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# Growth Performance and Pork Quality of Finishing Pigs Fed Diet Supplemented with Sacha Inchi Oil and Herbal Plants

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## ABSTRACT

**The study aimed to evaluate the effects of dietary soybean oil (SO) substitution with Sacha inchi oil (SIO) supplemented with herbal plants (HP, *Bidens pilosa*, *Angelica sinensis*, and *Ramulus cinnamomi*) on growth performance, carcass characteristics, and pork quality parameters. A total of 144 Duroc × (Landrace × Yorkshire) crossbred pigs (63.1 ± 0.4 kg) were randomly allocated to one of the three dietary treatments: a basal diet containing 2% SO without HP (CONT), a basal diet containing 1% SO, 1% SIO and 1% HP (TRT1), and a basal diet containing 2% SIO and 1% HP (TRT2). Each treatment includes 4 replicate pens containing 12 pigs, balanced by sex and body weight. The experiment lasted for 70 days. The results show no effects of the dietary treatments on average daily gain, average daily feed intake, and feed efficiency. Likewise, there were no differences in carcass moisture losses, lean percentage, pH, and colors between the dietary treatments. The pigs fed the SIO diets with HP had lower backfat thickness (p=0.02) than their counterparts fed the SO diet. In pork, a significant decrease in lipid and cholesterol, and an increase in polyunsaturated fatty acids (PUFA), especially omega-3 and omega-6, were found (p<0.01) in the SIO groups when compared to the control one. The PUFA percentage increased linearly with the levels of SIO. In conclusion, replacing SO with SIO associated with HP did not affect animal performance but produced a leaner carcass and upgraded pork quality.**

*Keywords: fattening pigs; growth performance; herbal plants; meat quality; Sacha inchi oil*

## INTRODUCTION

Literature data show that dietary fat influences the fatty acid composition of pork (Hanczakowska *et al.,* 2015; Świątkiewicz *et al.,* 2016). Vegetable oils, including canola oil, flaxseed oil, palm oil, sesame oil, soybean oil (SO), and sunflower oil, often contain high health-beneficial polyunsaturated fatty acids (PUFA). Several previous studies revealed that the increased intake of PUFA has beneficial impacts on human health, e.g. improvement of immune function, brain development, and cardiovascular disease prevention (Ma *et al.,* 2016; Tien *et al.,* 2019).

In Viet Nam, Sacha inchi (*Plukenetia volubilis* L.) is known as Sacha peanut or mountain peanut. This new medicinal plant is recognized by the Vietnam Ministry of Agriculture and Rural Development (MARD, 2019) as a super herbal plant (HP) in Vietnam because of its high PUFA content and antioxidant capacity (Tien *et al.,* 2019). The $\alpha$-linolenic acid (ALA) level of Sacha inchi oil (SIO) is comparable to that of flaxseed oil (about 47%) and approximately six-fold higher than that of SO (Fanali *et al.,* 2011). In human nutrition, SIO has been proposed for the functional food as well as pharmaceutical and cosmetic industries (Wang *et al.,* 2018; Cárdenas *et al.,* 2021). The SIO dietary supplementation improved animal weight gain and feed efficiency (Nájera *et al.,* 2018), decreased fat and cholesterol content in meat (Ordoñez *et al.,* 2019), and increased long-chain PUFA biosynthesis (Lima *et al.,* 2019). However, animal-derived meat products with enriched n-3 PUFA concentration are more susceptible to oxidative damage (Nguyen *et al.,* 2018), reducing the shelf life periods of meat products (Amaral *et al.,* 2018). Thereby, enriching PUFA-rich diets with antioxidant substances, including phytogenic, enhances the oxidative stability of animal products (Kalakuntla *et al.,* 2017; Kishawy *et al.,* 2019).

