain, FCR, mortality rate, EEI, selected carcass slaughter parameters and some strength and morphometric parameters of the tibia bone on broiler chickens.

400 one-day-old Ross 308 male chicks were split into 8 groups of 10 chicks each in 5 repetitions. The chicks were allocated at random to the control group (negative – without AGP), I – receiving AGP, and to groups given 2% herbal additives: hop – II, lime – III, lemon balm – IV, pansy – V, peppermint – VI and nettle – VII. The study involved herbs contained essential oils of: hop cones (0.42%), lemon balm leaves (0.077%), peppermint leaves (2.92%), as well as flavonoids: pansy herb (0.37%), and lime flower (0.78%).

During the experiment chickens' body weight was controlled on the 21st, 35th and 42nd days of breeding, set FCR, EEI and postslaughter evaluation were performed on 10 male chicks selected from each group. The right-leg tibia was sampled for analysis from chickens slaughtered on day 42. The bones were mechanically stripped of soft tissues, weighed (with 0.1 g accuracy), packed into labeled plastic bags and frozen (at a temperature of –25°C) until the beginning of analyses. An Instron Universal Testing Machine (Model 3369) was used to determine bone ultimate strength and maximum elastic strength and yielding deformation, bending point resistance and load-to-deformation ratio. The geometric properties of bones (cross-section area, second moment of interia, mean relative wall thickness) and cortical indexes (cortical layer, cortical index, cortical surface, cortical surface index) were estimated on the basis of measuring the external and internal horizontal and vertical axes in the cross section of the bones at the site of fracture. Bone mineralization was degreased and dried to a constant weight in a muffle furnace and mineral content was determined.

On 21st day of life the body weight of chickens receiving an admixture of lemon balm and nettle was significantly higher ($P < 0.01$) compared to the body weight of birds fed with AGP, hop and lime and control groups. The highest slaughter weight was recorded in chickens fed on a mix with an addition of nettle (2435 g), while significantly lower body weight ($P < 0.05$) was revealed in the control group (2112 g) and the group receiving hops (2109 g). The addition of lime, lemon balm, pansy and nettle significantly ($P < 0.05$) increased the slaughter yield of chicks compared to the control group, the AGP group and the group receiving hops.

The largest increase in bone elasticity occurred as a result of using additives such as hop, pansy and nettle in the mixes. The value of the dy in these groups compared to the control group and the group receiving an antibiotic were on average more than 20% higher. The value of the Wf in the group receiving pansy compared to the control group and the group receiving AGP were higher by 22.4% and 21.9% respectively ($P < 0.05$).

Regardless of the species of herb added higher values were recorded for the following parametres: Ix, A, CS and Wy/dy. A 2% addition of hop, nettle and pansy increased the dy value, whereas an addition of hop, lemon balm and pansy contributed to increased Wy compared to bone properties measured in the control group and in the group receiving the antibiotic. The body weight of chicks in experimental groups (except for the group fed on nettle) on the 42nd day of breeding was similar to the body weight of control chicks and chicks fed on mixes with an antibiotic. Moreover, the conversion of feed per 1 kg of weight gain with the use of lime, lemon balm and/or nettle did not deviate from the conversion of feed by birds in the control group and the group receivig antantibiotic. The introduction of lime, lemon balm, pansy and nettle increased the slaughter yield and the addition of pansy, mint and nettle contributed to a reduction in the share of abdominal fat compared to the AGP group.

Keywords: chicken, herbs, growth performance, carcass characteristics, bone parameters

The European ban on antibiotic growth promoters (AGP) in animal feed has accelerated and led to investigations of alternative feed additives to be used in animal production. Breeders, as well as environmentalists, are increasingly more approving of herbs in which they see a potential to reduce the pollution caused by poultry production. The primary aim of using herbs in poultry feeding is accelerating metabolism and improving the birds' health. This is achieved, among other things, by increasing the number of beneficial intestinal microorganisms at the cost of pathogenic bacterial flora, which results in an enhanced use of feed nutrients with reduced environmental emissions of ammonia and hydrogen sulfide (15, 27).

