Growth performance, gastrointestinal tract responses, and meat characteristics of broiler chickens fed a diet containing the natural alkaloid sanguinarine from *Macleaya cordata*[1]

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Primary Audience: Nutritionists, Researchers

SUMMARY

Until the end of 2005, antibiotics were used in Europe in poultry nutrition as growth-promoting agents. The general European Union ban on antibiotic growth promoters, beginning in 2006, has encouraged the search for effective alternatives. Research not only on performance, but also on the physiological responses of birds is still sparse. This experiment was conducted to characterize, in addition to performance indices, the physiological effect of an alkaloid preparation, Sangrovit, obtained from the aerial parts *Macleaya cordata*, on the gastrointestinal tract (mainly ceca) of broiler chickens. Carcass meat characteristics and the fatty acid profile of breast meat were evaluated as well. One-day-old broiler chicks (Cobb 500) were fed a wheat-corn-soybean meal control diet without (control) or with a 30 mg/kg dose of the alkaloid preparation for 5 wk. The Sangrovit treatment did not significantly improve final BW, FCR, or breast muscle weight when compared with the control treatment. The n-6:n-3 fatty acid ratio in breast meat was significantly increased by the Sangrovit treatment. The sensory evaluation of breast and thigh meat did not reveal any negative influence of dietary supplementation with the alkaloid preparation. Supplementation of 30 mg/kg of the alkaloid-containing preparation Sangrovit in broiler diets without growth promoters can help perpetuate a beneficial cecal environment, reducing the activities of bacterial β-glucosidase ($P = 0.095$) and β-glucuronidase ($P = 0.075$) as well as decreasing pH of the digesta ($P = 0.060$).

Key words: broiler, carcass trait, ceca, growth, sanguinarine

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DESCRIPTION OF PROBLEM

The use of antibiotics for growth promotion in poultry has been banned in many countries; therefore, alternatives to traditional subtherapeutic antibiotic usage have received much attention [1, 2]. One approach that may be a promising feeding strategy is dietary supplementation with plant extracts that have beneficial multifunctional properties originating from their biologically active constituents [3, 4]. Isoquinoline alkaloids represent one of the most interesting groups of plant secondary metabolites that display some medicinal properties, including antimicrobial, anti-inflammatory, and immunomodulatory effects [5]. It has been reported that a structurally related quaternary benzo[*c*]phenanthridine alkaloid sanguinarine, the main active component of the natural feed additive Sangrovit [6], promotes animal growth by increasing feed intake and improving amino acid utilization [4, 7]. Sangrovit contains a mixture of the intact aerial parts and the fraction of quaternary benzo[*c*]phenanthridine alkaloids from *Macleaya cordata* (Willd.) R. Br. The recommended dietary level of this preparation for broilers and growing turkeys has been reported as 20 to 50 ppm. It has even been observed that male Wistar rats fed Sangrovit at 7,000 mg/kg of feed for 90 d showed no changes in hematology markers, oxidative stress parameters, or the morphological structure of selected organs [8]. The main activity of sanguinarine is exhibited in the lower part of the gastrointestinal tract because of its modulatory effect on microbial activity [9]. It should be pointed out that the sensory quality of meat can be influenced by several factors, including direct transfer of aroma-active components from feed to meat, changes in the composition of fatty acids, and the production of aroma-active microbial metabolites in the gastrointestinal tract, which are absorbed and deposited in meat [10].

The objective of this work was to determine the effect of the herbal preparation Sangrovit [6], obtained from *M. cordata*, added at a dietary level of 30 mg/kg, on growth performance, cecal parameters [bulk effect, pH, microbial enzyme activity, and short-chain fatty acid (**SCFA**) production], and selected meat and carcass traits (breast and thigh muscle weights, fatty acid composition, and sensory evaluation) in broiler chickens.

MATERIALS AND METHODS

The procedures related to bird care were approved by the Bird Care and Use Committee of the Lithuanian Veterinary Academy in Kaunas.

General Husbandry Practices

The feeding trial was conducted using 1,000 one-day-old Cobb 500 broiler chickens [11] allocated to 2 treatments, with 10 replicates of 50 chickens per replicate pen. The birds were kept on deep litter and had free access to feed and water. During the first week of the experiment, the chicks were maintained on 24 h of light, and an 18-h light schedule was used thereafter.

