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Effects of Dietary Supplementation with a Mixed Powder of Medicinal Plants on the Growth Performance, Carcass Characteristics, Chemical Composition, and Meat Quality of Pigs

Nguyen Cong Oanh[1], Nguyen Thi Huyen[2], Nguyen Dinh Tien[1] & Vu Dinh Ton[1]

[1]Faculty of Animal Science, Vietnam National University of Agriculture, Hanoi 131000, Vietnam
[2]Faculty of Food Science and Technology, Vietnam National University of Agriculture, Hanoi 131000, Vietnam

Abstract

The study was conducted to evaluate the effects of a medicinal plant mixture (MP) (60% *Bindens pilosa* L., 15% *Urena lobata* L., 15% *Pseuderanthemum palatiferum*, 5% Ramulus Cinnamomi, and 5% *Illicium verum* Hook. f.) as a feed additive to promote the growth performance and meat quality of grower-finisher pigs. Forty-eight crossbred pigs (Duroc × (Landrace × Yorkshire)), with initial live body weights of 30.3 ± 1.42kg, were randomly allocated to four dietary groups, with three replicates of each group and four animals per replicate. The experimental pigs were fed a basal diet supplemented with MP powder at 0, 20, 40, or 60 g kg^{-1} of feed (T_0, T_{20}, T_{40}, and T_{60}) for 15 weeks. The growth performance, carcass quality parameters, chemical composition, fatty acids, and cholesterol contents of the pig meat were measured. There were no statistical differences (P >0.05) in the final live body weight, overall average daily gain, average daily feed intake, and feed conversion ratio among the control and MP treatments. MP supplementation significantly increased the protein content (P = 0.02) and decreased the cholesterol content (P = 0.04) of raw longissimus dorsi muscle. The obtained results indicate that the dietary MP supplementation tested could have the potential to improve meat quality and decrease the cholesterol content in pork with no adverse effects on the growth performance.

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Correspondence to
Nguyen Cong Oanh
ncoanh@vnua.edu.vn

ORCID
Nguyen Cong Oanh
https://orcid.org/0000-0001-7549-3389

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Introduction

Antibiotic use in animal production for growth promotion and disease prevention can contribute to the emergence of antibiotic resistance and an associated increase in public health risks (Suthathip *et al.*, 2016). Antimicrobial resistance is a big concern as a food safety issue worldwide. The European Union-wide ban on the use of antibiotics as growth promoters in animal feed entered into effect in January 2006. Since then, various materials such as organic acids, phytogenics, prebiotics, symbiotics, enzymes, and other feed additives (Gadde *et al.*, 2017) have been studied to find alternative ways to reduce and replace antibiotics in livestock production. In Vietnam, the use of antibiotics in animal feed as growth promoters has been banned since January 1, 2018 (The Government of Vietnam, 2017) and antibiotics used for disease prevention will be banned according to the roadmap beginning in 2021 and completely banned by 2025 (The Government of Vietnam, 2020). Therefore, there is an urgent need to find alternatives to use in livestock production for improving growth performance and satisfying consumer demands in domestic and foreign markets for safe and quality animal products.

