

Article

Enhancing Broiler Welfare and Foot Pad Quality through the Use of Medicinal Plant-Based Pellets as Bedding Material

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Abstract: The aim of this study was to investigate the impact of different bedding materials on both production performance and foot quality, assessed through the incidence, severity, and microbiological quality of foot pad dermatitis (FPD). A total of 2400 Ross 308 chickens were raised over 42 days, distributed across eight bedding material types (eight groups × four treatments × 75 chickens each). These pellets either lacked medicinal plant components or included 30% of plant parts, such as oregano (*Origanum vulgare*), summer savory (*Satureja hortensis*), lemon balm (*Melissa officinalis*), salvia (*Salvia officinalis*), and thyme (*Thymus vulgaris*). Production performance controls included body weight (BW) at 42 days of age, feed conversion ratio (FCR), and mortality. The severity of FPD was evaluated at 28, 35, and 42 days using a scale ranging from S0 to S3. A microbiological analysis of the feet was based on the FPD score. Broilers raised on straw chaff (bedding: 24% oregano and 6% summer savory, 18% oregano and 12% summer savory, and 24% oregano and 6% thyme) exhibited the highest BW. Straw chaff-reared broilers demonstrated the lowest FCR. The highest mortality occurred on 18% oregano and 12% summer savory bedding, which may have been caused by the high share of summer savory, which could be toxic. At 35 and 42 days, broilers in the 24% oregano and 6% summer savory group exhibited the best foot quality, while those on straw chaff and 18% oregano and 12% summer savory had the worst one. The influence of medicinal plants in the pellets was particularly notable in reducing *Listeria* sp. This reduction was likely due to the presence of carvacrol from summer savory, quercetin from lemon balm, and thymol from thyme. Based on our research, the best bedding materials for foot quality are 24% oregano with 6% summer savory and 18% summer savory with 12% salvia, while 18% summer savory with 12% lemon balm and 18% summer savory with 12% thymus were the most effective in limiting *Listeria* sp.

Keywords: bedding material; broiler; foot pad dermatitis; herbs



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1. Introduction

The use of medicinal plants, particularly herbs containing specific active substances, is increasingly prevalent in poultry production. The potential benefits of essential oils, alkaloids, flavonoids, and tannins include enhancing welfare [1], reducing reliance on feed antibiotics [2], combating intestinal parasites [3], and improving the sensory attributes of meat [4] and eggs [5]. Nutritional supplementation with medicinal plants has also been shown to enhance growth performance, antioxidant status, immunity, and intestinal health in broilers exposed to heat stress [6–8]. Primarily, derivatives from medicinal plants, such as extracts standardized to specific active compounds, are incorporated into the diet or

administered through drinking water. Their primary function is focused on supporting the gastrointestinal tract [9–11].

A well-balanced diet composed of high-quality components serves as the cornerstone for achieving optimal poultry production outcomes. However, even with the best feed, broilers cannot realize their full genetic potential if raised under suboptimal microclimate conditions. The conditions inside the poultry house are greatly influenced by the quality of the litter [12,13]. This becomes increasingly critical due to the progressive intensification of rearing and the management of larger flocks, despite consistent stocking rates per unit area [14,15]. Regarding broilers, the quality of the bedding material is gaining economic significance, particularly with the increasing incidence of foot pad dermatitis (FPD). Sub-optimal pad quality, characterized by lesions above 1 on the 4-point (0–3) Butterworth scale [16], hinders product export to Asian countries, where it is in high demand [17]. Several factors contribute to FPD, with the primary factor believed to be the quality of the litter, including its moisture content and microbiological status [17–19]. Consequently, the effective management and careful selection of suitable materials are crucial in combating FPD [17]. In the United States, broilers are often raised on pine shavings, while in Europe, straw is the preferred bedding material. In other regions, alternatives such as rice hulls and peanut hulls, peat, and ground maize cobs are used. The choice of bedding material is often influenced by the availability and cost of raw materials. In Europe, wheat or triticale straw is favored due to its high supply, low price, and high water absorption compared to other options [20]. In addition, pelletization can help reduce FPD occurrence, provided that the pellet size is small enough. Pelletizing not only prolongs the mulch's effectiveness but also facilitates the uniform incorporation of additives [21]. Various substances like aluminum sulfate, sodium bisulfate, and iron sulfate have been studied as litter supplements to lower pH and inhibit bacterial growth, resulting in reduced ammonia production [17,22]. While these compounds influence litter pH, the extent of their impact on reducing FPD intensity remains unclear, with authors noting only a decreasing trend [17,22]. In addition, the application of strongly acidic substances to the litter may restrict the use of the resulting manure in subsequent crop production and, at best, increase expenses related to field liming. Another approach involves using strongly alkalizing agents like gypsum, which, despite positively affecting litter parameters, can adversely affect feed utilization and increase poultry mortality [23].

Therefore, we hypothesized that integrating natural medicinal plants, not just as a dietary supplement but as an integral component of bedding alongside straw, could effectively mitigate the occurrence of FPD. This is attributed to the increased water absorption of the material and the inhibition of pathogenic microflora development. Gontar et al. [24] demonstrated that incorporating natural medicinal plants from the early stages of broilers' lives reduces the total count of mesophilic aerobic bacteria, yeasts, and molds in the bedding material. The authors attribute this effect to both the direct impact of essential oils and the increased water absorption compared to using straw alone. Nevertheless, analyzing the bedding material itself does not directly correlate with a response from the broilers. Therefore, the aim of this study was to assess the impact of using a combination of straw and specific medicinal plants on welfare, as gauged by the severity of FPD, and consequently on the production performance of broilers.

2. Materials and Methods

2.1. Bedding Material Production and Composition

In this study, eight types of mulch were utilized, with triticale straw being the primary component (Table 1). The first type comprised solely shredded straw in chaff form, approximately 1 cm in length (referred to as straw chaff). The second type of mulch was in pellet form and produced at the Research and Innovation Centre Pro-Akademia in Konstantynów Łódzki, Poland. The pellet manufacturing process involved a semi-industrial pelletizing line from Nawrocki Pelletizing Technology in Znin, Poland, which included a mill, a miniPelleter granulator, and a vibratory cooling system. The resulting pellets measured as 6 ± 1 mm in

diameter and 10–35 mm in length (referred to as straw pellets). In the remaining bedding types, 30% of triticale straw was substituted with parts of medicinal plants as shown in Table 1. The detailed process of pellet production, as well as the characteristics of the various litter types used in this study—including the essential oil content, moisture content, water absorption capacity, pH value, and total count of aerobic mesophilic bacteria in raw materials—was previously described by Gontar et al. [24].

Table 1. Bedding materials’ composition.