Diets and Attributes Measured

The birds were fed starter and grower diets from 1 to 8 d and 9 to 35 d, respectively, without (control) or with treatment addition (Sangrovit [6] at 30 g/metric ton of feed). A basal diet (Table 1) was formulated to meet the nutrient requirements of broiler chickens [12]. The content of pure sanguinarine in the experimental diet averaged 0.36 mg/kg. Sanguinarine was determined by reverse-phase HPLC using a C_{18} column with phosphate buffer-acetonitrile-triethyloamine (65:34:1, by vol) as the mobile phase and fluorometric detection at 570 nm, with irradiation at 330 nm [9].

Feed intake, BW gain, and FCR were determined at 1, 8, 21, and 35 d. Mortalities were recorded daily and their BW were used to adjust for ADG, ADFI, and FCR. At the end of the trial, 15 chickens from each treatment, representing an average BW, were killed by cervical dislocation according to the recommendations of Close et al. [13] for euthanasia of experimental animals. The ceca and cecal contents were collected from each bird. Soon after euthanasia (approximately 30 min), cecal pH was measured using a microelectrode and pH/ion meter [14]. Samples of cecal contents were immediately transferred to microcentrifuge tubes and were stored at −70°C. The cecal wall was flushed clean with ice-cold saline, blotted on filter paper, and weighed (cecal wall weight). Dry matter of intestinal and cecal digesta was determined at 105°C. In fresh cecal digesta samples, ammonia was extracted

and trapped in a solution of boric acid in Conway dishes and was determined by direct titration with sulfuric acid [15].

The glycolytic activity in the cecal digesta was measured by the rate of ρ- and *o*-nitrophenol release from their nitrophenylglucosides according to the modified method of Djouzi and Andrieux, as described by Juśkiewicz et al. [16]. The following substrates were used: *p*-nitrophenyl-α-D-glucopyranoside (for α-glucosidase), ρ-nitrophenyl-β-D-glucopyranoside (for β-glucosidase), ρ-nitrophenyl-α-D-galactopyranoside (α-galactosidase), *o*-nitrophenyl-β-D-galactopyranoside (β-galactosidase), and ρ-nitrophenyl-β-D-glucuronide (for β-glucuronidase). The reaction mixture contained 0.3 mL of a substrate solution (5 m*M*) and 0.2 mL of a 1:10 (vol/vol) dilution (supernatant) of the cecal sample in 100 m*M* phosphate buffer (pH 7.0) after centrifugation at 7,211 × *g* for 15 min at 39°C. Incubation was carried out at 37°C and ρ-nitrophenol was quantified at 400 and 420 nm (*o*-nitrophenol concentration) after the addition of 2.5 mL of 0.25 *M* cold sodium carbonate. The activities of α- and β-glucosidase, α- and β-galactosidase, and β-glucuronidase were expressed as micromoles of product formed per minute (IU) per gram of digesta.

Cecal digesta samples were subjected to SCFA analysis by gas chromatography [17]. The samples (0.2 g) were mixed with 0.2 mL of formic acid, diluted with deionized water, and centrifuged at 7,211 × *g* for 10 min at room temperature. The supernatant was loaded onto a capillary column (30 m × 0.53 mm [18]) using an on-column injector. The initial oven temperature was 85°C and was increased to 180°C by 8°C/min and held at 180°C for 3 min. The temperatures of the flame-ionization detector and injection port were 180 and 85°C, respectively. The sample volume for gas chromatography analysis was 1 μL.

Carcass Traits and Sensory Characteristics of Meat

After the final BW was taken, another 20 chickens (closest to the average pen BW), 1

