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Addition of homeopathic products to pig diets in the finishing phase promotes improvement in growth performance

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Abstract

Homeopathic products (HP) are a preventive and therapeutic alternative in pig farming. This study evaluated the effect of the concentration of dietary HP on performance, carcass traits, meat quality, and plasma metabolites of growing-finishing pigs. A total of 60 crossbred male pigs (Agroceres PIC × DanBred), immunocastrated at 90 and 120 days old, with an initial BW of 30.71 ± 2.60 kg were allocated in a completely randomized design to three treatments: i) control diet (CT), without HP), ii) CT + HP_1 (Figotonus® and Sanoplus®) (1 g/kg of diet), and iii) CT + HP_2 (Figotonus and Sanoplus) (2 g/kg of diet). The results indicate that pigs fed diets containing HP_2 had a greater average daily gain compared with those fed the control diet, although a higher feed efficiency was observed when pigs were fed the HP_1 diet. Animals fed the HP_2 diet showed a slight increase in initial postmortem pH in the *Longissimus dorsi* muscle compared to the control group. Pigs fed HP_2 showed a higher initial temperature in the *L. dorsi* than those fed the control diet. However, there was no effect on plasma metabolite concentration. Based on the results of the present study, the HP_1 diet enhanced the performance of finishing pigs without negative effects on meat traits and plasma metabolites.

Keywords: feed additive, homeopathy, meat traits, pig production, plasma metabolites, swine

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Introduction

The high global demand for animal food has influenced the intensification of pig farming positively. However, high-density herds affect animal welfare negatively by promoting stress, triggering disease and mortality because of greater animal morbidity; this reduces performance and causes economic losses (Morés *et al.*, 2015). To improve the farm indicators, management measures such as environmental control, technical training, nutritional improvements, and the reduction of antibiotic use have been investigated. According to Brown *et al*. (2016), although the use of antibiotics in animal nutrition enhances performance, there are risks of animal and human cross- and multiple resistance to pathogens, and the presence of residues in animal food.

For this reason, the use of nutritional strategies and the search for alternative additives such as homeopathics, probiotics, prebiotics, symbiotics, essential oils, organic acids, phytotherapeutics, and nutraceuticals to totally or partially replace synthetic additives has intensified in recent years. These complementary additives provide optimal animal performance without affecting the quality of livestock products (Huyghebaert *et al.,* 2011; Thacker, 2013), decreasing the influence of external and internal factors that affect the production of growing-finishing pigs.

Growing-finishing pigs are usually subject to multiple stress agents, such as disease, environmental change, and different production management systems. Therefore, it is standard practice to add chemotherapeutic products to the diet in the growing-finishing phases to prevent, control, or treat disease. Thus, homeopathy stands out as a natural alternative, with biological effects to treat the symptoms presented

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in the system through experimentation (artificial disease), curing the symptoms (natural disease), and favouring welfare (Teixeira, 2011; Teixeira, 2012).

By using animal, vegetable, and mineral compounds in ultra-diluted formulations, homeopathic products do not contaminate the environment or leave residues in animal food. Thus, they contribute to the treatment and prevention of disease and are economically better because the production cost is lower compared with allopathic products (Pires, 2005). In recent years, the use of homeopathic products has increased in livestock because of benefits in the treatment and prevention of disease, parasite control, performance, metabolic changes, and behavioural disorders (Doehring & Sundrum, 2016; Custódio *et al.,* 2017).

In pig production, homeopathics have been used to treat problems in the digestive and reproductive tracts, improving the performance and immune system of the animals, and reducing stress (Felippelli & Valente, 2009; Deni *et al.,* 2015). Homeopathic products have been of benefit to various categories of animal in pig farming. Indeed, compared with antibiotics, HPs have been shown to improve performance and prevent diarrhoea in young pigs (Coelho *et al.,* 2009; Kiefer *et al.,* 2012). Moreover, they have been reported to reduce the number of animals with intestinal disorders, promote weight gain (Coelho *et al.,* 2014), and improve the percentage and quality of meat and the marbling of the pig carcass. No effect on blood parameters such as aspartate aminotransferase, alanine aminotransferase, and plasma urea nitrogen concentrations has been reported (Lima, 2018).