More than 4000 phytotherapeutic herbal plant species are widely cultivated and distributed in Vietnam (Oanh *et al.,* 2021), but most have not yet been evaluated in animal production. A lot of phytochemicals in herbal plants show antioxidant activity. They are also of interest when they are reputed to stabilize the physiological digestion of animals, thanks to antimicrobial activities, allowing to promote growth rate, improve gut health, and consequently enhance meat quality (Valenzuela-Grijalva *et al.*, 2017; Lillehoj *et al.*, 2018; Oanh *et al.*, 2021). *Ramulus cinnamomi* (*Cinnamomum cassia*) has shown antimicrobial and growth-promoting effects, cholesterol reduction and antioxidant capabilities, and improvement of animal product quality (Sang-Oh *et al.*, 2013; Luo *et al.*, 2020; Oanh *et al.*, 2021). *Bidens pilosa* compounds have exhibited strong antimicrobial and antioxidant activities (Falowo *et al.*, 2019), antidiarrheic action in pigs (González & Ly, 2001), and gut microbiota modulation in poultry (Chang *et al.*, 2016). *Angelica sinensis* has presented many biological activities, including anti-inflammatory, immunomodulatory, neuroprotective, anti-hepatotoxic, and antioxidant activities (Wu *et al.*, 2019; Hou *et al.*, 2021).

In a previous study, Oanh *et al.* (2022) reported that broilers fed a basal diet supplemented with 2% SIO and 1% powder mixture of cinnamon and star anise enhanced meat quality. Especially, the n-3 PUFA content in meat was approximately four-fold higher than that of broilers fed a basal diet supplemented with 2% SO. The diet containing plant-derived n-3 PUFA-rich sources supplemented with natural antioxidant substances positively generated animal meat enriched with n-3 PUFA with a longer shelf life and improved sensory quality (Oanh *et al.*, 2022). To our knowledge, research on dietary supplementation of SIO and HP in pig diets remains limited. Therefore, this study was carried out to investigate the impacts of replacing dietary SO with SIO supplemented with herbal plants (HP, *B. pilosa*, *A. sinensis*, and *R. cinnamomi*) mixture in the pig diet on growth parameters, physical quality, and fatty acid profile of pork during the fattening period.

## MATERIALS AND METHODS

### Ethical Approval

The research protocol was approved by the Ethics Committees on Animal Experiments, Vietnam National University of Agriculture (VNUA), Hanoi, Vietnam (Code number: VNUA - 2021/05).

### Preparation of Herbal Plants, Oils, and Feed Materials

*A. sinensis* (dried roots) and *R. cinnamomi* (dried twigs of *C. cassia*), which were cultivated and harvested annually according to the recommendation of a national standard process, were purchased from a local herb market (Hoa Binh Province, Vietnam). *B. pilosa* (aerial parts), a species of plant that grows wild, was harvested directly from a natural field during the summer bloom period (Hai Duong Province, Vietnam), then they were dried under the sun (28-33 °C) for 4 to 5 days. The dried herbal plants were separately ground into powder and proportionally mixed as an HP mixture containing 70% *B. pilosa*, 20% A. *sinensis*, and 10% *R. cinnamomi* before being incorporated into the experimental diets. The HP ratio (70:20:10) was chosen from availability, biological activities, and traditional experiences. The polyphenol and flavonoid concentrations of the HP were 5.02 mg GAE/g and 10.2 mg QUE/g DM, respectively, and they were determined at the Department of Chemistry, Faculty of Natural Resources and Environment, VNUA, Hanoi, Vietnam.

Soybean oil and SIO used in the experiment were purchased from a local oil firm (Quang Ninh, Vietnam). The SO consisted of 33% total saturated fatty acids (SFA) and 67% total unsaturated fatty acids (UFA), including 2.07% n-3 PUFA and 29.9% n-6 PUFA. The SIO contained 8.83% SFA and 91.17% UFA, including 38.5% n-3 PUFA and 39.4% n-6 PUFA.

The main feed materials, including maize, rice bran, soybean meal, fish meal, and other ingredients, were purchased and formulated by a local feed company in Vietnam.