Material Type	Bedding Material Composition					
	Ingredient 1		Ingredient 2		Ingredient 3	
	Plant	Content %	Plant	Content %	Plant	Content %
Straw chaff ¹	triticale straw	100	-	-	-	-
Straw pellets ¹	triticale straw	100	-	-	-	-
P1	triticale straw	70	oregano	24	summer savory	6
P2	triticale straw	70	summer savory	18	oregano	12
P3	triticale straw	70	summer savory	18	lemon balm	12
P4	triticale straw	70	summer savory	18	salvia	12
P5	triticale straw	70	summer savory	18	thyme	12
P6	triticale straw	70	oregano	24	thyme	6

¹ Control group. Oregano (*Origanum vulgare*), summer savory (*Satureja hortensis*), lemon balm (*Melissa officinalis*), salvia (*Salvia officinalis*), thyme (*Thymus vulgaris*).

2.2. Experimental Design, Chicken, and Their Husbandry

The impact of bedding material type on broiler rearing was investigated at the Agricultural Experimental Station Wilanów Obory (Warsaw University of Life Sciences, Warsaw, Poland). Two 42-day production cycles were conducted: the first from 1 May to 15 June and the second from 31 September to 12 October 2020. For each cycle, a total of 1200 one-day-old Ross 308 broilers (males only) were acquired for rearing from a commercial hatchery. On each specified date, the broilers were divided into 16 floor pens, each containing 75 broilers, following the scheme outlined in Figure 1.

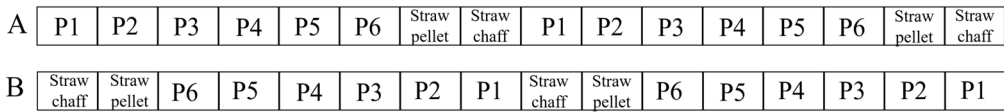


Figure 1. Distribution of experimental groups and schematic representation of single-pen equipment. (A): First cycle, (B): Second cycle. Bedding material types for different experimental groups—Straw chaff: 100% nonpelleted straw chaff; Straw pellet: 100% pelleted straw chaff; P1: pelleted 70% straw chaff, 24% *Origanum vulgare*, and 6% *Satureja hortensis*; P2: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *O. vulgare*; P3: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Melissa officinalis*; P4: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Salvia officinalis*; P5: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Thymus vulgaris*; P6: pelleted 70% straw chaff, 24% *O. vulgare*, and 6% *T. vulgaris*.

The reorganization of each group between cycles I and II aimed to neutralize the impact of the group’s positioning in the production hall. Before placement, 1.1 kg of bedding material was evenly distributed in each compartment for every 1 m² of space. Broilers were raised following the guidelines established for Ross 308 by Aviagen Inc., Huntsville, AL, USA, with a stocking rate of 11.4 broilers/m². In the first week of life, temperatures were maintained at 32–34 °C under radiant heat and 24 °C throughout the

house. As the broilers matured, the temperature was gradually reduced to 22–23 °C by 28 days of age. A light program of 23 h of light and 1 h of darkness was implemented until day 7 of age, transitioning to 18 h of light and 6 h of darkness for older broilers. The broilers were provided with ad libitum access to a commercially produced wheat–maize–soya-based diet in a three-stage system: 0–14 days (starter: 2985.5 MJ/kg of energy, 21.9% crude protein), 15–35 days (grower: 3057.2 MJ/kg of energy, 20.8% crude protein), and 36–42 days (finisher: 3152.8 MJ/kg of energy, 19.3% crude protein). Each pen was equipped with two automatic feeders, and water was supplied ad libitum through an automatic watering line fitted with bell drinkers (two drinkers per pen).

The body weight of broilers (BW; ± 0.1 g) was assessed on day 1 (initial body weight; IBW) and before slaughter on day 42. Feed intake (FI) (kg) was consistently monitored throughout the rearing period, with records kept for dead and culled broilers. Using the obtained results, the average BW at the end of rearing, feed conversion ratio (FCR; kg/kg), and mortality rate (%) for the 42 days were computed.

After 42 days of rearing and an 8 h feed interval, six broilers from each pen were randomly chosen for culling. Consequently, 24 broilers from each experimental group (6 broilers $\times$ 4 treatments) were culled. Following selection, the broilers were weighed (± 1.0 g) and tagged with a wing tag displaying a unique number for further identification. Stunning was administered using an alternating sinusoidal voltage of 380 V and 50 Hz, lasting for 4 s. Subsequently, the broilers were bled by cutting the jugular vein. After slaughter and decapitation, the broilers underwent scalding for approximately 5 min at 63 °C (± 2 °C), followed by plucking and evisceration. The carcasses were refrigerated at 4 °C for 24 h. Following the cooling period, the weights of the carcass, muscle gizzard without contents, liver (after gall bladder removal), and heart were determined. The carcass was dissected to determine the weights of breast muscle, leg muscle, and abdominal fat. The slaughter yield (carcass weight/BW before slaughter $\times$ 100%) and the proportions (g/100 g) of the breast muscle, leg muscle, abdominal fat, heart, liver, and gizzard in the carcass weight were then calculated.

2.3. Foot Pad Dermatitis Score

At 28, 35, and 42 days of age, the FPD of all broilers was evaluated on a 0–3 scale following the methodology outlined by Butterworth [16]. The scale is defined as follows:

- 0: Complete absence of foot pad skin lesions.
- 1: Single lesion with light-colored erythema and mildly enlarged skin scales.
- 2: Enlarged dark lesion with brownish exudate.
- 3: Visible necrotic skin lesion of the foot pad with loss of epidermis and dark skin around it, with small lesions also observed on the pads of individual toes.

For a more detailed visualization of the variations in FPD severity within each of the four categories, review images were captured using a MicroPublisher 5.0 RTV digital image analysis camera (QImaging, Surrey, BC, Canada) with reflected light lamps and screens (Kaiser, Schalksmühle, Germany). Additionally, histological micrographs were obtained through hematoxylin and eosin staining following the methodology by Ostaszewska et al. [25]. These images are presented in Figure 2.

At 42 days of age, 3 broilers from each pen were selected for microbiological testing, comprising 3 broilers per pen $\times$ 2 treatments $\times$ 2 cycles for FPD categories 0, 1, 2, and 3. Specifically, broilers from the straw chaff and straw pellet groups were selected for FPD category 3 based on availability. The broilers underwent slaughter using the previously outlined procedure, where the right ankle was severed at the hock joint and placed in a BagFilter (Interscience, Saint Nom, France) before scalding. Following this, the samples were transferred to a sample transport box (HTGNB-085, Xiamen, Fujian, China) under controlled temperatures of 20 °C (± 2 °C) and transported for approximately 1.5 h to the Research and Innovation Centre Pro-Akademia laboratory (Konstantynów Łódzki, Poland).