Table 1. Composition of the basal diets

Item	Starter, d 1 to 8	Grower, d 9 to 35
Ingredient (composition), %		
Wheat (12.6% CP)	42.73	34.79
Corn (10.2% CP)	18.00	16.00
Wheat meal (15.0% CP)	—	5.00
Barley (13.0% CP)	—	5.00
Soybean meal (47.0% CP)	27.50	23.40
Rapeseed meal (38.0% CP)	—	4.00
Fish meal (65.0% CP)	1.00	—
Spray-dried hemoglobin (90.0% CP)	1.50	—
Soybean oil	4.20	6.50
Monocalcium phosphate[1]	1.40	1.55
Limestone	1.50	1.45
Sodium bicarbonate	0.21	0.27
Salt	0.15	0.15
L-Lysine-hydrochloride	0.18	0.40
L-Threonine	0.07	0.09
DL-Methionine	0.36	0.29
Premix[2]	0.60	0.60
Sand[3]	0.60	0.51
Calculated nutrient composition, %		
ME, kcal/kg	3,050	3,131
CP	22.14	20.06
Crude fat	6.62	9.26
Crude fiber	2.41	3.00
Crude ash	4.62	4.72
Lysine	1.27	1.24
Methionine	0.61	0.53
Methionine + cysteine	0.98	0.89
Threonine	0.85	0.79
Tryptophan	0.27	0.24
Linoleic acid	3.24	4.55
Calcium	1.00	0.96
Sodium	0.17	0.16
Chlorine	0.13	0.17
Potassium	0.87	0.86
Magnesium	0.10	0.12
Phosphorus (available)	0.47	0.49

[1]Composition: phosphate, 22.9% (relative solubility in water, 80%); calcium, minimum of 16.7%; ash insoluble in HCl, 1.5%; fluorine, maximum of 0.10%; arsenic, maximum of 6 mg/kg; lead, maximum of 4 mg/kg; cadmium, 4 mg/kg.

[2]Provided the following per kilogram of diet: vitamin A, 5,000 IU; vitamin D_3, 1,000 IU; vitamin E, 20 mg; vitamin K_3, 0.9 mg; vitamin B_1, 0.6 mg; vitamin B_2, 3 mg; vitamin B_6, 1 mg; biotin, 0.04 mg; pantothenic acid, 7 mg; folic acid, 0.5 mg; niacin, 15 mg; vitamin B_{12}, 6 μg; I, 0.72 mg; selenium, 0.28 mg; copper, 8 mg; manganese, 67.5 mg; zinc, 51 mg; iron, 64 mg.

[3]Sand was partly replaced by the Sangrovit preparation (Phytobiotics GmbH, Etville, Germany) in the experimental treatment.

from each pen, were randomly selected, tagged, and fasted for 8 h. After being killed, the birds were scalded, defeathered, and eviscerated. The carcasses were chilled in an aerated chill tank for 30 min, removed, and allowed to drain, and chill weight was recorded. Carcass meat characteristics (weights of carcass, breast, thigh meat, and abdominal fat) were evaluated. Meat (breast, thigh muscle) pH was measured at 0, 24, 48, and 72 h after cooling the carcasses. After carcass measurements, a skinless breast meat sample was collected from 1 carcass/pen to determine fatty acid composition [19].

The sensory evaluation was performed according to a descriptive sensory strategy. The sensory panel consisted of 8 trained panelists. A structured scale was used for evaluation of the samples. The left side of the scale, corresponding to the lowest intensity of each attribute, was given a value of 1, and the right side, corresponding to the highest intensity, was given a value of 7. Boiled chicken meat was analyzed in this study. Samples were placed in boiling water and were boiled for exactly 20 min. Samples were quartered lengthwise and served immediately to panelists, along with room-temperature water, tea, and unsalted crackers. Panelists were instructed to clean the palate with water or tea between evaluations of each sample. The following characteristics were assessed: overall odor intensity, boiled chicken odor, atypical odor, intensity of color, tenderness, chewiness, juiciness, fibrousness, mouthfeel, boiled chicken taste, atypical taste, and aftertaste.

Statistical Analysis

The data were analyzed using a 1-way ANOVA test, and differences were considered significant at $P < 0.05$ [20]. The Statistica software package version 6.0 [21] was used for statistical calculations. Changes in sensory attributes influenced by diet type were evaluated with a 2-tailed *t*-test for paired samples. The statistical analysis was carried out with SPSS software version 15.1 [22].

RESULTS AND DISCUSSION

Dietary treatments had no effect on BW and feed utilization in either the starter or grower phase (Table 1). Data available in the literature on the performance of broilers treated with the Sangrovit preparation are inconsistent, but to our knowledge, there have been no reports that a dietary sanguinarine-containing preparation can the depress growth of birds. In a study with growing Ross 308 chickens, a dietary treatment with 20 mg/kg of Sangrovit did not affect the productivity of birds and did not enhance dietary protein utilization [23]. In another study [4], Cobb × Cobb male chicks fed Sangrovit at 50 and 25 ppm (1 to 21 d and 22 to 42 d, respectively) had improved BW and FCR at 21 d of age.