### Animals and Experimental Design

This experiment was carried out from October to December 2022 at the experimental farm of the Faculty of Animal Science, VNUA, Hanoi, Vietnam. The experiment was performed on 144 pigs, including 72 barrows and 72 females (age:110 days old; breed: Duroc × (Landrace × Yorkshire); live body weight (BW): 63.1 ± 0.4 kg). Pigs were allocated to one of the three diet groups of 4 blocks according to sex and initial BW. The 48 animals in each group were divided into 4 replicate pens of 12 pigs each. Diet group 1 (CONT) was fed with a basal diet supplemented with 2% SO without an additional 1% HP; diet group 2 (TRT1) and group 3 (TRT2) were based on the CONT where, respectively, half or the whole of SO was replaced with SIO, and with additional 1% HP. Pigs were housed in the same experimental conditions. Each pen (3 m × 5 m) was equipped with an automatic feeding system and two automatic water nipples. Pigs were housed in the same conditions (temperature: 26-30 °C, relative humidity: 65%-85%) over the entire experimental period. Water and feed were provided for *ad libitum* consumption throughout the experiment. The experiment lasted for 70 days. Diets were formulated and mixed to meet the nutrient requirements recommended by the National Research Council (NRC, 2012) for fattening pigs. The feed ingredients and nutrient values of experimental diets are shown in Table 1. Nutritional compositions of the diets were determined in the Central Laboratory at the Faculty of Animal Science, VNUA, Hanoi, Vietnam.

### Measurements, Sampling, and Chemical Analysis

**Growth performance.** At the beginning and at the end of the experiment, the animals were individually weighed using an electronic scale of 300 kg with an accuracy of 0.01 kg. The amount of offered feed and residuals were recorded daily on a pen basis. Average daily feed intake (ADFI, kg/pig/day), average daily gain (ADG, g/pig/day), and gain:feed ratio (G:F) were computed and estimated for each pen and diet group.

**Carcass traits.** At the end of the experiment, forty-eight pigs (2 barrows and 2 females per pen x 4 pens/diet x 3 diets) were randomly chosen and slaughtered

Table 1. Ingredients and chemical composition of the experimental diets

| Variables | Treatments | | |
|---|---|---|---|
| | CONT | TRT1 | TRT2 |
| Ingredients (g, as-fed basis) | | | |
| Corn | 380 | 380 | 380 |
| Soybean meal | 92.0 | 92.0 | 92.0 |
| Fish meal | 20.0 | 20.0 | 20.0 |
| Rice bran | 250 | 250 | 250 |
| Wheat bran | 200 | 200 | 200 |
| Limestone | 15.0 | 15.0 | 15.0 |
| Vitamin-mineral premix[1] | 5.00 | 5.00 | 5.00 |
| NaCl | 10.0 | 10.0 | 10.0 |
| L-lysine HCl, 98.5% | 5.00 | 5.00 | 5.00 |
| DL-Methionine, 98% | 3.00 | 3.00 | 3.00 |
| Soybean oil | 20 | 10 | - |
| Sacha inchi oil | - | 10 | 20 |
| Medicinal plants (HP) | - | 10 | 10 |
| Analyzed composition (% DM) | | | |
| Dry matter | 88.7 | 89.1 | 89.4 |
| Crude protein | 16.1 | 16.3 | 16.4 |
| Ether extract | 7.95 | 7.88 | 7.87 |
| Crude ash | 7.52 | 7.58 | 7.60 |
| Crude fiber | 5.11 | 5.22 | 5.25 |
| Calcium | 1.24 | 1.22 | 1.27 |
| Total phosphorus | 0.95 | 0.91 | 0.90 |
| Metabolizable energy[2] (MJ/kg DM) | 14.7 | 14.5 | 14.4 |
| Lysine[3] | 1.10 | 1.08 | 1.09 |
| Methionine[3] | 0.50 | 0.46 | 0.48 |

Note: [1]Provided in 1 kg: CuSO4, 250-300 mg; FeSO4, 150-200 mg; ZnSO4, 250-300 mg; MnSO4, 150-200 mg; Biotin, 8 mg; digestive enzymes, 100 g; Coarse sand, 2%; Sufficient carrier for 1000 g; Moisture, 10%.
[2]Calculated ME value.
[3]Nutrient data were estimated data.

by electrical head-only stunning followed by exsanguination. The slaughter process was performed in compliance with the protocol of slaughter for estimating carcass compositions of pigs from Vietnamese Standard as described by Oanh *et al.* (2019). Warm carcass weight (kg), carcass weight (kg), killing-out percentage (%), dressing percentage (%), backfat thickness (mm), and lean percentage (%) were determined as described by Oanh *et al.* (2021).