A number of medicinal plants have received more attention from animal scientists as feed additives for raising animals due to their beneficial effects on the activation of digestive enzymes secretion, immune stimulation, and their antibacterial, antiviral, and antioxidant properties (Zhou *et al.*, 2013; Ahmed *et al.*, 2016; Fan *et al.*, 2019; Luo *et al.*, 2020). Vietnam is one of the tropical countries with high biodiversity of herbal plant species, accounting for 11% of the 35,000 species of herbal plants known worldwide (Vu *et al.*, 2020). For example, Ramulus Cinnamomi (*Cinnamomum cassia* Presl), star anise *(Illicium verum* Hook. f.*)*, *Bindens pilosa* L., *Urena lobata* L., and *Pseuderanthemum palatiferum* are medicinal plants that are widely distributed and considered as natural feed additives (Matysiak *et al.*, 2012; Xuan & Khanh, 2016). Phytochemical analyses have reported the bioactive components of Ramulus Cinnamomi (a source of *trans*-cinnamaldehyde and its derivatives), star anise fruits (a source of alkaloids, essential vitamins, and tannins), the aerial parts of *B. pilosa* (a source of flavonoids and other phenolic compounds), the aerial parts of *U. lobata* (a source of flavonoids and saponins), and the aerial parts of *P. palatiferum* (a source of flavonoids and other phenolics) along with their antimicrobial, antifungal, antioxidant, and cholesterol-lowering functions, and their quality as animal feed products (Dieu *et al.*, 2006; Cortés-Rojas *et al.*, 2013; Sang-Oh *et al.*, 2013; Quan *et al.*, 2019; Patra *et al.*, 2020). A significant decrease in the oxidation capacity of animal feed products owing to phenolic compounds in medicinal plants has been shown (Amaral *et al.*, 2018), thus improving the meat quality (including shelf life and flavor). Several studies have been conducted to assess the dietary effects of Ramulus Cinnamomi, star anise, *B. pilosa*, *U. lobata* and *P. palatiferum* individually in pigs and broilers, especially on growth performance, gut microbiota, and immunity; however, few of these studies have evaluated their effects on meat quality (Sang-Oh *et al.*, 2013; Luo *et al.*, 2020). To the best of our knowledge, the combined effects of the mentioned medicinal plants on the growth performance, carcass characteristics, and meat quality have not yet been studied. Mixtures of these medicinal plants are expected to exert their beneficial effects from chemical and pharmaceutical properties. Therefore, the present study aimed to assess the growth performance, meat composition, carcass parameters, and meat quality of grower-finisher pigs fed long-term diets supplemented with increasing levels of medicinal plant mixtures (Ramulus Cinnamomi, star anise, *B. pilosa*, *U. lobata*, and *P. palatiferum*).

Materials and Methods

Sources of medicinal plants

The aerial parts of *B. pilosa*, *P. palatiferum*, and *U. lobata* were harvested during the vegetative growth phase at the medicinal gardens of private agricultural farms located in Cam Giang district, Hai Duong province, Vietnam. Ramulus Cinnamomi and star anise fruits were harvested during fructification from a forest garden in Huu Lung district, Lang Son province, Vietnam.

B. pilosa and *P. palatiferum* (herbaceous plants) were separately dried in a mechanical drier at 45-50°C for 8 hours. *U. lobate* (semi-woody plant) was dried at 50-55°C for 8 hours. Ramulus Cinnamomi and star anise (woody plants) were separately dried at 60-65°C for 8 hours. After drying, their materials were separately stored in air-tight bags. They were ground into a fine powder and proportionally mixed as a powder (MP) containing 60% *B. pilosa*, 15% *U. lobata*, 15% *P. palatiferum*, 5% Ramulus Cinnamomi, and 5% star anise, before incorporation into the animal diets. This ratio of the medicinal plant mixture (60:15:15:5:5) was determined by the availability and cost of the materials and following the recommendations of traditional experiences.

Animals and experimental design

The experiment was conducted from April to August 2020 at a private pig production farm located in Cam Giang district, Hai Duong province, Latitude 20° 57' 0" E and Longitude 106° 13' 0" E. Forty-eight crossbred growing pigs (Duroc × (Landrace × Yorkshire)) with initial body weights (IBW) of 30.3 ± 1.42 (SD) were used in this study. The pig individuals each wore an ear number and were allocated to one of four dietary treatments according to equal IBWs and sex ratios. Each diet group had three replicate pens with four pigs (2 barrows and 2 gilts) per pen (2m × 3m) installed along with one automatic feeding and two automatic drinking nipples. The temperature in the pig house ranged between 27 and 30°C, while relative humidity was maintained at 70-85% during the entire experimental period. The pigs were fed one of four diets, a basal diet (control diet, T_0) and three experimental diets (T_{20}, T_{40}, and T_{60}) based on the T_0 diet supplemented with MP at 20, 40, and 60 g kg^{-1}, respectively, during the total 15 weeks of the experiment. Pigs were fed *ad libitum* during the whole experimental period and animals always had free access to water by nipple drinkers.