Therefore, this study was performed to evaluate the effect of concentration of dietary HP on growth performance, carcass traits, meat quality, and plasma metabolites of growing-finishing pigs.

Material and methods

This study was carried out in the swine facility of Professor Antônio Carlos dos Santos Pessoa Experimental Farm of Universidade Estadual do Oeste do Paraná (Unioeste), located in Marechal Cândido Rondon, Brazil (24°33'22" S, 54°03'24" W; altitude, 420 m). This study was approved by the Ethical Committee for the Use of Animals in Experimentation at the Universidade Federal da Bahia (protocol number 85/2019).

The experimental shed was cleaned and disinfected before housing the animals for a 14-day period. At the beginning of the experiment, animals were weighed and identified. Pigs were housed in a double curtain-sided concrete facility with a ceramic roof, and two concrete pen rows. Pen sizes were 5.8 m^2 and they were equipped with semi-automatic feeders and nipple drinkers. The experimental period was 97 days.

During the experiment, maximum and minimum temperature and relative humidity were controlled by opening and closing the side curtains. Climatic records were taken with a digital hygrometer thermometer (J Prolab Ind. and com., Paraná, BR) placed in the centre of the facility at the animals' loin height. The temperature ranged from 24.75 ± 2.20 °C to 29.55 ± 2.92 °C during the growing phase and from 23.89 ± 1.81 °C to 27.34 ± 2.38 °C during the finishing phase. The average relative humidity was 73.58 ± 10.92% and 76.90 ± 7.82% during growing and finishing phases, respectively.

A total of 60 crossbred male pigs (Agroceres PIC × DanBred), immunocastrated at 90 and 120 days old (vaccinated against gonadotropin releasing hormone; GnRH), with an initial BW of 30.71 ± 2.60 kg, were allocated in a completely randomized design to three treatments with six replications for the control treatment and seven replications for treatments with HP. A pen containing three animals was considered the experimental unit.

Treatments consisted of i) control diet (CT, with no HP), ii) CT + HP_1 (Figotonus and Sanoplus, 1 g/kg of diet), and iii) CT + HP_2 (Figotonus and Sanoplus, 2 g/kg of diet). Sanoplus is generally prescribed for respiratory and intestinal problems. It is a homeopathic complex composed of *Lachesis muta* 10^{-12}, *Baptisia tinctoria* 10^{-60}, *Staphysagria* 10^{-400}, *Lycopodium clavatum* 10^{-12}, *Thymulinum* 10^{-12}, *Sarcolatic acidum* 10^{-14}, *Eberthynum* 10^{-18}, and minerals *Silicea terra* 10^{-14}, *Ferrum phosphoricum* 10^{-14}, and *Antimonium tartaricum* 10^{-14}. Figotonus is indicated for liver dysfunctions and injuries and is a homeopathic complex composed of minerals and medicinal plants, such as phosphorus 10^{-14}, *Carboneum tetrachloricum* 10^{-30}, sulphur 10^{-18}, *Chelidonium majus* 10^{-12}, *Cardus marianus* 10^{-12}, *Myrica cerifera* 10^{-12}, *Chionantus virginica* 10^{-30}, *Berberies vulgaris* 10^{-12}, and *Leptandra virginica* 10^{-12}.

Experimental diets were iso-nutritional and formulated to meet requirements (Rostagno *et al*., 2017) of each animal phase: growing I (30 to 50 kg BW), growing II (50 to 70 kg BW), finishing I (70 to 100 kg BW), and finishing II (100 to 135 BW) (Table 1). All diets were provided as mash. Pigs were fed *ad libitum* and had free access to water throughout the experiment. Animals were individually weighed on a digital scale (Digi-tron, 50 kg model, Curitiba, PR, Brazil) at the beginning and the end of the study. Average daily weight gain (ADWG, kg/day) was determined by the difference between initial and final bodyweight, divided by the number of days of housing. To determine the average daily feed intake (ADFI, kg/day), the amounts of feed offered to and refused by animals were recorded daily. ADFI was calculated as subtracting the leftovers from the offered amount. Feed efficiency (FE, ADWG:ADFI) was calculated by dividing average daily gain by average daily feed intake.