The *Longissimus thoracis* muscles (LTM) at the 13-14$^{th}$ rib were sampled from the left side of each carcass immediately after slaughtering. Three subsamples of LTM (about 200 g) were taken, separately weighed and put in tight plastic bags. Then, one of the subsamples was stored at 4 °C for physical quality assessment at 24 h post-mortem. Other ones were then kept at -20 °C for analyzing chemical composition, cholesterol content, and fatty acid composition.

**Physical quality of pork.** pH values were determined at 45 min and 24 h post-mortem using a portable pH (pH-STAR, Germany). Other parameters of LTM were determined at 24 h after slaughtering. Meat color CIE Lab values (L*: lightness; a*: redness and b*: yellowness) were measured using the model CR-410 Chroma Meter (Minolta, Japan) as previously described by Choi *et al.* (2014). Drip loss and cooking loss, and shear forces were determined as described previously (Oanh *et al.*, 2019). The physical quality parameters of pork were measured at the Department of Animal Breeding and Genetics, Faculty of Animal Science, VNUA, Hanoi, Vietnam.

**Chemical composition of pork.** The chemical composition of LTM samples, including dry matter, crude protein, lipid, and total ash content, were analyzed following the method of the Association of Official Analytical Chemists (AOAC, 1990). The cholesterol content was analyzed by using a Shimadzu GCMS-QP2010 gas chromatography-mass spectrometry (Shimadzu, Kyoto, Japan) as previously described (Derewiaka & Obiedziński, 2010). The fatty acid profile was measured using Agilent 6890 plus gas chromatography equipped with a flame ionization detector (Agilent Technologies, USA) SP-2560 capillary GC column according to the previously described steps (Dinh *et al.*, 2019). The chemical composition and fatty acid profile of pork were determined in the Central Laboratory of Food Science and Technology, Faculty of Animal Science, VNUA, Hanoi, Vietnam.

## Statistical Analysis

The studied data were analyzed using the PROC MIXED procedure of SAS software (version 9.4, SAS Institute Inc., Cary, NC, USA). The statistical model consisted of the diets (n=3) as fixed effects and the blocks (n=4) as random effects. Pen was used as the experimental unit for the performance data, and individual pigs as the experimental unit for carcass traits and meat quality. The multiple comparisons of least squares means were performed according to Tukey adjustment. P values less than 0.05 were considered statistically significant, and p values ranging from 0.05 to 0.10 were considered a trend.

## RESULTS

### Pig Growth Variables

The experimental pigs were in good health without visible signs of disease during the study period. The initial and final live BW were not significantly different between diet groups. Moreover, dietary SO replacement with SIO, supplemented with HP, did not induce significant variations in ADG, ADFI, and G: F (Table 2).

### Carcass Traits of Pigs

A decrease in backfat thickness was observed in pigs fed the diets containing SIO and HP powder (15.8 and 15.9 mm) when compared to those fed the control diet (18.7 mm) (p=0.02). In contrast, the slaughter weight, warm and carcass weights and their percentages were not significantly affected by the treatments (Table 3).

### Physical Quality of Pork

The diets did not change meat pH values at 45 min (ranging from 6.31 to 6.39) and 24 h post-mortem (ranging from 5.51 to 5.53). The diets did not influence the physical quality traits of LTM at 24 h after slaughtering, including drip loss, cooking loss, and meat color values (L*, a*, and b*) (Table 4).