Studies involving herbs as a replacement for AGP have been carried out primarily in terms of their effect on the performance of broiler chicken breeding, influencing the breeding effectiveness, such as weight gain or feed conversion ratio. Most authors cited herein noted that chickens administered herbal preparations in feed have better productive performance (8, 40). The use of herbal extracts, and especially garlic, improved feed conversion ratio (FCR) compared to virginiamycin (33). Studies by Fritz et al. (13) recorded performance comparable with, or even better than that obtained with the use of avoparcin, and that was due to an addition of milfoil and St. John's wort. Alcicek et al. (1), replacing avilamycin with exotic herbs, recorded a faster growth rate of chickens, improved slaughter yield and feed conversion ratio. Herbs affect slaughter parameters in a broiler carcass (26). Herbal additives reduce carcass fat (12, 38), and the presence of herbs, such as ginger, anis or dill in feed mixes significantly decrease the content of intramuscular fat (9). The use of EXTRACT in the studies by Jamroz et al. (17) improved feed conversion ratio, increased the share of breast muscle in the carcass, and at the same time reduced the share of depot fat. Similar results for chickens fed on thyme and rosemary were recorded by Hernandez et al. (16).

Selecting birds for rapid growth is one of the reasons for reduced bone elasticity in their limbs (39, 43). Consequently, numerous problems have occurred including deformations, fractures and infections, and, as a result, increased bird mortality rate. The alterations occurring in the bone structure throughout the birds' lives are reflected in their altered mechanical parameters. The skeleton is not only a supporting structure for the birds but it is also an important source of minerals for the needs of metabolism (19). Reichmann and Connor (34) demonstrated that the degree of bone mineralization affects bone strength and insufficient mineralization is linked to an increased risk of fractures. The overall growth, including the skeletal system, depends on the composition of the mixes used in feeding (14, 23).

The content of biologically active ingredients such as phytosterols, flavonoids and glycosides in herbs appears to facilitate bone metabolism and promotes proper bone density (45). On the other hand, herbs such as peppermint, rosemary, salvia, tilia, hop or thyme are rich in monoterpenes which are the main components of essential oils. Mühlbauer et al. (28) and Dolder et al. (7) proved that monoterpenes are responsible for inhibiting bone resorption through their direct influence on osteoclasts.

The number of studies involving the use of herbs in chicken nutrition and analysing their effect on the structural processes of bone formation, so vital to the animals' welfare, is limited. The reason may be insufficient insight as the variety of herbal species is enormous and their effects extremely extensive. Therefore, this study was deemed justified.

The study aimed to determine the effect of replacing the antibiotic in feed mixes with various herbal additives on the core chicken breeding parameters such as weight gain, FCR, mortality rate, European Efficiency Index (EEI), selected carcass slaughter parameters and some strength and morphometric parameters of the tibia bone on broiler chickens.

Material and methods

Animals and experimental design. All procedures used during the research were approved by the Local Ethics Committee for Animal Testing at the University of Life Sciences in Lublin.

400 one-day-old Ross 308 male chicks were split into 8 groups of 10 chicks each in 5 repetitions. The chicks were allocated at random to the control group (negative without AGP), I – receiving AGP, and to groups given 2% herbal additiveshop (*Humulus lupulus*) – II, lime (*Tilia cordata*) – III, lemon balm (*Melissa officinalis*) – IV, pansy (*Viola tricolor*) – V, peppermint (*Mentha piperita*) – VI and nettle (*Urtica dioica*) – VII.

The ingredients and nutritional value of a basal diet (Starter from 1 to 21, grower from 22 to 35 and the finisher 36 to 42 days of life) are shown in Table 1. The mixes were administered as pellets, and nestlings were given crumbles. Feed and water were provided *ad libitum*. The study involved herbs produced by Herbapol Lublin S.A. Company. The herbs contained essential oils of: hop cones (0.42%), lemon balm leaves (0.077%), peppermint leaves (2.92%), as well as flavonoids: pansy herb (0.37%), and lime flower (0.78%).