To assess urea and glucose concentration (mg/dL), blood samples were taken from 12 animals randomly per treatment at the beginning and the same animals were used at the end of each experimental phase. Blood samples were obtained via jugular vein puncture (18G; 1½″ needle). Blood was collected in vacutainer tubes containing EDTA or sodium fluoride. After sampling, blood samples were placed on ice in a styrofoam box (4 ºC) and sent to the laboratory. Plasma was obtained by centrifuging blood samples at 3000× *g* for 15 minutes (Centrifuge Mod. 80-2b, Centrilab Anvisa Laboratory). Plasma was removed from centrifuge tubes using Pasteur pipettes. Subsequently, plasma samples were placed in polypropylene-type tubes to be analysed for glucose (enzymatic-colorimetric Trinder method, Cat. 434) and urea (enzymatic-colorimetric method, Cat. 427) using a commercial kit (Gold Analyze) according to manufacturer's specifications.

At the end of the trial, all animals were weighed after fasting for 12 hours and then transported to the abattoir (*n* = 60). Carcass quantitative characteristics were collected, such as backfat thickness (mm), hot carcass weight (kg), quantity of meat (kg/carcass), carcass yield (%), and muscle percentage (%; determined using a Hennessy GP4/BP4 swine carcass typing pistol; Hennessy Grading Systems, Auckland, NZ).

Four hours after slaughter, samples (20 cm) of *L. dorsi* muscle (obtained from the section of the carcass in the P2 region of insertion of the last thoracic vertebra with the first lumbar at 6.0 cm from the midline of carcass cut) were collected. Samples were stored in coolers to be transported to the Animal Products Technology Laboratory at Unioeste, where they were properly stored and analysed according to the methods of Bridi & Silva (2009). For these analyses, three samples (2.5 cm thick) of the *L. dorsi* muscle were taken to determine marbling degree, liquid loss by dripping (LLD), liquid loss by thawing (LLT), liquid loss by cooking (LLC), shear force, meat colour evaluation, pH, and temperature. Analyses of pH and temperature in the *L. dorsi* muscle were performed using a portable meter (model HI 99163, Hanna Instruments Inc., Island of Rhodes, USA) within 4 h (post-mortem) and 24 h (post-slaughter).

Water retention capacity was determined by using LLD, LLT, and LLC methods as previously described by Bridi & Silva (2009). For LLD, samples were dried on paper towels, weighed, and placed individually in plastic nets, suspended in hermetically sealed plastic containers, and kept at 4 °C for 48 h. Then, samples were removed from the containers, dried with a paper towel and weighed. For LLT evaluation, samples were placed in plastic trays, wrapped in polyvinyl chloride plastic film, and kept at 4 ± 1 ºC for 48 h. Afterward, they were weighed again, and the loss of exudate was expressed as a percentage of the initial weight of the sample. For the measurement of LLC, samples were grilled on a preheated grill for 20 min at 170 °C until reaching an internal temperature of 40 °C, which was measured using a digital skewer thermometer (Digital Culinary Skewer Thermometer for Kitchen Food, TP101), inserted in the centre of the sample. Subsequently, samples were turned over and kept on the grill until they reached an internal temperature of 71 °C. Then, samples were removed from the grill, packaged, stored for 24 h in the refrigerator (4 °C), and weighed.

For shear force (SF) evaluation, a stainless-steel cylindrical sampler (1.27 cm in diameter) was used to remove sub-samples at six points from the pre-cooked sample, which were submitted to the shear test in a texturometer (model CT-3 Texture Analyzer), equipped with standard shear blades with inverted V-shaped cutting edge calibrated for force (15 g), deformation (20 mm), and speed (2.0 mm/s).

Meat colour was determined after exposing the sample to air from 15 to 20 min to provide muscle oxygenation. Colour parameters such as L* (luminosity), a* (red-green component), and b* (yellow-blue component) were determined using a Minolta CR-400 colorimeter device (Konica Minolta Holdings Inc., Tokyo, Japan). Results were expressed using the CIELAB colour system with an 8 mm aperture, area illumination (illuminant, C D65), and 0º viewing angle. Colour pattern was evaluated using a scale from 1 to 6 points (1 = pale pink and 6 = dark purplish), as previously described by Bridi & Silva (2009). Meat marbling was determined using photographic standards of a numerical scale from 1 to 7, where 1 represents meat with low marbling and 7 indicates meat with excessive marbling (Bridi & Silva, 2009).

