British Poultry Science

ISSN: 0007-1668 (Print) 1466-1799 (Online) Journal homepage: www.tandfonline.com/journals/cbps20

Sacha inchi (*Plukenetia volubilis* L.) oil inclusion in slow-growing broiler diets: impacts on performance, serum biochemistry, carcass, meat quality and fatty acid profile

O. Nguyen Cong, J.-L. Hornick & D. V. Nguyen

To cite this article: O. Nguyen Cong, J.-L. Hornick & D. V. Nguyen (06 Mar 2026): Sacha inchi (*Plukenetia volubilis* L.) oil inclusion in slow-growing broiler diets: impacts on performance, serum biochemistry, carcass, meat quality and fatty acid profile, British Poultry Science, DOI: 10.1080/00071668.2026.2625883

To link to this article: https://doi.org/10.1080/00071668.2026.2625883

Published online: 06 Mar 2026.

BRITISH POULTRY SCIENCE
https://doi.org/10.1080/00071668.2026.2625883

Taylor & Francis
Taylor & Francis Group

Sacha inchi (*Plukenetia volubilis* L.) oil inclusion in slow-growing broiler diets: impacts on performance, serum biochemistry, carcass, meat quality and fatty acid profile

O. Nguyen Cong [a], J.-L. Hornick [b] and D. V. Nguyen [a,c]

[a]Faculty of Animal Science, Vietnam National University of Agriculture, Hanoi, Vietnam; [b]Faculty of Veterinary Medicine, University of Liège, Liège, Belgium; [c]School of Environmental and Rural Science, University of New England, Armidale, Australia

ABSTRACT

1. The objective of this trial was to examine the effect of Sacha inchi oil (SIO), extracted from local nut sources common to the Amazon region, in broiler diets. The oil was substituted for soybean oil (SBO) within diets of slow-growing broilers and the effects on growth performance, carcass traits, serum biochemistry, objective meat quality and meat fatty acid profile were assessed.
2. A total of 400, mixed sex, 56 d old, crossbred Ho × Luong Phuong broilers were randomly allocated to one of four experimental diets: a control diet (CON) containing 4.5% SBO and three experimental diets with SIO at substitution levels of 33.3% (SI1), 66.7% (SI2) and 100% (SI3) instead of SBO for a feeding period of 56 days. Each diet was replicated in four replicated pens of 25 birds, comprising two pens of males and two pens of females.
3. Growth variables were recorded every two weeks. Blood samples were collected *via* puncture of the brachial vein one day prior to the completion of the experiment to determine serum biochemical indices. At the end of the study, four birds per pen were humanely slaughtered to evaluate carcass traits and breast samples were collected for assessments of meat technological quality and fatty acid profile.
4. The inclusion of SIO increased the proportion of *n*-3 PUFA, lowered the *n*-6/n-3 PUFA ratio and cholesterol content in breast muscle and reduced serum triglyceride and low-density lipoprotein levels, without detrimental effects on growth, carcass traits or meat quality variables.
5. The results demonstrated that SIO is a promising alternative lipid source for improving the nutritional value of poultry meat without adversely affecting productive performance or carcass characteristics.

ARTICLE HISTORY
Received 25 August 2025
Accepted 21 January 2026

KEYWORDS
Performance; oil; breast muscle; fatty acids

Introduction

Poultry production is the second-largest contributor to total meat production in Vietnam after pig production, with slow-growing indigenous chicken breeds comprising over 80% of the national flock (Birhanu et al. 2021). Chicken and its products are a dietary staple, consumed by 94.7% of households (Phuong et al. 2014). In recent years, increases in household incomes and population growth have increased the demand for local broiler meat (Dai et al. 2022). Vietnamese consumers show a strong preference for slow-growing indigenous chickens and their crossbreeds (*e.g.*, Ho × Luong Phuong) because these birds produce meat with a firmer texture, more pronounced flavour and lower fat content compared with fast-growing, commercial broilers. These characteristics align closely with traditional Vietnamese culinary expectations, particularly for dishes that emphasise firm, flavourful meat, such as boiled chicken commonly served during festive occasions. Demand is increasing for nutritionally superior chicken, particularly those which are higher in omega-3 polyunsaturated fatty acids (*n*-3 PUFA) and lower in cholesterol (Oanh et al. 2022). Consequently, slow-growing local broilers command a market price approximately four times higher than that of fast-growing, commercial breeds (Birhanu et al. 2021).