Experimental measurements. During the experiment chickens' body weight was controlled on the 21st, 35th and 42nd day of breeding and the amount of the feed consumed, as well as the birds' health condition were analysed. The resulting data formed the basis for determining the feed conversion ratio measured by calculating feed consumption per one kilogram of weight gain (FCR). The effectiveness of chicken fattening was determined on the basis of the EEI calculated by means of the following data: length of the fattening period, feed conversion, final body weight and survival rate in respective groups. Postslaughter evaluation (46) was performed on 10 male chicks selected from each group. The right-leg tibia was sampled for analysis from chickens slaughtered on day 42.

Tab. 1. Composition (%) and nutritive value of the mixtures

Item	Mixtures	
	Starter	Grower/Finisher
Maize	55.15	57.78
Soybean meal 46%	33.0	30.0
Yeast	2.0	2.0
Dried grass silage meal	2.0	2.0
Soya oil	3.0	4.0
Dicalcium phosphate	1.5	1.2
Limestone	1.5	1.5
NaCl	0.5	0.35
DL-methionine	0.15	0.15
L-lysine	0.2	0.02
Vitamin-mineral premix	1.0	1.0
Nutritive value of the mixtures		
[b]ME (MJ)	12.74	13.03
[a]Crude protein (%)	21.41	19.42
[a]Crude fibre (%)	3.43	3.33
[a]Crude fat (%)	4.61	5.08
[a]Total Ca (%)	1.01	0.94
[a]P total (%)	0.69	0.64
[b]Available P, %	0.43	0.41
[b]Total Ca /available P	2.12	1.90
[a]Cu (mg)	14.82	14.52
[a]Fe (mg)	40.31	39.82
[a]Zn (mg)	99.13	98.50
[b]Na	2.24	1.64
[a]Total lysine (%)	1.21	0.99
[a]Met + Cys (%)	0.77	0.75

Explanations: [a] values analysed; [b] values calculated using WinPasze, version PRO MAX UP Lublin;
Composition of premix starter/kg: vit. A 1 360 000 IU, vit. D_3 325 000 IU, vit. E 4000 mg, vit. K3 250 mg, vit B_1 200 mg, vit. B_2 600 mg, vit. B_6 300 mg, vit. B_{12} 2000 µg, biotyn 15 mg, folic acid 125 mg, nicotinic acid 3500 mg, D-calcium panthotenate 1200 mg, choline chloride 60 000 mg, Mn 9000 mg, Cu 2000 mg, Zn 10 000 mg, Fe 9000 mg, J 100 mg, Se 25 mg, Co 70 000 µg. Composition of premix grower/finisher/kg: vit. A 1 200 000 IU, vit. D_3 300 000 IU, vit. E 3000 mg, vit. K3 200 mg, vit B_1 150 mg, vit. B_2 500 mg, vit. B_6 250 mg, vit. B_{12} 1500 µg, biotyn 10 mg, folic acid 100 mg, nicotinic acid 2500 mg, D-calcium panthotenate 1000 mg, choline chloride 60 000 mg, Mn 9000 mg, Cu 2000 mg, Zn 10 000 mg, Fe 9000 mg, J 100 mg, Se 25 mg, Co 70 000 µg

Bone measurement. The bones were mechanically stripped of soft tissues, weighed (with 0.1 g accuracy), packed into labeled plastic bags and frozen (at the temperature of –25°C) until the beginning of analyses.

The mechanical properties of bones such as the maximum elastic (Wy) and ultimate (Wf) strengths were determined in INSTRON 3369 apparatus (Instron, Canton, MA, USA) as described previously. In addition, the following were calculated: yielding deformation (dy), bending point resistance (Wf/A), load-to-deformation ratio (Wy/dy) (10, 11).

Geometric and cortical properties of bones were estimated on the basis of horizontal and vertical diameter measurements of the mid-diaphyseal cross-section of bone. The cross-section area (A), the second moment of interia (Ix), and the mean relative wall thickness (MRWT) were determined using the following formulas: $Ix = 3{,}14(V^3H - v^3h)/64$, $A = 3{,}14(HV - hv)/4$, $MRWT = [(V - v)/v + (H - h)/h]/2$; the cortical layer thickness (CLT), the cortical index (CI), the cortical surface (CS) and the cortical surface index (CSI) were determined using the following formulas: $CLT = H - h$; $CI = (H - h/H) \times 100$; $CP = H^2 - h^2$; $CSI = (H^2 - h^2/H^2) \times 100$. Where H is the horizontal external diameter of the cross-section of the bone, h – horizontal internal diameter of the cross-section of the bone, V – vertical external diameter of the cross-section of the bone, v – vertical internal diameter of the cross-section of the bone (10, 11, 42).