The main feed ingredients were purchased locally for the two phases from a feed company. The raw feed materials were milled into flour prior to formulation. The complete diets were collected for chemical analysis. The ingredients of the basal diets in the two phases are shown in **Table 1**. The formulations of the iso-nitrogenous and iso-energetic experimental diets were based on the requirements for grower-finisher pigs (**Table 2**) following the recommendations of the National Research Council (NRC, 2012).

Table 1. Ingredients (%, as-fed basis) of the experimental diets

Ingredients	Treatment period	
	Growing phase (30-60kg)	Finishing phase (61-100kg)
Corn	33.9	38.6
Soybean meal	13.4	10.2
Fish meal	3.50	2.00
Rice bran	25.0	25.0
Wheat bran	20.0	20.0
Limestone	1.50	1.50
Vitamin-mineral premix[1]	0.50	0.50
Salt	1.00	1.00
Farm-enzyme[2]	0.50	0.50
L-lysine HCl, 98.5%	0.50	0.50
DL-Methionine, 98%	0.20	0.20

Note: Growing phase, 30-60kg (experimental weeks 0-7); finishing phase, 61-100kg (experimental weeks 8-15)

[1]*Premix in 1kg: $CuSO_4$, 250-300mg; $ZnSO_4$, 250-300mg; $FeSO_4$, 150-200mg; $MnSO_4$, 150-200mg; Biotin, 8mg; activity enzyme, 100g; coarse sand, 2%; sufficient carrier for 1000g; moisture, 10%*

[2]Farm-Enzyme in 1 kg: *Saccharomyces boulardii*, 10^9-2.10^{10} CFU/g; *Saccharomyces fibuliger*, 10^6-10^{10} CFU/g; *Lactobacillus acidophilus*, 10^9-3.10^9 CFU/g; *Candida tropicolis*, 10^5-10^8 CFU/g; moisture (max), 10%.

Table 2. Chemical compositions (% DM) and energy values (MJ/kg DM) of the experimental diets

Ingredients	Treatment period	
	Growing phase	Finishing phase
Dry matter	89.0	88.8
Crude protein	18.8	16.4
Ether extract	7.55	7.77
Ash	8.86	7.57
Crude fiber	5.24	5.14
Neutral detergent fiber	21.5	17.5
Calcium	1.39	1.25
Total phosphorus	0.85	0.91
Gross energy (MJ/kg DM)	18.6	18.8
Metabolizable energy[1] (MJ/kg DM)	13.9	14.5
Lysine[2]	1.33	1.18
Methionine[2]	0.54	0.49

Note: [1]Calculated data according to Noblet & Perez (1993); [2]Nutrient levels were calculated data.

Sampling and measurements

Pig performance

Animal individuals were weighed at the start of the experiment (day 0), at 7 weeks, and at the end of the experiment (15 weeks). The average daily feed intake (ADFI), average daily gain (ADG), and feed conversion ratio (FCR) were measured for each replicate, diet, and period through the entire experiment.

Carcass characteristics

At the end of the experiment, twenty-four pigs (six pigs per treatment, 3 barrows and 3 females) per group were manually slaughtered by cutting the jugular veins of the neck with a sharp knife. The slaughter process was performed according to the slaughtering rules for measuring carcass characteristics from local standards (The Vietnam Ministry of Science and Technology, 1984). The hot carcass weight (HCW, kg), killing-out percentage (KOP, %), carcass weight (CW, kg), dressing percentage (DP, %), and backfat thickness (BFT, mm) were determined as described in a previous study (Oanh *et al.*, 2019). Visceral organs including the heart, liver, kidneys, and spleen were collected as previously described (Oanh *et al.*, 2020).

Longissimus dorsi muscle (LDM) samples were immediately collected around the 11-14th ribs from the left side of each carcass after slaughter. Then each LDM sample was cut into four similar subsamples (around 200g per sample). Subsamples were separately weighed and placed in plastic zip-lock bags. Two subsamples were kept at 4°C for technological quality traits at 24 and 48h *post mortem*. The remaining two were immediately analyzed for their chemical composition, cholesterol content, and total omega-3 content.