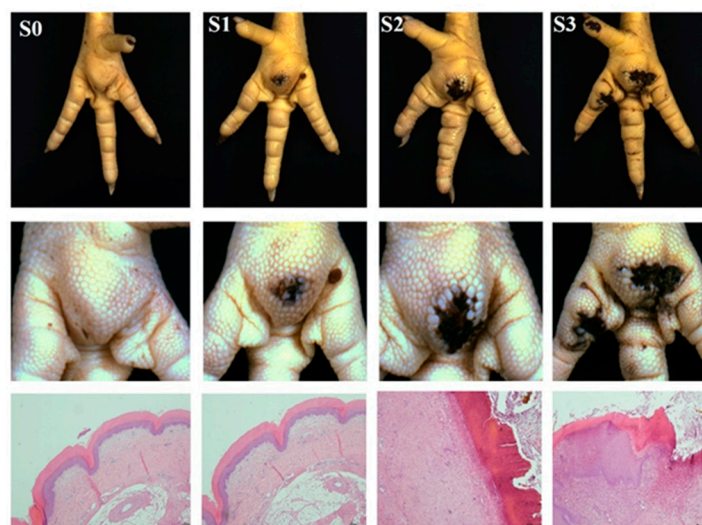


Figure 2. Foot pad dermatitis view of experimental broiler with varying degrees of dermatitis. S0–S3; FPD severity scales according to Butterworth [16]. Top and middle rows depict photographs at different magnifications. Bottom row displays histological micrographs corresponding to different stages of FPD.

Weighed samples from three foot pads of each combination mentioned were placed in 300 mL of Maximum Recovery Diluent (Oxoid, Hampshire, UK) in dedicated filter bags for homogenization (BagFilter P, Interscience, Shah Alam, Malaysia). The samples were gently shaken for 5 min in the liquid to transfer microorganisms from the skin surface to the liquid without tissue disintegration, using a Stomacher homogenizer (BagMixer, Interscience, Shah Alam, Malaysia). Tenfold dilutions of the inoculum were then prepared and spread on appropriate solidified growth media in Petri dishes. For determining the total count of mesophilic aerobic bacteria and yeasts and molds, 50 μ L of a previously diluted inoculum was plated on solidified Tryptone Soya Agar (Oxoid) and Sabouraud dextrose agar with chloramphenicol (Sabouraud dextrose agar, Oxoid). Incubation was carried out at 30 °C for 48 h (for total bacterial counts) and 72 h (for total yeast and mold counts). The results were expressed as the decimal logarithm of colony-forming units per gram of the sample (log CFU/g). Simultaneously, 50 μ L of each of the five inoculum dilutions was applied to the surface of CHROMagar™ *Salmonella* PLUS, CHROMagar™ *Staphylococcus*, CHROMagar™ ECC (*Escherichia coli* and coliforms), CHROMagar *Listeria*™, *Aspergillus* Differentiation Agar (Merck; Darmstadt, Germany), and CHROMagar™ *Candida* selective media. Incubation periods varied: 24 h for *Salmonella*, *Staphylococcus*, and *Escherichia* microorganisms; 48 h for *Listeria* and *Candida* microorganisms; and 72 h for *Aspergillus* microorganisms. After the specified incubation times, the presence of characteristic colonies was assessed based on the morphology described in the instructions provided by the selective medium manufacturer. Results were reported as the decimal logarithm of colony-forming units per gram of the sample (log CFU/g). In cases where a microorganism was detected but an unrepresentative number of colony-forming units was observed at the lowest test dilution required for a reliable microorganism count determination, a “+” symbol indicated a few colonies, while a “–” symbol indicated the absence of microorganisms of a particular strain type.

2.4. Gas Measurements

From day 7 to day 42 of rearing, the microclimate conditions in each pen were monitored weekly using a gas substance meter with a litter quality probe (VGA-001, Map-Pak, Klipspringer Ltd., Ipswich, UK) to measure the content of CO₂, H₂S, and NH₃ (ppm). Measurements were consistently taken directly above the litter surface each time.

2.5. Statistical Analysis

Results for quantitative variables are presented as means and pooled sem (SEM), while categorical variables are expressed as numbers and percentages with Clopper–Pearson confidence intervals (CI at the 95% confidence level). To compare means across groups, we analyzed variance (ANOVA) and performed multiple comparisons using Duncan’s procedure. *p*-Values for the treatments, as well as general means together with the standard error of the means (SEM) based on ANOVA, were presented. For comparisons of fractions (percentages) involving the FPD score, the chi-square test with Bonferroni correction for multiple comparisons was utilized. A generalized linear model evaluated the overall effect of treating binomial variables (FPD score). Comparisons of means for treatments with the control (straw chaff or straw pellet) were conducted using Dunnett’s test of multiple comparisons.

The significance level for all statistical tests was set at 0.05, and the analyses were conducted using Statistica 13 and R 4.0 [26].

3. Results

3.1. Production Performance and Carcass Yield

The choice of bedding material significantly influenced ($p = 0.003$) the BW of broilers at 42 days of age, as shown in Table 2. Among the bedding material types, the highest BW was observed in broilers reared on straw chaff and bedding materials P1, P2, and P6. Broilers on straw pellet and P5 bedding material had lower BW compared to those on straw chaff ($p < 0.05$), but their BW was similar to broilers on P1, P2, and P6 bedding material ($p > 0.05$). The lowest BW was noted in broilers kept on P3 and P4 bedding material, similar to the BW of broilers in the straw pellet, P2, and P5 groups ($p > 0.05$), but significantly lower compared to the BW of broilers in the straw chaff, P1, and P6 groups ($p < 0.05$).

Table 2. Effects of bedding pellets containing parts of medicinal plants on broiler production results.

Parameter	Experimental Group									<i>p</i> -Value	
	Straw Chaff ¹	Straw Pellet ¹	P1	P2	P3	P4	P5	P6	General Mean		SEM
IBW, g (1 d)	41.3 ^a	41.4 ^a	41.3 ^a	41.1 ^a	41.2 ^a	41.1 ^a	41.5 ^a	41.8 ^a	41.3	3.70	0.12
BW 42 d (g)	3772 ^{c,#}	3672 ^{ab,*}	3714 ^{bc}	3699 ^{abc}	3619 ^{a,*}	3612 ^{a,*}	3676.0 ^{ab,*}	3711 ^{bc}	3684	152	0.003
FI, kg	5.0 ^a	4.9 ^a	4.9 ^a	4.6 ^a	4.7 ^a	4.8 ^a	5.0 ^a	5.0 ^a	4.9	1.14	0.330
FCR, kg/kg	1.52 ^a	1.56 ^{ab}	1.53 ^{ab}	1.60 ^{b,*}	1.55 ^{ab}	1.54 ^{ab}	1.55 ^{ab}	1.54 ^{ab}	1.55	0.080	0.001
Mortality, %	5.70 ^a	7.30 ^a	8.70 ^a	13.7 ^b	9.30 ^{ab}	9.70 ^{ab}	7.00 ^a	7.30 ^a	8.60		

Values are means for four treatments of all groups (one treatment contains 75 broilers). ¹ Control groups. ^{a–c} Means within a row without a common superscript differ significantly according to Duncan’s multiple range test, $p < 0.05$. * Significant differences between straw chaff treated as control treatment based on Dunnett’s test of multiple comparisons, $p < 0.05$. # Significant differences between straw pellets treated as control treatment based on Dunnett’s test of multiple comparisons, $p < 0.05$. IBW = initial/hatch body weight; BW = body weight; FI = feed intake; FCR = feed conversion ratio. Straw chaff: 100% nonpelleted straw chaff; Straw pellet: 100% pelleted straw chaff; P1: pelleted 70% straw chaff, 24% *Origanum vulgare*, and 6% *Satureja hortensis*; P2: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *O. vulgare*; P3: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Melissa officinalis*; P4: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Salvia officinalis*; P5: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Thymus vulgaris*; P6: pelleted 70% straw chaff, 24% *O. vulgare*, and 6% *T. vulgaris*; d—days, g—grams.