Analysis of the feed. The content of dry matter, total protein, fat and crude fibre was determined in the feed mixtures according to AOAC (2). The content of mineral components (Ca, Mg, Cu, Fe, Zn) in feed was determined by atomic absorption spectrometry using a Unicam 939/959 apparatus, and general P (32) with a Helios α-Unicam apparatus, using molybdenum and vanadium as the reagent (NH_4VO_3, $(NH_4)_6Mo_7O_{24} \cdot H_2O$, H_2O). The amino acid composition was determined by ion-exchange chromatography using an INGOS AAA 400 amino acid analyser with post-column derivatization of ninhydrine and spectrophotometric detection according to the standard manufacturer's procedure and MCMiAŻ/PB-03 test procedure. The samples were hydrolyzed in aqueous solution (6N HCl + 0.5% phenol at a temperature of 110°C for 24 hours). Sulphur amino acids (cysteine and methionine) were determined in a separate analysis as oxidised derivatives (cysteic acid and methionine sulfone) resulting from oxidation with performic acid and then released from proteins during acid hydrolysis. Following this reaction, the tested samples were again subject to acid hydrolysis (3).

Statistical analysis. The results obtained were statistically analyzed (SEM and effects of diet) by ANOVA and Tukey's one-way range test, using Statistica v.10.0 software (41). P values < 0.01 and < 0.05 were considered significant. An asterisk indicates a statistically significant difference between the control and experimental groups.

Results and discussion

Broiler Performance. Adding herbs to feed mixes did not reduce the growth parameters in broiler chickens in the initial breeding period, as compared to the control group and to the group administered an AGP (Tab. 2). On 21[st] day of life the body weight of chickens receiving an admixture of lemon balm and nettle was significantly higher (P < 0.01) compared to the body weight of birds fed with AGP, hop and lime and control groups. On the other hand, the body weight of chickens fed on a mix with an addition of pansy and mint did not differ from that recorded in other experimental groups. The obtained results demonstrate that during the initial period of breeding the antibiotic added to the feed may be successfully replaced with herbs. Similarly, Guo et al. (15) observed that the rate of broilers' growth until

Tab. 2. Growth performance and carcass characteristic ($\bar{x}$)

Item	Groups								SEM	Influence of diets
	Control	I	II	III	IV	V	VI	VII		
Body weight (g):										
21. d	660^{cB}	677^{bcB}	676^{bcB}	661^{cB}	711^{aA}	689^{bAB}	684^{bAB}	693^{bA}	4.06	*,**
35. d	1415^{b}	1542^{ab}	1421^{b}	1411^{b}	1582^{ab}	1638^{a}	1605^{ab}	1648^{a}	17.88	**
42. d	2112^{b}	2249^{ab}	2109^{b}	2229^{ab}	2365^{ab}	2288^{ab}	2298^{ab}	2435^{a}	18.07	**
FCR (kg/kg) 1.-42. days	1.88^{B}	1.97^{B}	2.19^{A}	1.90^{B}	2.03^{B}	2.01^{B}	2.17^{A}	1.87^{B}	0.18	*
Mortality (%)	3.3	3.3	3.3	0.0	0.0	3.3	0.0	0.0	6.49	NS
EEI (pts)	168	194	153	165	179	179	178	205	0.82	NS
Dressing percentage (%)	71.0^{bB}	71.1^{bAB}	71.2^{bB}	73.3^{aA}	73.0^{aA}	73.0^{aA}	72.5^{abB}	73.1^{aA}	0.65	*,**
Share of breast muscle (%)	21.64	21.20	21.82	21.29	20.28	20.46	20.18	20.29	0.228	NS
Share of leg muscle (%)	18.33	19.56	18.95	20.34	17.82	19.52	18.87	19.71	0.219	NS
Share of abdominal fat (%)	2.1^{abAB}	2.3^{aA}	1.9^{abcAB}	1.9^{abcAB}	2.0^{abcAB}	1.6^{bcAB}	1.5^{bcAB}	1.4^{cB}	0.82	*,**