Table 1 Percentage composition and calculated ingredients of the experimental diets (as-fed basis)

Ingredients	Growing I			Growing II			Finishing I			Finishing II		
	C[1]	H[2]	H[3]	C[1]	H[2]	H[3]	C[1]	H[2]	H[3]	C[1]	H[2]	H[3]
Ground corn 7.8%	66.20	66.07	65.93	71.92	71.78	71.64	78.70	78.57	78.43	85.65	85.51	85.38
Soybean meal 45.4%	26.74	26.76	26.79	22.19	22.22	22.24	16.10	16.12	16.15	9.71	9.74	9.76
Soybean oil	2.53	2.58	2.63	2.22	2.27	2.31	1.82	1.86	1.91	1.48	1.53	1.58
Dicalcium phosphate	1.56	1.57	1.57	1.30	1.30	1.30	1.11	1.11	1.11	0.98	0.98	0.99
Calcitic limestone	0.75	0.71	0.68	0.67	0.63	0.60	0.61	0.58	0.55	0.58	0.55	0.52
Common salt	0.45	0.45	0.45	0.41	0.41	0.41	0.39	0.39	0.39	0.37	0.37	0.37
Mineral and vitamin premix[4,5]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Lysine sulphate	1.01	1.01	1.01	0.63	0.63	0.62	0.64	0.64	0.64	0.63	0.63	0.63
L-threonine	0.19	0.19	0.19	0.16	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14
DL-methionine	0.18	0.18	0.18	0.14	0.14	0.14	0.12	0.12	0.12	0.09	0.09	0.09
L- tryptophan	0.08	0.08	0.08	0.05	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05
Lincomycin	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Homeopathic product	-	0.10	0.20	-	0.10	0.20	-	0.10	0.20	-	0.10	0.20
Calculated composition												
Crude protein (%)	18.41	18.41	18.41	16.44	16.44	16.44	14.20	14.20	14.20	11.81	11.81	11.81
Metabolizable energy (Mcal/kg)	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35
Total calcium (%)	0.76	0.76	0.76	0.66	0.66	0.66	0.57	0.57	0.57	0.51	0.51	0.51
Available phosphorus (%)	0.38	0.38	0.38	0.32	0.32	0.32	0.28	0.28	0.28	0.25	0.25	0.25
Total sodium (%)	0.19	0.19	0.19	0.17	0.17	0.17	0.16	0.16	0.16	0.15	0.15	0.15
Digestible lysine (%)	1.35	1.35	1.35	1.03	1.03	1.03	0.89	0.89	0.89	0.74	0.74	0.74
Digestible methionine + cysteine (%)	0.68	0.68	0.68	0.60	0.60	0.60	0.53	0.53	0.53	0.44	0.44	0.44
Digestible threonine (%)	0.75	0.75	0.75	0.67	0.67	0.67	0.58	0.58	0.58	0.48	0.48	0.48
Digestible tryptophan (%)	0.26	0.26	0.26	0.20	0.20	0.20	0.18	0.18	0.18	0.14	0.14	0.14

[1] Control diet (CD) without homeopathic products

[2] CD + addition of HP_1 (Figotonus and Sanoplus, 1 g/kg of diet)

[3] CD + addition of HP_2 (Figotonus and Sanoplus, 2 g/kg of diet)

[4] Growing mineral and vitamin premix (minimum amount per kg of product): folic acid 94.75 mg, pantothenic acid 3.184 mg, biotin 28.70 mg, copper sulphate 20.83 g, iron sulphate 25.00 g, iodine sulphate 500.30 mg, manganese sulphate 12.4 g, niacin 6,948.45 mg, sodium selenite 90.00 mg, vitamin A 2,374,050 IU, vitamin B_1 318.40 mg, vitamin B_{12} 6,983 mg, vitamin B_2 1,420.45 mg, vitamin B_6 606.10 mg, vitamin D_3 474,810 IU, vitamin E 16,715.50 IU, vitamin K_3 782.30 mg, zinc oxide 29.84 g, antioxidant 4,759 mg, mineral matter (max) 350.00 g, tylosin 14,675 ppm