It has been reported that dietary sanguinarine is not metabolized into potentially harmful benz[*c*]acridine and passes along the small intestine with almost no absorption [8, 24]. Jankowski et al. [9] found that feeding broilers 20 mg/kg of Sangrovit resulted in a significantly increased activity of mucosal maltase and reduced duodenal villus height, but without any changes in pH in the small and lower intestine. The main sites of bacterial fermentation in poultry are the ceca, and with respect to the reported antibacterial property of sanguinarine [25, 26], cecal parameters should be taken into account when assessing the physiological response of birds to dietary Sangrovit.

In the present study, cecal tissue and digesta weight, as well as the concentrations of cecal DM and ammonia, were not affected by dietary addition of Sangrovit (Table 2). There was a tendency toward lower digesta pH in the ceca of broilers fed the Sangrovit diet ($P = 0.060$). Based on an analysis of bacterial enzyme activity, Sangrovit had a relatively small but positive influence on the cecal ecosystem. The addition of this preparation did not reduce the activities of bacterial α-glucosidase, β-galactosidase, or α-galactosidase in the cecal digesta. β-Glucuronidase and β-glucosidase activities tended to decrease in the Sangrovit group ($P = 0.075$ and $P = 0.098$, respectively). β-Galactosidase, α-galactosidase, and α-glucosidase activities can facilitate the fermentation of resistant starch, raffinose-family oligosaccharides, and lactose, leading to the production of SCFA that serve as an energy source. The β-glucuronidase and β-glucosidase activity levels are often used as markers of pathogenic

Table 2. Effect of the Sangrovit preparation on growth performance and cecal parameters in broiler chickens from 1 to 35 d of age

Item	Control[1]	Sangrovit[2]	SEM[3]	*P*-value
BW, g				
1 d	44.8	44.6	0.1	0.998
8 d	161	156	1	0.728
21 d	686	701	6	0.658
35 d	1,753	1,766	13	0.742
Feed conversion, kg of feed/kg of BW gain				
1 to 8 d	1.62	1.69	0.04	0.642
9 to 21 d	1.74	1.71	0.02	0.785
22 to 35 d	2.07	2.01	0.04	0.699
1 to 35 d	1.91	1.87	0.03	0.348
Cecal tissue, g/kg of BW	2.89	3.01	0.11	0.325
Cecal digesta, g/kg of BW	4.02	4.78	0.23	0.111
pH of cecal digesta	6.11	5.97	0.08	0.060
Ammonia, mg/g of cecal digesta	0.59	0.63	0.03	0.652
DM of cecal digesta, %	18.8	20.5	0.9	0.154
Enzyme, U/g of cecal digesta				
α-Glucosidase	2.09	2.79	0.28	0.255
β-Glucosidase	0.78	0.66	0.11	0.098
α-Galactosidase	4.18	5.96	0.54	0.069
β-Galactosidase	3.29	3.70	0.43	0.263
β-Glucuronidase	2.07	1.80	0.26	0.075
Short-chain fatty acid, μmol/g of cecal digesta				
Acetate	92.2	89.7	3.5	0.425
Propionate	14.8	13.5	0.8	0.628
Isobutyrate	1.06	0.80	0.09	0.201
Butyrate	26.8[b]	32.8[a]	1.4	0.016
Isovalerate	1.54	1.16	0.14	0.105
Valerate	2.27	2.39	0.12	0.389
Total	139	140	4	0.444
Profile of short-chain fatty acid, % of total				
C_2	66	64	1	0.758
C_3	11	10	1	0.618
C_4	19[b]	23[a]	1	0.008

[a,b]Mean values within a row without a common superscript are different ($P < 0.05$).

[1]Broiler chickens fed a wheat-corn-soybean basal diet without supplementation for 35 d.

[2]Broiler chickens fed a basal diet supplemented with 30 mg/kg of the Sangrovit preparation (Phytobiotics GmbH, Etville, Germany) for 35 d.