Technological quality of the longissimus dorsi muscle

The raw LDM samples were measured using a portable pH meter (pH-STAR, Matthäus, Germany) at 45min, 24h, and 48h *post mortem*. The other following parameters were determined at 24 and 48h: lightness (L^*), redness (a^*), and yellowness (b^*) values were measured using the model CR-410 Chroma Meter (Japan) observer as previously described (Oanh *et al.*, 2019); drip loss percentage (DL_{24} and DL_{48}) and drip cooking percentage (CL_{24} and CL_{48}) were measured as previously described (Oanh *et al.*, 2019); and shear forces (SF) were measured by a Warner Bratzler (USA) as previously described (Zhang *et al.*, 2008).

Chemical composition, cholesterol content and total omega-3 contents of the pig meat

The dry matter, crude protein, lipids, and ash contents of the raw LDM samples were analyzed according to the methods of the Association of Analytical Chemists (AOAC, 1990). Cholesterol content was measured by gas chromatography-mass spectrometry (GC-MS) (Derewiaka & Obiedziński, 2010). Total omega-3 content was analyzed using GC equipped with a flame ionization detector (FID) and a capillary column (Ding *et al.*, 2017).

Chemical analysis

The chemical compositions of the diets were analyzed for dry matter, crude protein, ether extract, ash, crude fiber, neutral detergent fiber, phosphorus, and calcium according to the AOAC (1990). Gross energy was analyzed by a bomb calorimeter E2K (Germany).

Data analysis

Data were treated using PROC MIXED in SAS (version 9.4), with the diets as the fixed effect, and the pens as the random effects. The experimental unit for the performance parameter was the pen, and the pig individual was used as the experimental unit for the carcass characteristics, meat quality, and chemical compositions data. A similar model for the repeated measures data was performed but included the effect of a compound symmetry structure of covariance. Orthogonal polynomials were analyzed to measure the linear and quadratic effects of MP inclusions. Multiple comparisons of least-square means were conducted using Tukey adjustments. Significant differences were described as P <0.05 and a trend as 0.05 < P < 0.10.

Results

Animal performance

The performances of the experimental pigs are shown in **Table 3**. There were no animal losses during the experimental period in the present study. There were no differences (P> 0.05) in the IBW, FBW, ADFI, or FCR among the pigs fed the T_0, T_{20}, T_{40}, or T_{60} diets during both experimental periods (**Table 3**).

Carcass characteristics

No significant differences (P >0.05) were observed in the HCW, KOP, CW, or DP (**Table 4**). A trend for a decrease in the BFT was observed with increasing MP supplementation in the diet. There was a linear effect (P = 0.02) of the heart proportion in the FBW with increasing MP in the diet. No such effect was observed for the kidneys, liver, or spleen among the diets.

Meat quality of the longissimus dorsi muscle

The pH values at 45min, 24h, and 48h (pH_{45}, pH_{24}, and pH_{48}), drip losses at 24 and 48h (DL_{24} and DL_{48}), cooking loss at 24 and 48h (CL_{24} and CL_{48}), shear forces at 24 and 48h (SF_{24} abd SF_{48}), and meat color CIE (a^*_{24}; L^*_{48}, a^*_{48}, and b^*_{48}) of the LDM were not influenced (P >0.05) by MP inclusion in the diets (**Table 5**). However, increasing trends in L^*_{24} (linear, P = 0.08; quadratic, P = 0.06), in $a*_{24}$ (quadratic, P = 0.06), and in b^*_{24} (linear, P = 0.09) were observed with increasing MP in the diets.

Chemical composition, cholesterol content, and total omega-3 content of the meat

The dry matter, ash, and lipids of the raw LDM were not affected (P >0.05) by the diets (**Table 6**). However, a significant increase in protein content (P = 0.02) of raw LDM was observed with the level of MP in the diet. There was a significant decrease (P = 0.04) in cholesterol content with increasing MP in the diet. Total omega-3 content was statistically not affected (P = 0.75) by dietary MP (**Table 6**).