[5] Finishing mineral and vitamin premix (minimum amount per kg of product): folic acid 70.00 mg, pantothenic acid 2,346 mg, biotin 21.10 mg, Copper sulphate 20.83 g, iron sulphate 25.00 g, iodine sulphate 335.20 mg, manganese sulphate 14.10 g, niacin 5,146.45 mg, sodium selenite 76.50 mg, vitamin A 1,749,300 IU, vitamin B_1 234.60 mg, vitamin B_{12} 5,150 mg, vitamin B_2 1,046.60 mg, vitamin B_6 446.60 mg, vitamin D_3 349,960 IU, vitamin E 13,040.35 IU, vitamin K_3 576.40 mg, zinc oxide 30.16 g, Antioxidant 3,170 mg, mineral matter (max) 360.00 g, tylosin 14,675 ppm

Before evaluating the result of the analysis of covariance (ANCOVA) and variance (ANOVA), an analysis of standardized residuals was carried out to find outliers. Outliers were identified based on the normal distribution curve, in which values greater than or equal to three standard deviations were considered influential. The normality of experimental errors and the homogeneity of variances between treatments for the different variables were previously evaluated using the Shapiro-Wilk and Levene tests, respectively. The following overall model was used:

$$Y_{ij} = m + T_i + \beta\ (X_{ij} - \underline{X}_{..}) + \varepsilon_{ij},$$

where: Y_{ij} = the dependent variable in each plot, measured in the i-th treatment class and in the k-th replication; m = overall average; T_i = fixed effect of treatment classes, for i = (1, 2 and 3); β = regression coefficient of Y over X; X_{ij} = average observation of the covariate (initial bodyweight) in each plot, measured in the i-th treatment class and in the k-th replication; X = overall average for the X covariate; ε_{ij} = random error of the plot associated with each observation, Y_{ij}. For carcass traits, meat quality, and plasma metabolites, the statistical model used was the one mentioned above, without including the covariate effect.

Data were submitted to ANCOVA or ANOVA. Differences between treatment averages (P <0.10) were performed using a Student's *t*-test. Statistical analyses were performed using the SAS University Edition (SAS Inst. Inc., Cary, NC, USA). All data were presented as averages with standard error of the mean.

Results and Discussion

Our results suggest pigs fed with diets containing HP_2 showed greater (P =0.033) daily weight gain compared with the control group, although greater feed efficiency (P =0.086) was observed in pigs that consumed the HP_1 diet. In addition, the initial bodyweight covariate was significant in almost all growth performance variables (Table 2).

Table 2 Growth performance of pigs fed diets containing homeopathic products in the growing-finishing phases

Variables$^{1)}$	Experimental treatments$^{2)}$			SEM$^{3)}$	P-value$^{4)}$	P-value$^{5)}$
	Control	HP_1	HP_2			
Growing I (30.77 to 52.26 kg)						
IBW (kg)	31.67	30.08	30.68	0.549	-	-
ADFI (kg/day)	1.70	1.75	1.71	0.030	0.206	<0.000
ADWG (kg/day)	1.02	1.02	1.01	0.020	0.371	<0.000
FBW (kg)	53.22	51.63	52.08	0.916	0.371	<0.000
FE (G:F)	0.60	0.58	0.59	0.007	0.849	0.292
Growing II (52.26 to 69.15 kg)						
ADFI (kg/day)	2.15	2.07	2.19	0.046	0.585	0.040
ADWG (kg/day)	1.054	1.050	1.06	0.023	0.821	0.026
FBW (kg)	70.09	68.44	69.06	1.173	0.500	0.000
FE (G:F)	0.48	0.50	0.48	0.008	0.431	0.672
Finishing I (69.15 to 95.51 kg)						
ADFI (kg/day)	2.78	2.84	2.86	0.071	0.427	0.004
ADWG (kg/day)	1.21	1.20	1.17	0.021	0.681	0.005
FBW (kg)	96.88	94.86	94.97	1.552	0.573	<0.000
FE (G:F)	0.43	0.42	0.41	0.007	0.390	0.334
Finishing II (95.51 to 144.13 kg)						
ADFI (kg/day)	3.23	3.22	3.47	0.067	0.113	0.016
ADWG (kg/day)	1.28^{b}	1.37^{ab}	1.38^{a}	0.023	0.033	0.017
FBW (kg)	143.02	144.33	144.89	2.116	0.117	<0.000
FE (G:F)	0.39^{b}	0.42^{a}	0.39^{b}	0.005	0.086	0.424
Total period (30.77 to 144.13 kg)						
ADFI (kg/day)	2.47	2.47	2.56	0.026	0.256	<0.000
ADWG (kg/day)	1.14	1.15	1.15	0.013	0.893	<0.000
FBW (kg)	143.02	144.33	144.89	2.116	0.117	<0.000
FE (G:F)	0.47	0.48	0.47	0.004	0.432	<0.000