The observed differences in BW ($p = 0.003$) and the consistent FI across all groups ($p = 0.330$) substantiated the impact of bedding material on FCR values ($p = 0.001$), as indicated in Table 2. Broilers reared on straw chaff showed significantly lower FCR, while those raised on P2 bedding material exhibited the highest FCR ($p < 0.05$). Notably, rearing on P2 bedding material correlated with the highest mortality rate, particularly when compared to broilers on straw chaff, which had the lowest loss percentage (Table 2).

The type of bedding material used, including the presence of medicinal plant components in the P1–P6 bedding materials, had no noticeable effect on the results of the slaughter analysis of the broilers (Table 3).

Table 3. Effects of bedding pellets containing parts of medicinal plants on broiler carcass yield.

Parameter	Experimental Group								General Means	SEM	p-Value
	Straw Chaff ¹	Straw Pellet ¹	P1	P2	P3	P4	P5	P6			
Carcass weight, g	2784 ^a	2753 ^a	2730 ^a	2752 ^a	2701 ^a	2723 ^a	2738 ^a	2799 ^a	2747	139	0.480
Carcass yield, %	75.0 ^a	75.9 ^a	75.4 ^a	74.6 ^a	75.0 ^a	75.4 ^a	75.0 ^a	75.9 ^a	75.3	1.80	0.468
Breast meat, %	32.9 ^a	32.9 ^a	32.8 ^a	31.7 ^a	33.2 ^a	32.9 ^a	32.1 ^a	31.4 ^a	32.5	2.40	0.687
Leg meat, %	19.7 ^a	20.2 ^a	19.9 ^a	20.1 ^a	19.7 ^a	19.8 ^a	19.4 ^a	19.8 ^a	19.8	0.900	0.930
Gizzard, %	0.730 ^a	0.710 ^a	0.680 ^a	0.720 ^a	0.700 ^a	0.640 ^a	0.680 ^a	0.670 ^a	0.691	0.130	0.915
Liver, %	0.910 ^a	0.970 ^a	1.01 ^a	0.940 ^a	0.970 ^a	0.990 ^a	1.02 ^a	0.970 ^a	0.974	1.340	1.000
Heart, %	0.320 ^a	0.330 ^a	0.350 ^a	0.330 ^a	0.340 ^a	0.330 ^a	0.340 ^a	0.330 ^a	0.333	0.201	0.842
Abdominal fat, %	1.49 ^a	1.74 ^a	1.39 ^a	1.54 ^a	1.65 ^a	1.41 ^a	1.53 ^a	1.57 ^a	1.54	0.742	0.474

Values are means of 24 broilers from each group (6 broilers × 4 treatments); yield (carcass weight/BW before slaughter × 100%); and the proportions (g/100 g) of the breast muscle, leg muscle, abdominal fat, heart, liver, and gizzard in the carcass weight. ¹ Control groups. ^a No significant differences were found according to Duncan's multiple range test and between straw chaff or straw pellets treated as control treatments based on Dunnett's test of multiple comparisons; $p < 0.05$. Straw chaff: 100% nonpelleted straw chaff; Straw pellet: 100% pelleted straw chaff; P1: pelleted 70% straw chaff, 24% *Origanum vulgare*, and 6% *Satureja hortensis*; P2: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *O. vulgare*; P3: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Melissa officinalis*; P4: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Salvia officinalis*; P5: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Thymus vulgaris*; P6: pelleted 70% straw chaff, 24% *O. vulgare*, and 6% *T. vulgaris*.

3.2. FPD Score

By the 28th day of broiler life, notable differences in foot pad quality were already evident (Table 4). During this period, the percentage of broilers with the most favorable FPD indicator (0) ranged from 76% to 96%. Distinctions between experimental groups were primarily observed for indices S0 and S1 ($p < 0.001$), with only a few broilers having S2 and S3 lesions (0–3.8%, 0–1.8%, respectively) ($p > 0.05$). The most favorable FPD outcomes were observed in broilers reared on P1 material, where 96.1% of broilers showed no skin lesions, and no lesions of S2 and S3 occurred (Table 4). Slightly inferior results ($p > 0.05$) were noted in broilers reared on straw pellets and P2, P4, and P6 materials. The poorest FPD quality was confirmed in broilers reared on straw chaff, where only 76.4% of broilers were without skin lesions, and the presence of lesions in S2 and S3 was already observed by day 28. Similarly, suboptimal foot quality was identified in broilers reared on P3 material, attributed to the relatively high proportion of broilers assessed with FPD S3 (1.8%), although this difference was not statistically significant at this time ($p = 0.061$).

For older broilers at 35 days (Table 5) and 42 days (Table 6), the favorable trend of the most advantageous FPD parameters persisted in the P1 group. This is evident from the notably high proportion of broilers without foot lesions (S0) (94.2% and 84.2%, respectively). Slightly fewer broilers without FPD symptoms were observed in the P4 group ($p > 0.05$). The fewest broilers with an FPD score of S0 were confirmed in the straw chaff group at both 35 and 42 days of age (Tables 5 and 6). Broilers maintained on straw chaff also exhibited the highest prevalence ($p < 0.001$) of advanced FPD lesions scored as S2 and S3 at 42 days of age, whereas in groups P1, P4, and P6, S3 lesions were not observed (Table 6).

Table 4. Effects of bedding pellets containing parts of medicinal plants on 28-day-old broiler foot pad quality.