Discussion

Animal performance

In the present work, pigs fed diets containing MP during the grower-finisher phases had no significant differences in the performance parameters when compared to the control group. Some previous studies have been carried out to evaluate the effects of different blends of medicinal plants on the production parameters of finishing pigs. A recent experiment by Hanczakowska *et al.* (2015) found that the growth performance of finishing pigs fed a diet supplemented with a medicinal extract mixture from *Salvia officinalis*, *Urtica dioica*, *Melissa officinalis*, and *Echinacea purpurea* was unaffected when compared to pigs fed a control diet. Likewise, Ahmed *et al.* (2016) reported that grower-finisher pigs fed a diet supplemented with a natural herb combination (pomegranate, *Ginko biloba*, and licorice) had no significant effect on the FBW or ADG compared to animals receiving a control diet, but the ADFI decreased and FCR increased. A study by Yan *et al.* (2011) demonstrated that growing pigs fed a diet supplemented with medicinal extracts (ginger, black pepper, buckwheat, thyme, and curcuma) had enhanced ADG and ADFI but not FCR. Likewise, Liu *et al.* (2008) reported that a supplement blend of many herbal extracts enhanced the growth performance of finishing pigs. Similarly, another study (Kwon *et al.*, 2005) exposed that an herbal extract supplementation (*Artemisia sp*., *Acanthopanax sp*., and garlic) in the diets of grower-finisher pigs improved their growth performance, while Ahmed *et al.* (2016) reported a reduced ADFI and increased FCR for growing pigs fed a diet containing a natural herb combination (pomegranate, *Ginkgo biloba*, and licorice). The contradictory results regarding the growth parameter responses to medicinal plants could be expected owing to contextual parameters (species, plant parts used, physical and pharmacological properties, age of the plant, harvest time, geographical origin, processing method, and various dosages used) (Wenk, 2003; Hashemi & Davoodi, 2011; Lei *et al.*, 2018).

Carcass characteristics

A recent study (Liu *et al.*, 2008) reported that medicinal plant supplementation improved the carcass characteristics and technological quality of pork. In the current study, the carcass characteristics were not significantly different between pigs fed diets supplemented with MP and pigs fed the control diet. Lower (by approximately 12%) backfat thickness (BFT) was observed in pigs receiving a mixture of medicinal plants. In another study (Ahmed *et al.*, 2016), supplementation with a medicinal plant

Table 3. Feed intake, daily gain, and feed conversion ratio (LSM) of grower-finisher pigs fed diets supplemented with medicinal plant powder

Items	Dietary treatment[1]				SEM	*P*-value	
	T_0	T_{20}	T_{40}	T_{60}		Linear	Quadratic
N	12	12	12	12			
IBW (kg)	30.3	30.4	30.3	30.3	0.42	0.93	1.00
Growing Phase (30-60kg)							
FBW_1 (kg)	65.6	65.1	64.6	64.2	1.49	0.48	0.98
$ADFI_1$ (kg/d)	1.84	1.86	1.83	1.80	0.04	0.37	0.56
ADG_1 (g/d)	750	737	731	720	31.8	0.50	0.98
FCR_1 (kg/kg)	2.46	2.53	2.51	2.50	0.06	0.64	0.53
Finishing Phase (61-100kg)							
FBW_2 (kg)	104.3	104.9	105	105.4	2.93	0.78	0.97
$ADFI_2$ (kg/d)	2.38	2.51	2.56	2.65	0.09	0.05	0.83
ADG_2 (g/d)	716	737	749	764	41.1	0.40	0.94
FCR_2 (kg/kg)	3.33	3.42	3.42	3.48	0.09	0.30	0.83
Overall							
ADG (g/d)	732	737	740	744	29.3	0.77	0.97
FCR (kg/kg)	2.91	3.01	3.00	3.03	0.06	0.19	0.58

Note: LSM, least square means; SEM, standard error of the mean; N, number of animals; d, day; g, gram; IBW, initial live body weight; FBW, final live body weight; ADG, average daily gain; ADFI, average daily feed intake; FCR, feed conversion efficiency (kg feed/kg gain)

[1]*T_0, control diet; T_{20}, T_{40}, and T_{60} mixed with 2, 4, and 6% of blend powder of medicinal plants, respectively.*

Table 4. Carcass parameters and visceral organs (LSM) in finisher pigs fed diets supplemented with medicinal plant powder