### Chemical Composition and Fatty Acid Profile of Pork

The experimental pigs had lower contents of lipid and cholesterol in LTM ($p \le 0.01$) (Table 5), while dry matter and crude protein tended to decrease ($p=0.06$). In this study, the type of diets significantly affected ($p<0.01$) the fatty acid profile of LTM (Table 6). A decrease in SFA and an increase in UFA was observed in LTM from pigs offered diets supplemented with SIO. In particular, the PUFA percentage in LTM was significantly increased in the experimental groups. Pigs fed the diet containing 2% SIO had markedly higher n-3 PUFA (1.60%) and n-6 PUFA (15.6%) proportions than those fed the CONT diet (0.26% and 7.17% respectively). A decrease in the n-6/n-3 PUFA ratio was observed in pigs fed SIO containing diets ($p<0.01$).

## DISCUSSION

Substituting dietary SO with SIO did not alter the measured growth performance, including ADG, ADFI, and G:F, which is consistent with previous reports when changing plant-derived PUFA-rich oil supplementation in pig diets (Corino *et al.*, 2014; Huang *et al.*, 2020; Souza *et al.*, 2020). Oanh *et al.* (2021) indicated that pig diets containing SO and supplemented with 2, 4, and 6% herbal plant powder (60% *B. pilosa*, 30% *Urena*

Table 2. Performance parameters of finishing pigs fed diet supplemented with Sacha inchi oil and herbal plant powder

| Variables | Treatments | | | SEM | p-value |
|---|---|---|---|---|---|
| | CONT | TRT1 | TRT2 | | |
| Number of animals | 48 | 48 | 48 | | |
| Initial live body weight, kg | 63.18 | 63.10 | 63.04 | 0.77 | 0.99 |
| Final live body weight, kg | 112.3 | 112.1 | 113.3 | 1.33 | 0.78 |
| Average daily gain, g/pig/day | 703.6 | 699.7 | 718.5 | 23.5 | 0.84 |
| Average daily feed intake, kg/day | 2.23 | 2.17 | 2.25 | 0.07 | 0.69 |
| Grain:Feed | 0.318 | 0.323 | 0.320 | 0.01 | 0.89 |

Note: SEM= standard error of the mean; CONT= a diet containing 2% soybean oil (SO) without herbal plants (HP); TRT1= a diet containing 1% SO and 1% Sacha inchi oil (SIO), and 1% HP; TRT2= a diet containing 2% SIO and 1% HP.

Table 3. Carcass quality traits of finishing pigs fed diet supplemented with Sacha inchi oil and herbal plant powder

| Variables | Treatments | | | SEM | p-value |
|---|---|---|---|---|---|
| | CONT | TRT1 | TRT2 | | |
| Number of animals | 16 | 16 | 16 | | |
| Slaughtered weight, kg | 112.3 | 112.4 | 113.3 | 1.97 | 0.90 |
| Warm carcass weight, kg | 90.0 | 90.3 | 91.2 | 1.74 | 0.84 |
| Carcass weight, kg | 79.1 | 79.6 | 80.1 | 1.55 | 0.89 |
| Killing-out percentage, % | 80.2 | 80.4 | 80.6 | 0.32 | 0.66 |
| Dressing percentage, % | 70.5 | 70.8 | 70.8 | 0.37 | 0.82 |
| Backfat thickness, mm | 18.7$^{a}$ | 15.8$^{b}$ | 15.9$^{b}$ | 0.75 | 0.02 |
| Lean percentage, % | 61.2 | 62.7 | 62.6 | 0.90 | 0.44 |

Note: SEM= standard error of the mean; CONT= a diet containing 2% soybean oil (SO) without herbal plants (HP); TRT1= a diet containing 1% SO and 1% Sacha inchi oil (SIO), and 1% HP; TRT2= a diet containing 2% SIO and 1% HP. Mean in the same row with different superscripts differ significantly ($p<0.05$).