[3]SD for all birds divided by the square root of the number of broilers.

microflora proliferation leading to undesirable metabolic changes [27, 28]. It could be assumed that in the present experiment, the Sangrovit preparation used, at a dose of 30 mg/kg of diet, did not suppress the fermentation processes in the ceca, but rather exerted some beneficial effects, as indicated by the reduced digesta pH, decreased β-glucuronidase activity, and unchanged total SCFA concentration. Among the SCFA, an increased concentration of butyric acid was observed in the Sangrovit group ($P < 0.05$). Beneficial physiological properties of butyric acid, in addition to its role as a source of energy for colonocytes, include gene expression modulation, signal transduction, protein degradation, and cell cycle differentiation [29].

Average carcass and breast muscle weights of broilers fed the diet with the Sangrovit preparation were higher by 1 and 3%, respectively, compared with the control group (Table 3). The thigh muscle weight in the Sangrovit group was lower by 2.44% than that in the control treatment. However, the above-mentioned differences were not significant ($P > 0.05$). The pH value of breast and thigh muscles was not affected by dietary treatment.

Table 3. Carcass traits and meat characteristics in broiler chickens fed a control diet or a diet supplemented with the Sangrovit preparation

Item	Control[1]	Sangrovit[2]	SEM[3]	*P*-value
Carcass weight, g	1,555.5	1,566.8	39.1	0.854
Breast weight, g	390.1	401.9	13.2	0.659
Thigh weight, g	307.3	299.7	8.3	0.412
pH of breast muscle				
After 0 h	5.76	5.78	0.01	0.777
After 24 h	5.77	5.73	0.01	0.895
After 48 h	5.81	5.75	0.01	0.621
After 72 h	5.76	5.70	0.02	0.489
pH of thigh muscle				
After 0 h	5.80	5.80	0.02	0.899
After 24 h	5.82	5.85	0.02	0.842
After 48 h	5.78	5.87	0.02	0.741
After 72 h	5.97	5.94	0.06	0.769
Fatty acid composition of breast meat, % (wt/wt)				
Myristic (C14:0)	0.82	0.71	0.05	0.625
Palmitic (C16:0)	25.25	23.47	0.52	0.745
Palmitoleic (C16:1n-7)	3.01	2.95	0.21	0.689
Heptadecanoic (C17:0)	0.19	0.18	0.01	0.784
Stearic (C18:0)	7.66	7.36	0.19	0.583
Oleic (C18:1n-9)	30.66[a]	27.86[b]	0.68	0.039
Linoleic (C18:2n-6)	22.91[b]	28.83[a]	0.44	0.011
α-Linolenic (C18:3n-3)	1.36[a]	0.78[b]	0.04	0.001
Arachidic (C20:0)	0.25	0.17	0.02	0.325
Gadoleic (C20:1n-9)	0.38[a]	0.27[b]	0.01	0.042
Eicosatrienoic (C20:3n-3)	0.79	0.74	0.05	0.742
Arachidonic (C20:4n-6)	3.89	4.22	0.19	0.384
Eicosapentaenoic (C20:5n-3)	0.33[a]	0.20[b]	0.02	0.000
Docosatetraenoic (C22:4n-6)	1.09	1.33	0.10	0.425
Docosapentaenoic (C22:5n-3)	0.78[a]	0.60[b]	0.04	0.007
Docosahexaenoic (C22:6n-3)	0.62[a]	0.35[b]	0.05	0.000
Partial sum of fatty acids[4]				
SFA	34.17	31.89	0.61	0.125
MUFA	34.05	31.08	0.58	0.246
PUFA	31.77[b]	36.27[a]	0.77	0.031
n-3	3.88[a]	2.67[b]	0.04	0.001
n-6	27.89[b]	34.38[a]	0.59	0.024
Fatty acid ratio				
PUFA:SFA	0.93[b]	1.14[a]	0.02	0.044
n-6:n-3	7.19[b]	12.88[a]	0.51	0.000
C16:1:C16:0	0.12	0.13	0.02	0.612
C18:1:C18:0	4.00[a]	3.79[b]	0.08	0.037
C18:0:C16:0	0.30	0.31	0.03	0.842

[a,b]Mean values within a row without a common superscript are different ($P < 0.05$).

[1]Broiler chickens fed a wheat-corn-soybean basal diet without supplementation for 35 d.

[2]Broiler chickens fed a basal diet supplemented with 30 mg/kg of the Sangrovit preparation (Phytobiotics GmbH, Etville, Germany) for 35 d.

[3]SD for all birds divided by the square root of the number of broilers.