^{a,b}Average values followed by different lowercase letters in the row differ according to Student's *t*-test at the 10% probability level

[1] IBW: initial bodyweight, ADFI: average daily feed intake, ADWG: average daily weight gain, FBW: final bodyweight, FE: feed efficiency

[2] Control diet (CD, without homeopathic products), CD + HP_1 (Figotonus and Sanoplus, with 1 g/kg diet) or CD + HP_2 (Figotonus and Sanoplus, with 2 g/kg diet)

[3] SEM: standard error of mean; [4] Effect of experimental diets; [5] Effect of covariate initial bodyweight

The effect of covariates on the growth performance variables demonstrated the importance in improving the accuracy of the statistical model and affected the results of the final analyses significantly. To the authors' current knowledge, there are few reports of studies involving the use of HP for growing-finishing pigs as an alternative feed additive. In the present study, the greater daily weight gain observed in animals that consumed the 2 g/kg HP diet could be explained by the immunostimulant action working directly, or through metabolic changes (Teixeira, 2010). There was no health challenge during the experimental period (absence of mortality) and the animals were treated according to animal welfare criteria. The response for challenged animals is more evident when HP is added to diets (Coelho *et al.,* 2009; Coelho *et al.,* 2014); the absence of a significant difference among treatments in the growing phase can be explained by the good sanitary conditions in which the pigs were housed.

Previous studies have also reported the benefits of HP to growth performance. Corroborating the results of the present study, Soto *et al.* (2008) tested a dose of 5 mL HP/100 L water (*Echinacea angustifolia, Avena sativa, Ignatia amara, Calcarea carbonica*) administered twice a day, and obtained lower weight loss in piglets (from 0 to 7 days after weaning). A positive result using HP (phosphorus 30 cH) and biotherapeutics (*Escherichia coli* 30 cH) was also reported by Coelho *et al.* (2009), who observed higher weight gain in newborn piglets in the prevention of colibacillosis. Coelho *et al*. (2014) evaluated an oral dose of 0.1 mL HP, *China officinalis* 30cH, and biotherapeutics (*E. coli* 30cH) in piglets and reported greater weight gain and reduced stress. Higher weight gain during the weaning period of piglets (7.80 ± 0.23 kg of bodyweight) was observed in studies by Cuesta *et al.* (2010), when they administered a single oral dose (3 mL) of a homeopathic nosode to pregnant sows.

Higher feed efficiency was observed in animals fed HP_1, despite the absence of difference in bodyweight gain when compared to the control diet. Performance variables are affected by multiple factors and feeding has a positive impact on swine production (Barbosa *et al.,* 2005). Homoeopathic products tested in the present study were composed of mineral, vegetable, and animal (biological) ingredients. Homeopathic composition and action influence digestibility positively by increasing enzymes that play a role in nutrient assimilation (Mazón-Suástegui *et al.,* 2020) and antioxidant activity (Mazón-Suástegui *et al.,* 2016), which favours growth performance.