Parameter FPD, Score	Experimental Group								<i>p</i> -Value *
	Straw Chaff ¹	Straw Pellet ¹	P1	P2	P3	P4	P5	P6	
<i>N</i>	292	287	284	279	285	279	295	292	
(<i>n</i>)	223	262	273	252	244	256	256	264	
(%)	76.4 ^a	91.3 ^{bc}	96.1 ^c	90.3 ^{bc}	85.6 ^{ab}	91.8 ^{bc}	86.8 ^{ab}	90.4 ^{bc}	<0.001
CI (%)	71.1–81.1	87.4–94.3	93.2–98.1	86.2–93.5	81.0–89.5	87.9–94.7	82.4–90.4	86.4–93.5	
(<i>n</i>)	57	21	11	25	25	21	30	14	
(%)	19.5 ^b	7.30 ^a	3.90 ^a	9.00 ^a	9.00 ^a	7.50 ^a	10.2 ^a	4.80 ^a	<0.001
CI (%)	15.1–24.5	4.60–10.9	1.90–6.80	5.90–12.9	6.10–12.9	4.70–11.2	7.10–14.2	2.60–7.90	
(<i>n</i>)	10	4	0	2	11	2	8	11	
(%)	3.40 ^a	1.40 ^a	0.000	0.700 ^a	3.90 ^a	0.700 ^a	2.70 ^a	3.80 ^a	0.101
CI (%)	1.70–6.20	0.400–3.50	0.000–1.3	0.100–2.60	1.90–6.80	0.000–2.60	1.20–5.30	1.90–6.60	
(<i>n</i>)	2	0	0	0	5	0	1	3	
(%)	0.700 ^a	0.000	0.000	0.000	1.80 ^a	0.000	0.300 ^a	1.00 ^a	0.061
CI (%)	0.100–2.50	0.000–1.30	0.000–1.30	0.000–1.30	0.600–4.00	0.000–1.30	0.000–1.90	0.20–3.00	

Values are means for four treatments of all groups (one treatment contains 75 broilers). ¹ Control groups. ^{a–c} Means within a row without a common superscript differ significantly, $p < 0.05$, based on pairwise multiple comparisons using the chi-square test with the Bonferroni correction; CI = confidence interval for 95% probability level based on Clopper–Pearson; * *p*-value based on a generalized linear model for a binomial variable. Straw chaff: 100% nonpelleted straw chaff; Straw pellet: 100% pelleted straw chaff; P1: pelleted 70% straw chaff, 24% *Origanum vulgare*, and 6% *Satureja hortensis*; P2: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *O. vulgare*; P3: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Melissa officinalis*; P4: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Salvia officinalis*; P5: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Thymus vulgaris*; P6: pelleted 70% straw chaff, 24% *O. vulgare*, and 6% *T. vulgaris*.

Table 5. Effects of bedding pellets containing parts of medicinal plants on 35-day-old broiler foot pad quality.

Parameter FPD, Score	Experimental Group								<i>p</i> -Value *
	Straw Chaff ¹	Straw Pellet ¹	P1	P2	P3	P4	P5	P6	
<i>N</i>	288	284	277	269	277	275	286	282	
(<i>n</i>)	161	236	261	201	223	248	231	243	
(%)	55.9 ^a	83.1 ^{bc}	94.2 ^d	74.7 ^b	80.5 ^{bc}	90.2 ^{cd}	80.8 ^{bc}	86.2 ^c	<0.001
CI (%)	50.0–61.7	78.2–87.3	90.8–96.7	69.1–79.8	75.3–85.0	86.0–93.4	75.7–85.2	81.8–90.0	
(<i>n</i>)	77	34	16	53	38	23	31	30	
(%)	26.7 ^b	12.0 ^a	5.80 ^a	19.7 ^{ab}	13.7 ^a	8.40 ^a	10.8 ^a	10.6 ^a	<0.001
CI (%)	21.7–32.2	8.40–16.3	3.30–9.20	15.1–25.0	9.90–18.3	5.40–12.3	7.50–15.0	7.30–14.8	
(<i>n</i>)	46	13	0	15	14	4	22	9	
(%)	16.0 ^d	4.60 ^{bc}	0.000	5.60 ^{bc}	5.10 ^{bc}	1.50 ^{ab}	7.70 ^{cd}	3.20 ^{abc}	<0.001
CI (%)	11.9–20.7	2.50–7.70	0.000–1.30	3.20–9.00	2.80–8.30	0.400–3.70	4.90–11.4	1.50–6.00	
(<i>n</i>)	4	1	0	0	2	0	2	0	
(%)	1.40 ^a	0.400 ^a	0.000	0.000	0.70 ^a	0.000	0.70 ^a	0.000	<0.067
CI (%)	0.40–3.50	0.000–1.90	0.000–1.30	0.000–1.30	0.10–2.60	0.000–1.30	0.10–2.50	0.000–1.30	

Values are means for four treatments of all groups (one treatment contains 75 broilers). ¹ Control groups. ^{a–d} Means within a row without a common superscript differ significantly, $p < 0.05$, based on pairwise multiple comparisons using the chi-square test with the Bonferroni correction; CI = confidence interval for 95% probability level based on Clopper–Pearson; * *p*-value based on a generalized linear model for a binomial variable. Straw chaff: 100% nonpelleted straw chaff; Straw pellet: 100% pelleted straw chaff; P1: pelleted 70% straw chaff, 24% *Origanum vulgare*, and 6% *Satureja hortensis*; P2: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *O. vulgare*; P3: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Melissa officinalis*; P4: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Salvia officinalis*; P5: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Thymus vulgaris*; P6: pelleted 70% straw chaff, 24% *O. vulgare*, and 6% *T. vulgaris*.

Table 6. Effects of bedding pellets containing parts of medicinal plants on 42-day-old broiler foot pad quality.

Parameter FPD, Score	Experimental Group								p-Value *
	Straw Chaff ¹	Straw Pellet ¹	P1	P2	P3	P4	P5	P6	
N	283	278	273	260	272	265	281	271	
(n)	116	196	230	191	189	218	208	192	
(%)	41.0 ^a	70.5 ^b	84.2 ^d	73.5 ^{bc}	69.5 ^b	82.3 ^{cd}	74.0 ^{bcd}	70.8 ^b	<0.001
CI (%)	35.2–47.0	64.8–75.8	79.4–88.4	67.7–78.7	63.6–74.9	77.1–86.7	68.5–79.0	65.0–76.2	
(n)	86	56	41	46	64	39	52	62	
(%)	30.4 ^b	20.1 ^{ab}	15.0 ^a	17.7 ^a	23.5 ^{ab}	14.7 ^a	18.5 ^a	22.9 ^{ab}	<0.001
CI (%)	25.2–36.1	15.7–25.4	11.0–19.7	13.3–22.9	18.6–28.9	10.8–23.6	14.2–23.6	18.1–28.4	
(n)	59	21	2	20	17	8	17	17	
(%)	20.8 ^c	7.60 ^b	0.700 ^a	7.70 ^b	6.30 ^b	3.00 ^{ab}	6.00 ^b	6.30 ^b	<0.001
CI (%)	16.3–26.1	4.70–11.3	0.100–2.60	4.80–11.6	6.30–9.80	1.30–5.80	3.60–9.50	3.70–9.90	
(n)	22	5	0	3	2	0	4	0	
(%)	7.80 ^b	1.80 ^a	0.000	1.20 ^a	0.70 ^a	0.000	1.40 ^a	0.000	<0.001
CI (%)	4.90–11.5	0.600–4.10	0.000–1.30	0.200–3.30	0.100–2.60	0.000–1.30	0.400–3.60	0.000–1.30	