Table 4. Technological quality of pork in finishing pigs fed diet supplemented with Sacha inchi oil and herbal plant powder

| Variables | Treatments | | | SEM | p-value |
|---|---|---|---|---|---|
| | CONT | TRT1 | TRT2 | | |
| Number of animals | 16 | 16 | 16 | | |
| pH at 45 min | 6.34 | 6.39 | 6.31 | 0.04 | 0.26 |
| pH at 24 h | 5.53 | 5.51 | 5.53 | 0.02 | 0.74 |
| Drip loss at 24 h, % | 1.26 | 1.15 | 1.20 | 0.20 | 0.93 |
| Cooking loss at 24 h, % | 26.1 | 27.0 | 26.8 | 1.19 | 0.86 |
| Lightness at 24 h | 54.1 | 55.4 | 55.4 | 1.33 | 0.68 |
| Redness at 24 h | 12.3 | 13.1 | 13.3 | 0.36 | 0.17 |
| Yellowness at 24 h | 6.29 | 6.16 | 6.07 | 0.32 | 0.89 |

Note: SEM= standard error of the mean; CONT= a diet containing 2% soybean oil (SO) without herbal plants (HP); TRT1= a diet containing 1% SO and 1% Sacha inchi oil (SIO), and 1% HP; TRT2= a diet containing 2% SIO and 1% HP.

Table 5. Chemical composition of pork in finishing pigs fed diet supplemented with Sacha inchi oil and herbal plant powder

| Variables | Treatments | | | SEM | p-value |
|---|---|---|---|---|---|
| | CONT | TRT1 | TRT2 | | |
| Number of animals | 16 | 16 | 16 | | |
| Dry matter, % | 28.2 | 27.5 | 27.1 | 0.35 | 0.06 |
| Crude protein, % | 24.9 | 24.3 | 24.3 | 0.24 | 0.06 |
| Lipid, % | 2.50[a] | 2.36[a] | 1.85[b] | 0.21 | 0.01 |
| Total ash, % | 1.17 | 1.14 | 1.13 | 0.02 | 0.25 |
| Cholesterol content, mg/100g | 528[a] | 472[b] | 409[c] | 9.01 | <0.01 |

Note: SEM= standard error of the mean; CONT= a diet containing 2% soybean oil (SO) without herbal plants (HP); TRT1= a diet containing 1% SO and 1% Sacha inchi oil (SIO), and 1% HP; TRT2= a diet containing 2% SIO and 1% HP. Mean in the same row with different superscripts differ significantly ($p<0.05$).

Table 6. Fatty acids composition of pork in finishing pigs fed diet supplemented with Sacha inchi oil and herbal plant powder

| Variables | Treatments | | | SEM | p-value |
|---|---|---|---|---|---|
| | CONT | TRT1 | TRT2 | | |
| Number of animals | 16 | 16 | 16 | | |
| Saturated fatty acids (SFA, %) | 44.6[a] | 41.8[b] | 39.0[c] | 0.48 | <0.01 |
| Unsaturated fatty acids (UFA, %) | 55.5[c] | 58.2[b] | 61.0[a] | 0.47 | <0.01 |
| Monounsaturated fatty acids (MUFA, %) | 48.5[a] | 45.7[ab] | 43.9[b] | 0.86 | <0.01 |
| Polyunsaturated fatty acids (PUFA, %) | 6.93[c] | 12.5[b] | 17.2[a] | 1.29 | <0.01 |
| Omega-6 fatty acids, % | 7.17[b] | 11.8[ab] | 15.6[a] | 1.21 | <0.01 |
| Omega-3 fatty acids, % | 0.26[c] | 0.73[b] | 1.60[a] | 0.07 | <0.01 |
| Omega-6: Omega-3 ratio | 28.2[a] | 15.9[b] | 9.91[c] | 0.45 | <0.01 |

Note: SEM= standard error of the mean; CONT= a diet containing 2% soybean oil (SO) without herbal plants (HP); TRT1= a diet containing 1% SO and 1% Sacha inchi oil (SIO), and 1% HP; TRT2= a diet containing 2% SIO and 1% HP. Mean in the same row with different superscripts differ significantly ($p<0.05$).

*lotata,* and 10% *R. cinnamon*) had no effects on growing-finishing pig performance. In addition, Oanh *et al.* (2022) demonstrated that no significant differences were found for ADG, ADFI, and FCR in broiler chickens fed a diet supplemented with 2% SIO and 1% medicinal plant powder (cinnamon and star anise). However, Li *et al.* (2013) revealed that broilers fed a diet supplemented with A. *sinensis* showed improved FCR, and enhanced immune systems compared with animals fed a control diet.