Items	Dietary treatment[1]				SEM	*P*-value	
	T_0	T_{20}	T_{40}	T_{60}		Linear	Quadratic
N	6	6	6	6			
Carcass Characteristics							
FBW, kg	104.7	105.5	106.5	106.9	1.35	0.73	0.24
HCW, kg	84.0	85.4	85.8	85.7	1.20	0.42	0.37
KOP, %	80.2	80.9	80.6	80.2	0.45	0.22	0.65
CW, kg	73.6	75.4	75.2	75.2	1.13	0.30	0.52
DP, %	70.3	71.4	70.6	70.4	0.49	0.11	0.42
BFT, mm	18.9	16.6	16.4	16.1	0.91	0.12	0.12
Visceral Organs (% FBW)							
Heart	0.40	0.38	0.37	0.36	0.01	0.02	0.79
Kidneys	0.30	0.30	0.31	0.32	0.01	0.18	0.80
Liver	1.46	1.45	1.49	1.52	0.05	0.34	0.96
Spleen	0.14	0.13	0.15	0.14	0.008	0.65	0.69

Note: [1]T_0, control diet; T_{20}, T_{40}, and T_{60} mixed with 2, 4, and 6% of blend powder of medicinal plants; LSM: Least square means; SEM: Standard error of the mean; N, number of animals; FBW: Final body weight; HCW: Hot carcass weight; KOP: Killing-out percentage; CW: Carcass weight; DP: Dressing percentage; BFT: Backfat thickness.

combination significantly reduced BFT while increasing lean production. Likewise, dietary cinnamaldehyde reduced the BFT of finishing pigs (Luo *et al.*, 2020). The presence of polyphenols in medicinal plants could alter intestinal lipid metabolism by decreasing lipogenesis and the stimulation of fatty acid β-oxidation, thereby reducing BFT and increasing lean production (Wang *et al.*, 2014). On the other hand, no significant differences in most internal organs were recorded among the diets. A trend of a lower heart rate in pigs fed MP diets was not clear and probably due to contingent statistical significance.

Technological quality of the longissimus dorsi muscle

The pH value of pig meat *post mortem* is an important indicator of quality evaluation as it is related to the color, water holding capacity, tenderness, and shelf-life of the meat. Ultimate pH values of normal pork range between 5.4 and 5.8 (Monin, 2003). In this study, no dietary effects on the pH values at 45min, 24h, and 48h were recorded, and these pH values were within the normal range. Overall, meat quality was within the normal range of meat classification as described previously (Lengerken & Pfeiffer, 1987). The lack of effects of dietary MP supplementation on the DL and CL at 24 and 48 h were observed in the current study, which is consistent with the similar findings confirmed by previous authors (Janz *et al.*, 2007; Ranucci *et al.*, 2015). Although dietary MP supplementation did not significantly influence the CIE L*, a*, and b* at 24 and 48h, the LDM meat had a lighter color, especially the L*, a*, and b* parameters at 24 h in animals fed the MP diets compared to the control diet. This was probably due to the presence of polyphenol content in the MP diets resulting in decreased lipid oxidation and better LDM color parameters *post mortem* (Wenjiao *et al.*, 2014). Additionally, this study indicated a

Table 5. Technological quality of the meat (LSM) in finisher pigs fed diets supplemented with medicinal plant powder

Items	Dietary treatment[1]				SEM	*P*-value	
	T_0	T_{20}	T_{40}	T_{60}		Linear	Quadratic
N	6	6	6	6			
pH_{45}	6.32	6.36	6.34	6.34	0.03	0.43	0.96
pH_{24}	5.53	5.51	5.52	5.50	0.03	0.90	0.69
pH_{48}	5.51	5.50	5.49	5.49	0.02	0.97	0.44
Drip Loss, %							
DL_{24}	1.30	1.10	1.22	1.25	0.22	0.56	0.88
DL_{48}	1.50	1.61	1.65	1.65	0.22	0.75	0.65
Cooking Loss, %							
CL_{24}	25.64	25.50	26.9	27.0	1.54	0.92	0.37
CL_{48}	26.1	28.0	29.2	29.4	1.39	0.39	0.12
Shear Force, N							
SF_{24}	39.2	36.3	35.40	33.50	1.93	0.43	0.10
SF_{48}	41.6	37.3	35.5	35.9	3.01	0.33	0.23
Meat Color C.I.E.							
L^*_{24}	51.1	55.0	55.5	56.1	1.40	0.08	0.06
a^*_{24}	11.9	12.8	13.4	13.1	0.46	0.18	0.06
b^*_{24}	5.16	6.09	6.16	6.13	0.37	0.09	0.17
L^*_{48}	54.8	56.5	57.2	56.9	1.53	0.44	0.37
a^*_{48}	13.1	13.5	13.0	13.0	0.52	0.62	0.58
b^*_{48}	6.13	6.49	6.45	6.40	0.40	0.54	0.79