Values are means for four treatments of all groups (one treatment contains 75 broilers). ¹ Control groups. ^{a–d} Means within a row without a common superscript differ significantly, $p < 0.05$, based on pairwise multiple comparisons using the chi-square test with the Bonferroni correction; CI = confidence interval for 95% probability level based on Clopper–Pearson; * p -value based on a generalized linear model for a binomial variable. Straw chaff: 100% nonpelleted straw chaff; Straw pellet: 100% pelleted straw chaff; P1: pelleted 70% straw chaff, 24% *Origanum vulgare*, and 6% *Satureja hortensis*; P2: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *O. vulgare*; P3: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Melissa officinalis*; P4: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Salvia officinalis*; P5: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Thymus vulgaris*; P6: pelleted 70% straw chaff, 24% *O. vulgare*, and 6% *T. vulgaris*.

3.3. Total Count of Aerobic Mesophilic Bacteria, Yeasts, and Molds in Feet Tissues

The microbiological analysis results of broiler feet reared on different bedding material types with FPD scores are presented in Table 7 and illustrated in Figure 3. A significant effect of bedding material type was confirmed only for *Listeria* sp. ($p < 0.001$). The most numerous colonies were observed in broilers on bedding devoid of medicinal plants (such as straw chaff and straw pellets) and substrates P1 and P2. Conversely, substrates P3 and P6 exhibited the lowest colony numbers (Figure 3). The effect of the FPD score was evident in the total count of aerobic mesophilic bacteria ($p = 0.016$), the total count of yeasts and molds ($p = 0.039$), and *Listeria* sp. ($p < 0.001$) (Table 7). Typically, more severe FPD lesions were associated with increased counts of pathogenic microorganism colonies. This correlation was most pronounced between FPD advancement and *Listeria* sp. colony counts (Figure 3). Notably, colonies of all analyzed microorganisms were found even in feet classified as FPD S0 (Figure 3), highlighting a significant observation. The interaction between bedding material type and FPD score was significant only for *Listeria* sp. ($p < 0.001$), with substrates P3, P5, and P6 seemingly inhibiting colony development in FPD categories S0 and S1 (Figure 3).

3.4. Concentration of Harmful Gasses in Poultry Houses

The concentrations (ppm) of noxious gasses measured above the litter surface are presented in Table 8. Irrespective of the broilers' age and the type of bedding material used, no detectable concentrations of H_2S and NH_3 were observed ($p = 1.00$). The CO_2 concentrations remained low, ranging from 666.3 ppm on day 21 for broilers raised on straw pellets to 820.3 ppm on day 42 for broilers raised on P3 material. The concentration was not influenced by either the age of the broilers or the type of bedding material used ($p > 0.05$) (Table 8).

Table 7. Effects of bedding materials on the count of total bacteria (log CFU/g) in the broiler feet tissue on the 42nd day of life.

Parameter	FPD, Score	Experimental Group							
		Straw Chaff	Straw Pellet	P1	P2	P3	P4	P5	P6
<i>Salmonella</i> sp.	S0	—	—	—	—	—	—	—	—
	S1	—	—	—	+	—	—	—	—
	S2	+	+	—	3.51	—	—	—	—
	S3	—	+	na	na	na	na	na	na
<i>Candida</i> sp.	S0	—	—	—	—	2.81	—	—	—
	S1	+	—	—	—	2.96	—	—	—
	S2	+	—	—	+	3.51	—	+	—
	S3	+	+	na	na	na	na	na	na
<i>Aspergillus</i> sp.	S0	—	—	—	—	—	—	—	—
	S1	—	—	—	—	—	—	—	—
	S2	—	—	—	—	—	—	—	—
	S3	—	—	na	na	na	na	na	na

All main effects for six independent replicates (3 chicks $\times$ 4 treatments). ¹ Control groups. “+” indicates the observed growth of a few colonies; “—” indicates that microorganisms of a given type of strain have not been observed; na = not analyzed. S0–S3; advancement scales FPD according to Butterworth (2009) [16]. Type of bedding material with different experimental groups. Straw chaff: 100% nonpelleted straw chaff; Straw pellet: 100% pelleted straw chaff; P1: pelleted 70% straw chaff, 24% *Origanum vulgare*, and 6% *Satureja hortensis*; P2: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *O. vulgare*; P3: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Melissa officinalis*; P4: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Salvia officinalis*; P5: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Thymus vulgaris*; P6: pelleted 70% straw chaff, 24% *O. vulgare*, and 6% *T. vulgaris*.