Explanations: A, B – values in the rows with different letters differ significantly ($P < 0.01$); a, b, c – values in the rows with different letters differ significantly ($P < 0.05$); SEM – standard error of the means; NS = $P > 0.01$;* – $P < 0.01$; ** – $P < 0.05$

the 21st day was faster compared to the group which was given an antibiotic (Virginiamycin). Demir et al. (6), who enriched the mixtures with garlic, noted that weight gain and feed conversion were not worse than in the group administered antibiotics. The most significant differences between the productive performance of birds receiving antibiotics or herbs were identified, similar to these authors' studies, in the first breeding period. On 35th day of life an addition of pansy and nettle significantly increased ($P < 0.05$) the birds' body weight compared to the control group and the group receiving hop and tilia. The highest slaughter weight was recorded in chickens fed on a mix with an addition of nettle (2435 g), while significantly lower body weight ($P < 0.05$) was revealed in the control group (2112 g) and the group receiving hops (2109 g). Moreover, Jamroz et al. (17) demonstrated that a mixture of cinnamaldehyde, capsaicin and carvacrol (XTRACT) was more effective during the initial phase of breeding, as it improved weight gain in slaughter chickens by even 8%, in reference to the negative control group. These authors' studies showed that also in the subsequent breeding period nearly all herbs contributed to satisfactory weight gain in broiler chickens (Tab. 2). Those relationships were maintained until the end of the breeding process. The slaughter weight of broilers fed on mixes with single herbal additives was close to that of chickens receiving antibiotics, which denotes a possibility of substituting feed antibiotics without risking deteriorated performance. Among the studied herbs the best results were recorded for pansy and nettle, which may result from their specific composition. Tannins which are found in pansy reduce the permeability of the mucous membrane and have an anti-bacterial and anti-diarrhoeal effect, whereas flavonoids present in nettle relax the smooth muscles of the digestive tract and the bile ducts, as well as they reveal anti-inflammatory properties (18, 22). Other agents which may have contributed to the positive effect of plant extracts on birds' growth were probably their antioxidant properties (29). Additionally, phytoestrogens present in herbs reveal affinity to estrogen receptors and are capable of activating the latter. Since they may act similarly to hormones, they might affect chickens' growth and meat quality (35).

No information concerning the effect of herbs used in these authors' studies on the results of broiler chicken breeding was found in available literature. However, it is acknowledged that herbs do have a beneficial effect, which was confirmed in the case of herbs such as artichoke, anise, ginger, dill, rosemary or oregano, as well as with commercial herbal preparations such as ANIMON and NATUSTAT (4, 8, 9, 30).

Feed conversion per one kilogram of weight gain in broiler chickens was dependent on the species of the herb used (Tab. 2). In the groups given hop or peppermint the conversion of feed mixes was markedly worse, which might have been caused by the herbs' spicy and bitter taste and resinous odour which is characteristic of hop cones, whereas in the case of peppermint the main compound giving it the characteristic smell and flavour is menthol which makes ca. 50% of all the ingredients of the essential oil. However, it is commonly believed that herbs have a positive effect on feed conversion, though available literature did not include any works discussing herbs used in these authors' studies. Some indirect confirmation of the results mentioned above may be provided by studies focusing on purple coneflower, herbal extracts containing salvia, thyme, rosemary or commercial preparations, e.g. LIVOL CLASSIC (8, 30, 36).