Chicken meat is typically considered low in *n*-3 PUFA, but levels can be enhanced through dietary modification (Kanakri et al. 2017). Additionally, supplementing broilers can increase deposition of *n*-3 PUFA in meat and derived products (Alagawany et al. 2019, 2022). Higher dietary consumption of *n*-3 PUFA has been linked to reduced risk of various human health conditions, including cardiovascular disorders (Alagawany et al. 2019; Nguyen et al. 2018; Wang et al. 2025). Primary sources of *n*-3 PUFA comprise fish, fish oil, seafood, marine algae and certain plant-based oils (*e.g.*, linseed, chia seed and rapeseed), which can be incorporated into animal feed to enrich meat and other edible products with *n*-3 PUFA (Nguyen et al. 2018; Wang et al. 2025). However, while fish and seafood oils are rich sources of *n*-3 PUFA, their inclusion in poultry diets may adversely impact sensory characteristics, such as a fishy odour and taste, reducing consumer acceptability (Alagawany et al. 2019; Zamora et al. 2025). Therefore, there are recommendations using plant-based oils rich in PUFA as alternatives to fish oil in poultry nutrition (Oanh et al. 2022).

Sacha inchi (*Plukenetia volubilis* L.), known as the Inca nut or Sacha peanut, is a species indigenous to the Peruvian Amazon. It is taxonomically classified within

CONTACT D. V. Nguyen Don.Nguyen@une.edu.au School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia

the Euphorbia-ceae family, which comprises approximately 300 genera and 7500 species (Cárdenas et al. 2021). It is cultivated at elevations between 200 and 2000 m above sea level, with its growth largely influenced by the geoclimatic conditions of these environments (Mai et al. 2020). It is grown in Asian countries such as Thailand, China and Vietnam, as well as throughout Central and South America, where it serves as both a nutritional resource and as a driver of economic development (Cárdenas et al. 2021; Mai et al. 2020). Its fruit is star-shaped, measuring 2–4 cm in diameter, and is characterised by an expanded central region with compressed, star-like lobes. As the nut matures, its colour transitions from green to blackish-brown and the extracted oil correspondingly exhibits a darker colouration (Mai et al. 2020).

In Vietnam, Sacha inchi is recognised as a medical plant by the Ministry of Agriculture and Rural Development (MARD 2019). Due to its high nutritional value, it is considered as a 'super herbal plant' in Vietnam (Tien et al. 2019). In addition to its high PUFA content (78.0–84.2%), Sacha inchi seeds are a rich source of essential amino acids, high-quality proteins, phytosterols, tocopherols, phenolic compounds and minerals (Goyal et al. 2022; Lu et al. 2025; Torres Sánchez et al. 2023). Furthermore, extracted sacha inchi oil (SIO) is rich in bioactive compounds including PUFA, tocopherols and sterols (Lu et al. 2025; Mai et al. 2020). It contains a high *n*-3 PUFA proportion especially alpha-linolenic acid (ALA, C18:3n-3), followed by linoleic acid (LA, C18:2n-6) (Oanh et al. 2022; Zamora et al. 2025). Consequently, the *n*-6/n-3 PUFA ratio of SIO, ranging from 0.81 to 1.12 (Goyal et al. 2022), is close to the optimal 1:1 ratio recommended for human health (D'angelo et al. 2020). Consumption of SIO has been associated with multiple benefits in both humans and animals. In human, consuming SIO has been linked to reduced total serum cholesterol, decreased low-density lipoprotein cholesterol, lowered blood pressure (Silalahi 2022) and significant improvements in cognitive functions related to attention and memory (Cárdenas et al. 2021).