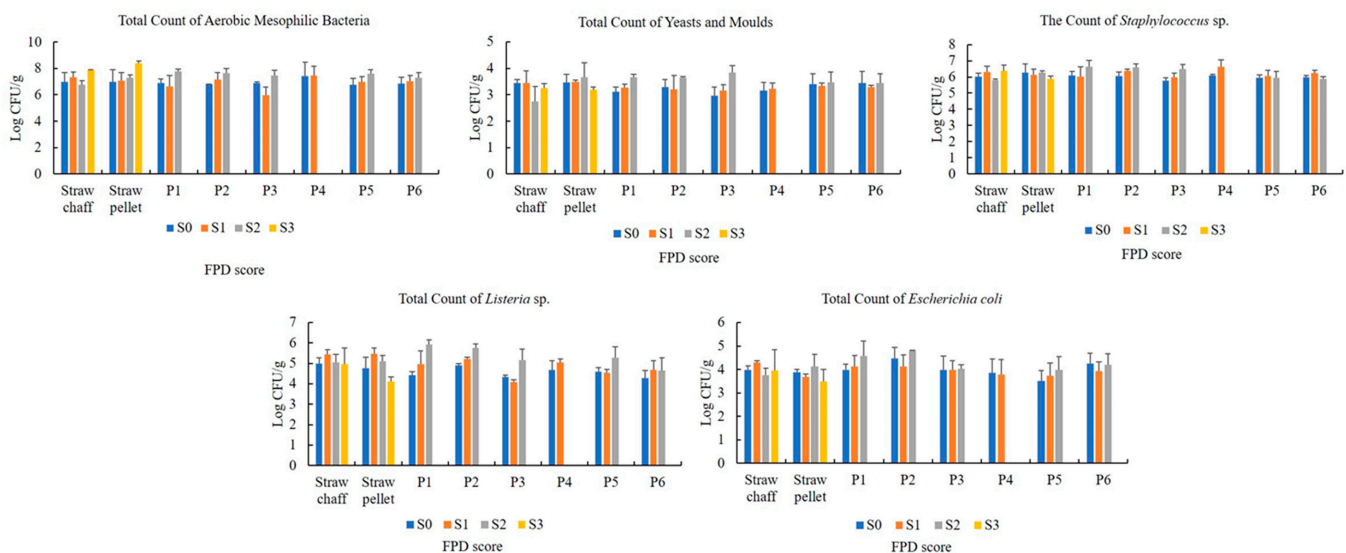


Figure 3. Effects of bedding materials and FPD score on broiler feet tissue microbiology at 42 days of life. Columns indicate means and vertical bars represent the standard deviation for six independent replicates. S0–S3; advancement scales FPD according to Butterworth (2009) [16]. All main effects for six independent replicates (3 chicks $\times$ 4 treatments). Straw chaff: 100% nonpelleted straw chaff; Straw pellet: 100% pelleted straw chaff; P1: pelleted 70% straw chaff, 24% *Origanum vulgare*, and 6% *Satureja hortensis*; P2: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *O. vulgare*; P3: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Melissa officinalis*; P4: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Salvia officinalis*; P5: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Thymus vulgaris*; P6: pelleted 70% straw chaff, 24% *O. vulgare*, and 6% *T. vulgaris*.

Table 8. Effects (means $\pm$ SD) of bedding pellets containing parts of medicinal plants on concentration (ppm) of CO₂, H₂S, and NH₃ in the poultry house.

Experimental Group												
Parameter		Straw Chaff ¹	Straw Pellet ¹	P1	P2	P3	P4	P5	P6	General Mean	SEM	<i>p</i> -Value
CO ₂	7 days	797 ^a	810 ^a	791 ^a	810 ^a	768 ^a	772 ^a	761 ^a	794 ^a	788	18.8	0.573
	14 days	751 ^a	747 ^a	773 ^a	770 ^a	755 ^a	759 ^a	756 ^a	746 ^a	757	9.93	0.999
	21 days	693 ^a	666 ^a	689 ^a	680 ^a	680 ^a	670 ^a	668 ^a	694 ^a	680	11.2	0.998
	28 days	727 ^a	750 ^a	768 ^a	795 ^a	782 ^a	757 ^a	734 ^a	734 ^a	756	24.4	0.651
	35 days	689 ^a	701 ^a	753 ^a	772 ^a	771 ^a	759 ^a	737 ^a	731 ^a	739	30.9	0.942
	42 days	774 ^a	779 ^a	809 ^a	812 ^a	820 ^a	777 ^a	759 ^a	745 ^a	784	26.8	0.989
H ₂ S	7–42 days	--	--	--	--	--	--	--	--			
NH ₃	7–42 days	--	--	--	--	--	--	--	--			

¹ Control groups. ^a No significant differences were found, $p < 0.05$. --: not detected. Straw chaff: 100% nonpelleted straw chaff; Straw pellet: 100% pelleted straw chaff; P1: pelleted 70% straw chaff, 24% *Origanum vulgare*, and 6% *Satureja hortensis*; P2: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *O. vulgare*; P3: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Melissa officinalis*; P4: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Salvia officinalis*; P5: pelleted 70% straw chaff, 18% *S. hortensis*, and 12% *Thymus vulgaris*; P6: pelleted 70% straw chaff, 24% *O. vulgare*, and 6% *T. vulgaris*.

4. Discussion

The aim of this study was to assess the impact of incorporating medicinal plants into straw pellets on broiler rearing and welfare, with a focus on FPD progression and the microbiological quality of foot lesions. The production analysis revealed better BW performance in broilers raised on straw chaff compared to those on straw pellets. The inclusion of oregano in the pellets (P1, P2, P6) resulted in BW levels at 42 days of age similar to those of straw chaff-reared chickens. In contrast, groups without oregano in the pellets (P3, P4, P5) exhibited lower BW compared to broilers reared on straw chaff, similar to those on straw pellets. Previous studies by Kheravii et al. [21] found no BW difference between broilers on straw chaff and pellets, while Biesek et al. [27] reported the highest BW in broilers raised on straw chaff compared to various pellet types. We hypothesize that this discrepancy may be attributed to the more robust development of the digestive tract in broilers that consume straw chaff, particularly during the early rearing period. Although there is no specific information on the quantity of straw chaff consumed by broilers, it is evident that they ingest straw. While straw lacks nutrients, it fills the digestive tract and may contribute to the enlargement of certain internal organs. In our study, there was a slight increase in the proportion of gizzard weight in BW in broilers reared on straw chaff. Biesek et al. [27] also demonstrated a significantly higher carcass weight with offal in broilers raised on straw chaff compared to pellets; however, when considering carcass weight alone, no differences were observed. Consequently, rearing on straw chaff seemingly yields a better BW outcome, yet this does not correlate with an improved tissue composition of the carcass. In particular, it does not change the breast and leg muscle weights, which are the most valuable elements of broilers. Nevertheless, the observed reduction in gizzard weight in broilers due to feeding exclusively with a commercial diet without gastroliths is becoming an increasingly noticeable problem [28,29]. Therefore, in the future, when using pellets as bedding material, it will be necessary to consider increasing feed fiber or administering gastroliths to stimulate the muscles of the entire digestive tract, particularly the gizzard.

An additional noteworthy observation concerning the BW of broilers pertains to the positive influence of oregano in the pellet. Oregano, a well-known herbaceous plant, contains an essential oil primarily composed of carvacrol and sesquiterpenes [30], which gives the plant robust antioxidant, hepatoprotective, cardioprotective, antimicrobial, and antifungal properties [30]. All these attributes are advantageous for broiler growth. However, the recognition of essential oils from medicinal plants, especially those in oregano, as growth

stimulants for animals varies greatly [31–33]. This is primarily because essential oils have an irritating odor that makes the diet or water unpalatable (bitter) to poultry [34,35], reducing feed consumption and potentially lowering BW gain. This effect does not occur when essential oils are present in the bedding material and the diet is free of foreign tastes and odors. Of course, the systemic effect of essential oils will affect other aspects of broiler well-being, such as having a greater impact on the severity of FPD than on the microbiological composition of the intestines. Therefore, future studies should investigate the simultaneous use of medicinal plants as dietary supplements and components of bedding materials.

The P2 group exhibited the highest mortality despite the inclusion of oregano in the pellet. This outcome could be attributed to the combination of oregano and summer savory in a single bedding material, with summer savory being predominant (18:12). In contrast, in group P1, the same plant materials were employed, but the proportion of summer savory to oregano was significantly lower (6:24). Carvacrol is the primary biologically active constituent in the essential oils of summer savory, akin to oregano. Excessive doses of carvacrol, including carvacrol carboxyacetic acid, can exhibit phytotoxic, cytotoxic, and potentially genotoxic effects [36]. However, these effects may be attributed not only to the biologically active compound itself but also to its source. There is no literature-based evidence confirming the toxic effect of biologically active summer savory compounds on poultry (or other birds). However, it cannot be ruled out that broilers may be sensitive to high concentrations of essential oils from certain herbaceous plants if these oils are used as bedding materials during the first days of life. Although this study does not provide definitive proof, it suggests the need for further investigation into the potential toxicity of summer savory essential oils on broilers. It is crucial to further investigate and monitor the health of broilers in their early days, considering the varying concentrations of summer savory in the bedding material used and its potential interaction with other medicinal plants.