In these authors' studies no influence of the experimental agent on broilers' mortality rate was noted (Tab. 2). Although the groups control, obtaining an addition of flavomycin, pansy and hop cones revealed mortality rates at the level of 3.3%, which actually

Tab. 3. Tibia bone parameters of the broiler chicken ($\bar{x}$)

Item	Groups								SEM	Influence of diets
	Control	I	II	III	IV	V	VI	VII		
Mechanical parameters										
dy (mm)	1.30^{B}	1.29^{B}	1.60^{A}	1.36^{AB}	1.38^{AB}	1.57^{A}	1.39^{AB}	1.60^{A}	0.74	*
Wy (N)	125.6^{bB}	124.7^{bB}	190.2^{aA}	124.3^{bB}	186.8^{aA}	195.6^{aA}	127.0^{bB}	178.1^{aA}	0.81	*,**
Wf (N·mm)	275.6^{b}	276.6^{b}	331.8^{ab}	324.6^{ab}	320.2^{ab}	337.4^{a}	317.8^{ab}	332.4^{ab}	0.82	**
Wy/dy (N/mm)	111.9^{B}	112.9^{B}	130.5^{A}	128.0^{A}	129.5^{A}	126.9^{A}	127.9^{A}	128.4^{A}	0.81	*
Wf/A (N·mm/mm)	13.4^{bB}	16.3^{aA}	13.6^{bB}	13.3^{bB}	13.4^{bB}	13.7^{bB}	13.5^{bB}	13.1^{bB}	0.82	*,**
Cortical indexes										
CLT (mm)	2.51	2.50	2.94	2.86	2.94	2.92	2.88	2.97	0.74	NS
CS (mm^2)	33.5^{bB}	34.9^{bB}	39.8^{aA}	39.9^{aA}	41.0^{aA}	39.7^{aA}	42.5^{aA}	42.3^{aA}	0.81	*,**
CI (%)	10.6	10.8	11.3	11.1	10.9	11.5	10.7	11.5	0.82	NS
CSI (%)	55.8^{ab}	58.5^{ab}	56.3^{ab}	56.6^{ab}	57.2^{ab}	55.1^{b}	62.2^{a}	59.9^{ab}	0.81	NS
Geometric features										
Ix (mm^4)	94.8^{cC}	95.9^{cC}	138.7^{abAB}	141.5^{abAB}	137.9^{abAB}	131.8^{bB}	142.6^{aAB}	146.9^{aA}	0.81	*,**
A (mm^2)	19.5^{bB}	19.1^{bB}	27.5^{aA}	28.4^{aA}	27.5^{aA}	29.6^{aA}	28.9^{aA}	29.5^{aA}	0.82	*,**
MRWT	0.44	0.43	0.44	0.45	0.47	0.46	0.44	0.47	0.81	NS

Explanations: A, B, C – values in the rows with different letters differ significantly ($P < 0.01$); a, b – values in the rows with different letters differ significantly ($P < 0.05$); SEM – standard error of the means; NS = $P > 0.01$;* – $P < 0.01$; ** – $P < 0.05$

meant one dead bird per group. Although the groups obtaining an addition of pansy and hop cones revealed mortality rates at the level of 3.3%, which actually meant one dead bird per group. The birds died in the first breeding period, which suggested a coincidence rather than the influence of the experimental agent.

Carcass characteristics. Enriching feed mixes administered to broiler chickens with herbs did modify slaughter yield (Tab. 2). The addition of tilia, lemon balm, pansy and nettle significantly ($P < 0.05$) increased the slaughter yield of chicks compared to the control group, the AGP group and the group receiving hops. The lack of significant influence on slaughter yield was noted by Makarski and Polonis (24) and Phommachan et al. (31), who used mixtures containing, among other herbs, nettle, milfoil, marigold, field horsetail, chamomile or caraway. On the other hand, a deteriorated slaughter yield was observed by Sarica et al. (37) and Mala et al. (25). In these authors' studies average musculature was not significantly varied, although experimental chickens were characterized by stronger musculature compared to those receiving the antibiotic. A beneficial effect of a plant extract on chickens' musculature was recorded by Jamroz et al. (17).

Single herbal additives (pansy, peppermint, nettle) significantly ($P < 0.05$) reduced carcass fat in reference to the group receiving antibiotics in feed (Tab. 2). Among the experimental chickens no significant changes were observed regarding the type of herbs. The significantly highest share of abdominal fat was characteristic of broilers receiving an antibiotic, while its lowest content was found with nettle. It is possible that the antioxidant properties of essential oils are utilized by the cells, thus having a sparing effect on the intracellular antioxidant systems (5). The obtained results correspond with earlier studies by Fritz et al. (12), which focused, among other herbs, on the nettle.