In a study by Kiefer *et al.* (2012), a 4 mL oral dose of HP (*Colibacillinum* 10^{-60}, *Mercurius dulcis* 10^{-30}, *Cinchona officinalis* 10^{-60}, *Enterococcinum* 10^{-400}, *Podophyllum peltatum* 10^{-6}, and *Colocynthis* 10^{-6}) administered to piglets had no effect on performance. However, the authors reported that HP reduced intestinal disorders by 95.2%. According to Duprat (1974), a small dose effect (secondary or reactive to the drug or substance) is attributed to actions and responses of the body because of the stimuli provided by the substance. This explains the significant effect observed only at the end of the experimental period. Another possible explanation is that effects and benefits obtained with HP depend on the symptoms, intensity of the process (acute or chronic), and intrinsic characteristics of the animal. Regarding the stage of the disease or symptoms, an acute pathological intensity induces an accelerated response, whereas in chronic diseases, the responses manifest slowly (Pires, 2005).

Animals that received an HP_2-based diet had a slight increase (P =0.099) in initial post-mortem pH in the *L. dorsi* muscle compared to the control group. Similarly, HP_1 pigs showed a higher (P =0.035) initial temperature in *L. dorsi* than those fed the control diet (Table 3).

Table 3 Meat attributes of pigs fed diets containing homeopathic products in the growing-finishing phases

Variables1)	Experimental treatments2)			SEM3)	*P*-value4)
	Control	HP$_1$	HP$_2$		
Quantitative traits of carcass					
Hot carcass weight (kg)	102.88	100.17	104.51	1.170	0.313
Carcass yield (%)	72.72	70.62	72.61	0.564	0.259
Quantity of meat (kg)	59.70	58.01	60.80	0.716	0.295
Percentage of muscle (%)	58.93	58.23	58.36	0.563	0.145
Backfat thickness (mm)	17.16	16.27	16.56	0.522	0.801
Meat quality traits					
Initial pH - 4 h	5.95^{b}	5.99^{ab}	6.14^{a}	0.037	0.099
Initial temperature - 4 h	17.26^{b}	18.04^{a}	17.75^{ab}	0.127	0.035
Final pH - 24 h	5.46	5.49	5.49	0.020	0.810
Final temperature - 24 h	6.67	7.36	6.74	0.181	0.288
Coloration	3.20	3.22	3.30	0.080	0.873
Marbling degree	2.10	2.44	2.50	0.166	0.578
Shear force (kgf/cm^2)	2.82	3.07	2.62	0.363	0.640
LLD (%)	5.12	4.89	5.33	0.336	0.879
LLT (%)	2.62	3.17	2.62	0.296	0.707
LLC (%)	23.87	26.16	24.35	0.761	0.463
L*	49.47	49.16	50.46	0.419	0.429
a*	9.05	9.36	8.90	0.260	0.780
b*	7.34	7.47	7.27	0.192	0.922

[a,b] Average values followed by different lowercase letters in the row differ according to Student's *t*-test at the 10% probability level

1) Initial pH: pH of muscle 4 hours post-slaughter, Initial temperature: temperature of muscle 4 hours post-slaughter, Final pH: pH of meat 24 hours post-slaughter, Final temperature: temperature of meat 24 hours post-slaughter, LLD: liquid loss by dripping, LLT: liquid loss by thawing, LLC: liquid loss by cooking, L*: luminosity, a*: red-green component, b*: yellow-blue component

[2] Control diet (CD), without homeopathic products), CD + HP$_1$ (Figotonus and Sanoplus, with 1 g/kg diet), or CD + HP$_2$ (Figotonus and Sanoplus, with 2 g/kg diet)

[3] SEM: standard error of mean

[4] Effect of experimental diets

In terms of meat qualitative parameters, animals fed 2 g HP/kg (HP$_2$) had a higher initial pH in *L. dorsi* than the control. However, this number was within standard levels (≥ 6.0), according to Bridi & Silva (2009). Pre-slaughter stress, including transportation, can increase body and muscle temperature, and muscle glycogen consumption, which can reduce acid lactic concentration in the muscle and increase pH (Terlouw, 2005).