The carcass characteristics, including killing-out, dressing, and lean percentage, did not differ between the experimental diets in this study. In a previous study, Hanczakowska *et al.* (2015) reported that substituting SO with rapeseed oil in a pig diet did not significantly affect carcass characteristics. However, in the present study, the backfat thickness of pork was lower in pigs fed diets with SIO and HP than in those fed a diet with SO. Recent findings regarding dietary supplementation alone or combined with various herb sources decreased carcass backfat thickness in pigs (Ahmed *et al.*, 2016; Luo *et al.*, 2020; Oanh *et al.*, 2021). Considering that the diets were iso-energetic and iso-nitrogenous, this could be due to high flavonoid concentration in natural herbal plants modulating host lipid metabolism by stimulating fatty acid β-oxidation and reducing lipogenesis, thereby reducing backfat thickness production (Wang & Liu, 2014; Oanh *et al.*, 2021).

In the current study, no significant differences in the physical quality parameters of pork among the diet groups were observed. This is consistent with a recent study that the replacement of dietary SO with rapeseed oil and supplemented or not with a nature herb mixture (sage, nettle lemon balm, and coneflower) did not change physical quality parameters, including pH value, water holding capacity, and surface colors of pork (Hanczakowska *et al.*, 2015). Similarly, Oanh *et al.* (2022) reported that substituting dietary SO with SIO and supplemented or not with herbal plant powder had no adverse effects on pH value, drip loss, cooking loss, and surface colors of broiler meat.

The SIO and HP addition in pig diets lowered the lipid and cholesterol content in LTM meat. Gorriti *et al.* (2010) showed that rats consuming SIO had decreased total cholesterol content compared to those fed a control diet. Ordoñez *et al.* (2019) also demonstrated that guinea pigs fed a diet with Sacha inchi pressed cake had unchanged meat dry matter and protein content but had lower fat and cholesterol contents in meat when compared to their counterparts fed a control diet. Oanh *et al.* (2021) also reported a lower lipid concentration in LTM from pigs fed a diet supplemented with medicinal plants (*B. pilosa*, *Urena lobata*, and *R. cinnamomi*) powder. Chirinos *et al.* (2015) revealed that n-3 PUFA-rich plant oils had high phytosterols that are worthy for human health by inhibiting cholesterol absorption. The content of phytosterols in SO is lower than that in SIO (58 vs 201 mg/kg, respectively) (Normén *et al.*, 2007). Furthermore, dietary supplementation with cinnamon showed hypocholesterolemia effects due to the diminished cholesterol synthesis in animal meat (Ciftci *et al.*, 2010). Therefore, in the present study, the lower cholesterol concentration in LTM meat could be due to the combined influence of the phytosterol content of SIO and HP.

Enrichment of pork with PUFA, especially n-3 and n-6 PUFA, enhances meat quality for the consumer and improves human health. In this work, substituting dietary SO with SIO and supplementing the diets with HP significantly increased the health-beneficial fatty acid contents in the LTM, especially higher n-3 PUFA and n-6 PUFA contents and lower n-6/n-3 PUFA ratio in the LTM meat. These results align with recent reports on substituting SO with PUFA-rich vegetable oils in animal diets (Mirshekar *et al.*, 2014; Leikus *et al.*, 2018; Oanh *et al.*, 2022). The increased content of n-3 and n-6 PUFA in the LTM of pigs fed SIO could be the direct and quick absorption of ALA from the diets in the digestive tract (Mirshekar *et al.*, 2015). As a result, SIO could replace totally other PUFA-rich vegetable oils for producing pork rich in n-3 PUFA with health-promoting properties.

## CONCLUSION

The results of this study indicate that partial or total replacement of SO by SIO and supplementing diet with HP in finishing pig diets decreased significantly backfat thickness, lipid, and cholesterol contents. The contents of n-3, n-6 PUFA, and total PUFA increased linearly with increased SIO levels. Moreover, animal growth performance, most carcass traits, and pork physical quality parameters were not significantly different between the diets. Further investigations are needed to determine SIO and HP feeding levels to produce optimal PUFA as well as long-chain PUFA in pork.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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