Bone measurement. Bone resistance in birds is one of the most vital issues during broiler chicken breeding which may be worsened by an inadequate composition of feed mixes and have a negative influence on the production output. These authors found that the herbs used and the antibiotic, Flavomycin, had an influence on bone elasticity (Tab. 3). The largest increase in bone elasticity occurred as a result of using additives such as hop, pansy and nettle in the mixes. The value of the dy in these groups compared to the control group and the group receiving an antibiotic were on average more than 20% higher. With the use of lime, peppermint and lemon balm, bone dy was comparable with that obtained for the bones of the chickens in the control group fed on mix with Flavomycin and the remaining experimental groups. On the other hand, the value of the Wf in the group receiving pansy compared to the control group and the group receiving AGP were higher by 22.4% and 21.9% respectively ($P < 0.05$). The values of the force above the dy of chickens' tibia were similar to Wy values. After 42 days of breeding, the agents which significantly ($P < 0.01$) affected Wy in chickens' bones were hop, lemon balm, pansy and nettle. It seems that substituting the antibiotic with herbs in chickens' diet may result in increasing their bone mass, as demonstrated in these authors' previous studies (20), and resistance to fractures due to a higher level of mineral absorption resulting from improved digestibility.

One of the parameters used to evaluate the resistance of bones to deformations is the Wy/dy (Tab. 3). An increase in this value is an indicator of the bone's improved resistance. The bone's Wy/dy, after a 42-day period of using herbal additives in feed mixes, was significantly higher compared to this parameter recorded for the bones of chickens in the control group and in the group administered AGP in feed. Thus, supposedly replacing a mix containing Flavomycin with herbs could lead to improved digestibility and availability of nutrients with regard to the development of a desirable micro flora in the digestive tract, which in consequence enhances the retention of minerals and stimulates adequate bone mineralization.

Single herbal additives in feed mixes significantly ($P < 0.01$) reduced the Wf/A of the bone in comparison with this value recorded while feeding chickens with a diet containing an antibiotic (Tab. 3). This could have resulted in altering the bone structure, expressed by high values of geometry parameters, since a significant influence of herbs was recorded on geometrical properties and cortical indicators. This effect was particularly reflected in the increased ($P < 0.01$, $P < 0.05$) values of the Ix, A and the CS of the bone (Tab. 3).

These authors' studies indicate that herbal additives used in chicken feed in place of the antibiotic had a positive effect on most bone strength parameters. These results are confirmed by the authors' previous studies (20, 21). Not only were strength parameters not reduced, but they were certainly improved.

The results of the study suggests that using herbs as an alternative for AGP seems justified, which is confirmed by enhanced chicken productive performance and improved strength and geometrical parameters of bones that are vital for the animals' welfare.

Regardless of the species of herb, added higher values were recorded for the following parametres: Ix, A, CS and Wy/dy. A 2% addition of hop, nettle and pansy increased the dy value, whereas an addition of hop, lemon balm and pansy contributed to increased Wy, compared to bone properties measured in the control group and in the group receiving the antibiotic. The body weight of chicks in experimental groups (except for the group fed on nettle) on the 42[nd] day of breeding was similar to the body weight of control chicks and chicks fed on mixes with an antibiotic, which denotes a possibility of substituting feed antibiotics without risking deteriorated breeding performance. Also, the conversion of feed per 1 kg of weight gain with the use of lime, lemon balm and/or nettle did not deviate from the conversion of feed by birds in the control group and the group receivig Flavomycin The introduction of lime, lemon balm, pansy and nettle increased the slaughter yield and the addition of pansy, mint and nettle contributed to a reduction in the share of abdominal fat compared to the AGP group.

Herbs and the secondary metabolites they contain provide a promising alternative to antibiotics used until recently as feed additives. However, in order to take appropriate advantage of the vast richness of bioactive plant food compounds, it is necessary to continue intensive research. It is possible that better knowledge of the mechanisms behind some of these substances will contribute to improving the methods of their application, as well as to creating new, more efficient preparations.

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