Note: [1]T_0, control diet; T_{20}, T_{40}, and T_{60} mixed with 2, 4, and 6% of blend powder of medicinal plants, respectively; LSM: Least square means; SEM: Standard error of the mean; N, number of animals.

Table 6. Chemical composition, and cholesterol content and total omega-3 content of meat (LSM) in finisher pigs fed diets supplemented with medicinal plant powder

Items	Dietary treatment[1]				SEM	*P*-value	
	T_0	T_{20}	T_{40}	T_{60}		Linear	Quadratic
N	6	6	6	6			
Chemical Composition							
Dry matter, %	27.4	27.6	28.0	27.7	0.40	0.58	0.33
Ash, %	1.47	1.46	1.38	1.37	0.03	0.99	0.02
Lipids, %	2.47	2.48	2.44	2.01	0.22	0.66	0.27
Protein, %	22.7^{a}	22.8^{a}	23.4^{ab}	24.1^{b}	0.29	0.89	0.005
Cholesterol and total omega-3 contents							
Cholesterol, mg/100 g	60.1^{a}	55.3^{ab}	54.6^{ab}	54.1^{b}	1.50	0.05	0.04
Total omega-3, mg/100 g	17.2	20.8	20.4	20.8	2.74	0.41	0.56

Note: [1]T_0, control diet; T_{20}, T_{40}, and T_{60} mixed with 2, 4, and 6% of blend powder of medicinal plants, respectively; LSM: Least square means; SEM: Standard error of the mean; N, number of animals. Mean values with different letters (a, b) in a row are significantly different ($P < 0.05$).

trend for decreased pork shear in pigs fed the MP diets, which is in agreement with the results of Luo *et al.* (2020) who reported that medicinal plant supplementation decreased the shear force in LDM leading to softer muscle and better taste.

Chemical composition, cholesterol content, and total omega-3 content of meat

In the current work, dietary MP supplementation did not affect the dry matter, ash, or lipids content in the LDM of finishing pigs. However, a significant increase in the crude protein content in the LDM for pigs fed the MP diets was measured compared to the control diet. This result is in agreement with the previous study of Liu *et al.* (2008), who stated that dietary herb extracts supplementation increased protein accretion. In addition, the dietary MP diets significantly decreased the cholesterol content of the pig meat, even in the blood serum (data not shown), which may have been due to the content of flavonoids of the medicinal plants (Zarrouki *et al.*, 2010; Ahmed *et al.*, 2016). Indeed, plant flavonoids could form insoluble complexes with cholesterol in the digesta and inhibit absorption of endogenous and exogenous cholesterol in the animal intestine (Ahmed *et al.*, 2016; Rao & Gurfinkel, 2000).

Conclusions

In the present study, it can be concluded that grower-finisher pig diets containing up to 60 g/kg of medicinal plant powder (*B. pilosa*, *U. lobata*, *P. palatiferum*, Ramulus Cinnamomi, cinnamon branches, and star anise) changed neither the growth performance nor the carcass characteristics in grower-finisher pigs. Dietary supplementation of MP at 60 g/kg improved meat protein and decreased the cholesterol content of the pig meat.

Further works are required to clarify the possible relationships between fatty acid composition, skatole concentration, and antioxidant capacity of pig meat, which are related to sensory quality, from animals fed diets with/without blends of medicinal plants.

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