In broiler production, SIO supplementation has shown promising effects on broiler performance. Nájera et al. (2018) demonstrated that feed conversion ratio (FCR) and average daily gain (ADG) were improved in broilers fed a diet containing 6% SIO for 49 d compared to those fed the control diet without SIO. Similarly, Lucas et al. (2011) reported that adding 5% SIO to broiler diets improved immune function and growth performance. In a recent study, dietary replacement of 2% soybean oil (SBO) with SIO combined with 1% herbal plant powder decreased cholesterol concentration and increased the *n*-3 PUFA content in slow-growing broilers (Oanh et al. 2022). González Sepúlveda et al. (2024) demonstrated that including up to 9% SIO in the diet of Ross 308 broilers did not cause adverse influences on their ADG and FCR, compared to equivalent levels of palm and chicken oil. However, research evaluating the impacts of SIO supplementation and its replacement levels on broiler growth performance, meat quality and fatty acid (FA) level remains limited. Therefore, the objective of the present study was to evaluate the impacts of dietary SIO inclusion on growth performance, FCR, blood parameters, carcass characteristics, meat quality and FA profile in low-growing broilers.

Materials and methods

Ethical statement

This experiment was carried out from October 2023 to February 2024 at the research station of the Faculty of Animal Science, the Vietnam National University of Agriculture (VNUA), Hanoi, Vietnam. The experimental protocols and methodology were approved by the VNUA Animal Ethics Committees (Approval No. VNUA- 2023/03).

Animals, experimental design and diets

A total of 400 crossbred Ho ×Luong Phuong (H × LP) broilers (1751 ± 15.8 g live weight, 56 days old, mixed sex) were used in this study. These birds were selected from 600, one-day-old chicks, which were raised under uniform feeding conditions at the same experimental station until 56 d of age. The birds were fitted with individually numbered plastic leg rings and randomly allocated into four treatment groups. Each treatment group comprised 100 birds (50 males and 50 females) housed in four replicates (3 × 4 m) each containing 25 birds as two separate sex pens. Each pen was fitted with two automatic drinkers and two plastic feeders. Each pens served as an experimental unit. The ambient temperature in the animal house ranged from 20°C to 28°C throughout the experiment. All birds were vaccinated against Newcastle, Gumboro and Marek's diseases prior to the experiment.

The four isonitrogenous and isocaloric experimental diets included CON (a basal diet containing 4.5% SBO (as-fed basis), SI1 (a basal diet containing 3.0% SBO and 1.5% SIO), SI2 (a basal diet containing 1.5% SBO and 3.0% SIO) and SI3 (a basal diet containing 4.5% SIO). All diets were formulated in accordance with the nutrient ranges recommended in the Cobb 500 Lineage Handbook (Cobb-Vantress 2018). Final formulations were adjusted to meet local nutritional recommendations for slow-growing broiler strains. The diet ingredients (as-fed basis) are presented in Table 1.

All solid components were ground into powder through a 2 mm screen and thoroughly mixed to form a feed mash, which was blended daily with the treatment oils. The designated feed mixtures were divided into two equal portions and provided at 07:30 and 13:30 each day during the trial. The feeding period lasted for 56 d, with a one-week adaptation period. The animals had *ad libitum* access to feed and water throughout the trial, with daily feed adjustments based on residual feed weight.

Sampling and measurements

The diet samples were collected separately on d 1, 28 and 56 of the experiment and stored at −20°C until analysis feed composition and FA profile. After the trial finished, the three timepoint samples were pooled and ground through a 1 mm screen. The dietary composition including dry matter, crude protein, ash, crude fibre and ether extract was analysed following the methods of AOAC (1990). Currently, no metabolisable energy (ME) value for SIO has been officially published in the poultry nutrition literature, so determining the ME of SIO was beyond the scope of the present study. However, the ME values of commonly used vegetable oils (*e.g.*, canola, soybean, sunflower, corn and palm oils) fall within a narrow range of 36.7–37.0 MJ/kg (Shoaib et al. 2023). Therefore, an average ME was adopted based on

Table 1. Ingredients and nutrient composition of experimental diets.