[4]SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

Fatty acid composition of breast meat from broilers fed diets without (control) or with the addition of sanguinarine (Sangrovit treatment) is presented in Table 3. To our knowledge, no reports are available concerning the effects of sanguinarine-containing preparations on the fatty acid composition of poultry meat. The predominant fatty acids in chicken meat from both treatments were palmitic (C16:0) and stearic (C18:0) acids as saturated fatty acids, oleic acid

Table 4. Mean values (points) of breast muscle sensory attributes

Item	Control[1]	Sangrovit[2]	SEM	*P*-value
Overall odor	6.08	6.04	0.22	0.821
Boiled chicken odor	5.42	5.92	0.11	0.498
Atypical odor	1.08	1.00	0.07	0.822
Color intensity	1.25	1.33	0.03	0.691
Tenderness	3.92	4.58	0.15	0.827
Fibrousness	5.00	5.25	0.20	0.779
Juiciness	3.67	4.08	0.12	0.621
Chewiness	4.42	5.17	0.26	0.222
Crunchiness	4.50	5.08	0.18	0.328
Mouthfeel	1.92	2.25	0.11	0.421
Overall taste	4.92	4.92	0.20	0.883
Boiled chicken taste	4.92	5.00	0.21	0.789
Atypical taste	1.25	1.42	0.06	0.661
Aftertaste	3.42	3.08	0.08	0.486
Acceptability	5.00	5.09	0.13	0.721

[1]Broiler chickens fed a wheat-corn-soybean basal diet without supplementation for 35 d.

[2]Broiler chickens fed a basal diet supplemented with 30 mg/kg of the Sangrovit preparation (Phytobiotics GmbH, Etville, Germany) for 35 d.

(C18:1n-9) as a monounsaturated fatty acid, and linoleic (18:2n-6) and arachidonic (20:4n-6) acids as polyunsaturated fatty acids. Consumption of the diet with the phytogenic preparation affected the concentrations of 7 of the 16 fatty acids analyzed, thereby affecting the partial sum of fatty acids. In the Sangrovit treatment, an increase ($P < 0.05$) was observed in the sum of polyunsaturated fatty acids compared with birds fed the control diet. This was mainly due to the increase in C18:2n-6. The n-6:n-3 ratio was significantly elevated in the Sangrovit group. It has been reported that the ratio of n-6 to n-3 fatty acids in the typical modern diet of North America and Europe is still much higher than that recommended (i.e., 2:1) [30]. Therefore, the dietary treatment with 30 mg/kg of Sangrovit did not provide an additional desirable effect (from a human nutrition point of view) on the fatty acid composition of breast meat. It could also be assumed that that supplementation of the diet with Sangrovit might cause a decrease in stearoyl-coenzyme A desaturase activity because there was less oleic acid in the Sangrovit treatment; thus, a significant decrease in the C18:1:C18:0 ratio was observed in comparison with the control group. On the other hand, the 16:1:16:0 ratio remained unaffected by Sangrovit. The ratios of C16:1 to C16:0 and C18:0 to C18:1 represent the activity of stearoyl-coenzyme A desaturase [31]. The index of elongase activity, the ratio of C18:0 to C16:0, did not differ significantly between groups.

The mean values of breast muscle sensory properties are given in Table 4. The overall odor was intensive for all breast samples (>6 on the scale used), whereas an atypical odor was not detected in any sample evaluated. There was no significant influence of the feed treatment on odor, color, taste, or texture properties of the breast meat samples. Both types of meat were evaluated by panelists as acceptable. Similar results were obtained for the thigh meat sensory evaluation (data not shown).

CONCLUSIONS AND APPLICATIONS

1. Dietary addition of Sangrovit, a sanguinarine-containing product from *M. cordata*, supplemented to a broiler diet at the level of 30 mg/kg, did not significantly improve final BW and feed utilization.
2. A dietary dose of 30 mg/kg of Sangrovit had some beneficial effects on cecal fermentative processes in broilers (higher butyric acid concentration, and a tendency toward lower digesta pH and decreased β-glucuronidase activity).
3. The sensory evaluation of meat did not reveal any negative traits. However, the n-6:n-3 fatty acid ratio in breast meat was

significantly increased by the Sangrovit treatment. Therefore, more research is needed to asses the effect of the alkaloid sanguinarine on meat quality.

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