The crucial parameter assessing the well-being of broilers scrutinized in this study was the prevalence and severity of FPD. Various factors, including the genotype, stocking density, age at slaughter, and initial quality of broilers, influence the occurrence of FPD [37]. Since all these variables were standardized in this study, the primary focus was on the quality of the bedding material, specifically its moisture-absorbing capacity. This attribute has consistently been highlighted in previous studies as a predisposing factor for FPD [17,38,39]. For example, replacing wet litter with dry litter resulted in the recovery of foot pad lesions in about 2 weeks [22,39]. Earlier, Gontar et al. [24] revealed superior water absorption by P1 and P3–P6 materials (346.43–392.27%) compared to straw chaff, straw pellets, and P2 (242.43–300.58%). This superior water absorption is reflected in FPD control, with optimal foot quality observed in 42-day-old broilers raised on P1, P4, and P6 materials. In contrast, broilers raised on P2 material exhibited significantly inferior foot quality, as the bedding material's water absorption was only 242.43% [24]. We also suggest that the limited moisture absorption capacity was the second contributing factor to the elevated mortality observed in P2 broilers, following the excessive concentration of carvacrol derived from summer savory oil.

The microbiological analysis conducted by Gontar et al. [24] on bedding materials revealed that incorporating medicinal plant components into the pellets led to a decrease in the total count of mesophilic aerobic bacteria, total yeast, and mold, and contributed to lower counts of *Staphylococcus* sp., *Escherichia* sp., *Listeria* sp., *Salmonella* sp., and *Candida* sp. However, the examination of the microbiological quality of the feet did not yield unequivocally positive results. The most noticeable impact was observed in the reduction in *Listeria* sp., particularly in the P3 and P5 materials, when considering FPD scores of S0 and S1, with S2 excluded. Carvacrol [40], quercetin [41], and thymol [40] were identified as the most significant phenolic compounds inhibiting the growth of *Listeria* sp. Previously, the antimicrobial activity of thymol and carvacrol has been tested and confirmed in numerous in vitro tests [42,43]. Thymol and carvacrol are structurally similar and have been proven to exert synergistic antimicrobial effects [43]. It is noteworthy that Gram-negative bacteria

are more tolerant to essential oils than Gram-positive bacteria such as *Listeria* sp. due to their hydrophilic constituents in the outer membrane [44,45]. In both the P3 and P5 materials, carvacrol originated from summer savory parts rather than oregano, unlike the other materials. This distinction is vital because the origin and structure of a given phenolic compound influence its efficacy [46,47]. In addition, only the P3 material incorporated lemon balm, whose essential oil is primarily rich in quercetin [48]. In contrast, the P5 material used thyme, with its oil being almost half-composed of thymol [49]. Notably, thyme was also present in the P6 material, but in combination with oregano, not summer savory. It is intriguing why a substantial dose of carvacrol from summer savory and oregano in the P2 material did not yield as potent effects against *Listeria* sp. We posit that the cumulative effect of two other compounds with documented strong activity against *Listeria* sp. was more effective than a higher dose of the same compound, even if derived from different plant species. We consider this outcome a key finding of this study, as reducing *Listeria* sp. during the broiler rearing stage may help minimize listeriosis outbreaks in subsequent stages of food production. This zoonosis carries a high mortality rate and is recognized as a significant public health concern [50,51].

Other microbiological analysis results showed a stronger correlation with the severity of FPD than with the type of bedding material utilized. As FPD intensified, there was an increase in the quantity of mesophilic aerobic bacteria, yeasts, molds, and *Listeria* sp. This suggests that the biologically active compounds in the plant materials present in the mulch material may primarily act superficially. Pathogens entering the deeper layers of the feet through damaged skin, as depicted in Figure 2, do not directly come into contact with the mulch and can continue to proliferate. This is supported by the observation of individual colonies of *Salmonella* sp. and *Candida* sp., which were not detected with the S0 FPD score. While this study, for the first time, analyzed the microbiological quality of feet based on the FPD score, drawing definitive conclusions is challenging. However, Cavani et al. [52] examined the microbiological quality of the tibiotarsal region in broilers and similarly demonstrated that superficial lesions (scores 1 and 2) exhibited better microbiological quality (without inflammatory processes) than deep lesions (score 3). Although the tibiotarsal region has less contact with the substrate (litter) than the feet, in broilers, the increasing reluctance to move and frequent adoption of a sitting position make it the second or third most susceptible body area to infections through wounds from pathogens in the litter (if the chest area is included). Decreased mobility can significantly impact the microbial quality of the feet depending on the FPD score. Broilers with more advanced FPD lesions have limited mobility, which has been consistently observed and documented [53–55]. Consequently, broilers with more severe FPD lesions may lean on their chest and elevate their feet to minimize ground contact due to pain. As a result, the progression of FPD may have contributed to a reduced frequency of foot contact with the bioactive components in the bedding materials.

The analysis of the concentrations of CO₂, H₂S, and NH₃ released from the litter indicated that neither the form (chaff, pellets) nor the inclusion of medicinal plant parts in the pellets influenced these parameters. Encouragingly, concentrations of H₂S and NH₃ remained within acceptable limits throughout the broiler rearing period, as did the low levels of CO₂. Detrimental effects on broilers are typically observed when the concentration of CO₂ surpasses 3000 ppm, and this condition persists for at least 14 days [56]. In this study, CO₂ concentrations never exceeded 1000 ppm, even at 42 days of the broilers' life.

5. Conclusions

The use of medicinal plant components in straw pellets used as bedding for broilers has the potential to enhance foot quality by mitigating FPD and reducing the prevalence of pathogenic microorganisms. However, the effectiveness depends on the specific medicinal plant species and the biologically active compounds they contain. Optimal FPD results were achieved with P1 and P4 materials. However, the plant composition of P3 and P5 materials exhibited a more favorable impact on diminishing *Listeria* sp., likely attributed to the presence

of quercetin from lemon balm (P3) and thymol from thyme (P5). Conversely, P2, with 18% summer savory and 12% oregano, displayed the least favorable characteristics—lowest water absorption in bedding, highest broiler mortality, and inferior foot quality. Consequently, this bedding material is not recommended for use in broiler rearing.

As this study is the first to use medicinal plants as broiler bedding material, the long-term effects of their use should be investigated in future research. It would be particularly important to analyze other doses of plants containing quercetin and thymol. Investigating the simultaneous use of these compounds as part of both bedding material and dietary supplements would be intriguing. This approach could synergistically improve the well-being of broilers by influencing the microbiology of the digestive tract and the external living environment.

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Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors upon request.

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