By stimulating the immune system, HP reduces stress, promotes animal welfare, and maintains homeostasis in the body (Filippsen *et al.,* 2011), which can be observed in the results of pH and temperature in the *L. dorsi* after 24 h. Gomide *et al*. (2013) reported that controlling pH and temperature during the muscle transformation into meat is a crucial factor for meat quality. Although differences in temperature and initial pH in *L. dorsi* were found between control group and pigs fed HP, carcass characteristics and meat quality were not affected by HP treatments. The temperature at the beginning of rigor mortis has a direct influence on biochemical processes that occur in the muscle and has a considerable effect on the carcass and meat (Moura *et al.,* 2015).

Although most of the HP used in this study was composed of plant-based matter with some antioxidants, these did not contribute to the meat quality. Lima (2018) tested HP (3 g of Sanoplus/kg diet and 3 g Figotonus/kg diet) in diets for growing-finishing pigs and observed an effect on marbling degree, percentage of muscle, and the amount of meat. The discrepancy in the results may be because of differences in the composition and level of addition of HP in the two studies. Antioxidants from HP can contribute to meat quality parameters, similar to plant extracts (Shah *et al*., 2014). However, the low relative phenol concentration of natural ingredients of HP used in this study was probably not sufficient to affect meat composition. No treatment effect was observed ($P > 0.1$) on plasma metabolites concentrations, particularly glucose and urea (Table 4).

Table 4 Concentration of plasma metabolites of pigs fed diets containing homeopathic products in the growing-finishing phases

Variables	Experimental treatments[1]			EPM[2]	*P*-value[3]
	Control	HP_1	HP_2		
Growing I (30.77 to 52.26 kg)					
Glucose (mg/dL)	88.51	88.74	88.63	0.110	0.714
Urea (mg/dL)	19.28	17.84	18.13	0.432	0.293
Growing II (52.26 to 69.15 kg)					
Glucose (mg/dL)	88.94	88.73	88.64	0.095	0.497
Urea (mg/dL)	17.06	16.23	18.05	0.653	0.531
Finishing I (69.15 to 95.51 kg)					
Glucose (mg/dL)	88.75	88.90	88.66	0.090	0.617
Urea (mg/dL)	16.94	16.26	18.38	0.715	0.533
Finishing II (95.51 to 144.13 kg)					
Glucose (mg/dL)	88.56	88.56	88.49	0.048	0.834
Urea (mg/dL)	14.69	15.18	16.22	0.541	0.490

[1] Control diet (CD), without homeopathic products; CD + HP_1 (Figotonus and Sanoplus, with 1 g/kg diet); CD + HP_2 (Figotonus and Sanoplus, with 2 g/kg diet)
[2] SEM: Standard error of the mean
[3] Effect of experimental diets

In the current study, animals fed HP did not show changes in blood glucose and urea concentration, which is assessed by the level of protein in the diet and by renal function (Murray, 2013). Figotonus is used to treat liver malfunction and liver overload processes regardless of the origin (feed, drug, or toxin). The urea concentration in animals that received HP ranged from 15.42 to 51.42 mg/dL, which can be considered a normal concentration in pigs (Friendship *et al.,* 1984; Friendship *et al.,* 1992). Although growth rate differed between treatments in the finishing I phase, the urea concentration did not change between treatments in either phase because feed intake, and hence protein content, was similar.

As glucose is the main energy source for several metabolic processes, changes in its blood concentration may indicate metabolic issues or the use of glucose for other purposes (e.g., disease or health challenge) (González & Silva, 2006; Murray, 2013). Blood glucose concentrations observed in the present study ranged from 72 to 150 mg/dL and concur with those previously reported for pigs (Friendship *et al*., 1984; Friendship *et al*., 1992). Plasma metabolite concentrations agree with those reported by Lima (2018), who also did not observe differences when the animals were fed HP. However, HP-fed pigs may show changes in plasma metabolites because of homeopathic complex composition (Mazón-Suástegui *et al.,* 2016), interactions with other additives or ingredients, as well as factors related to management and overall health status of the animals.

Conclusions

Based on the results of the present study, adding 1 g HP/kg diet enhanced performance of finishing pigs without any negative effects on meat traits and plasma metabolites. Future studies are needed to elucidate the mechanisms of action of homeopathic products in swine diets.

Authors' contributions

All the authors contributed equally and commented on the early and final version of the manuscript.

Conflict of interest declaration

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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