Ingredients (%, as-fed basis)	CON	SI1	SI2	SI3
Maize	50	50	50	50
Rice bran	25	25	25	25
Soybean meal	15	15	15	15
Fish meal	2.0	2.0	2.0	2.0
Limestone	2.4	2.4	2.4	2.4
L-lysine HCl 98.5%	0.3	0.3	0.3	0.3
DL-methionine 98%	0.1	0.1	0.1	0.1
Premix[1]	0.5	0.5	0.5	0.5
Salt	0.2	0.2	0.2	0.2
Soybean oil (SBO)	4.5	3.0	1.5	0
Sacha inchi oil (SIO)	0	1.5	3.0	4.5
Total	100	100	100	100
Nutritional compositions (% DM)				
Dry matter	88.9	89.1	89.1	89.0
Crude protein	16.9	16.8	16.7	16.7
Ash	6.74	6.75	6.86	6.96
Crude fibre	3.90	3.90	3.92	3.91
Ether extract	9.50	9.50	9.50	9.50
Metabolisable energy[2] (MJ/kg)	13.50	13.50	13.50	13.50

Note: CON: diet containing 4.5% SBO, SI1: diet containing 3.0% SBO and 1.5% SIO, SI2: diet containing 1.5% SBO and 3.0% SIO, SI3: diet containing 4.5% SIO. [1]Premix in 1 kg: 250-300 mg CuSO4; 250–300 mg ZnSO4; 150–200 mg MnSO4 and FeSO4; 150–200 mg biotin; 8 mg enzyme; 100 g coarse sand; 2% carrier for 1 kg; 10% moisture. [2]Metabolisable energy: estimated values.

these oils (approximately 36.82 MJ/kg) as an estimate for SIO when calculating the dietary values. The ME of the diets was estimated using the EC 152/2009 annex VII formulae of European Union (2009). Diet composition is displayed in Table 1.

Growth performance

To measure live body weight (LBW), the birds were weighed individually in the morning before feeding at the beginning, fortnightly and the end of the experiment using an electronic scale (maximum capacity 5 kg; accuracy 0.01 g; Vibra Shinko DJ5000TW, Japan) to determine ADG for each period and overall. The amount of feed provided and left-over was weighed at the end of each day to determine daily feed intake (FI) and calculate FCR for each period and for the entire experiment.

Blood serum analysis

One day before the end of the experiment, 32 broiler chickens (eight birds per treatment group, two birds per pen) were randomly selected for the blood collection *via* puncture of the brachial vein using sterile needles and syringes. The samples were collected separately in 2 ml serum tubes. The serum tubes were then centrifuged at 6000 rpm for 10 min to obtain purified serum. The purified serum was analysed using the Cobas 8000 modular analyser series (Roche Diagnostics, Basel, Switzerland) for the following biochemical parameters; aspartate aminotransferase (AST), alanine aminotransferase (ALT), total bilirubin, total proteins, albumin, urea, creatinine, triglycerides, total cholesterol (TCH), high-density lipoprotein (HDL) and low-density lipoprotein (LDL).

Carcass measurements

Upon completion of the trial, after 8 h of feed deprivation, 64 birds (16 birds per treatment) were randomly selected, four from each pen, for slaughter. Slaughtering was performed according to the Vietnamese standard procedures (Doan et al. 2011). Carcass and cut-up traits were recorded and weighed including live body, carcass, skin-on breast muscle, skin-on and bone-in thigh, heart, gizzard, liver, spleen, lung, abdominal fat and shank weight. Carcass and cut yield were calculated relative to the LBW prior to slaughter. Thigh meat (skinless, deboned and with visible fat removed) and skinless breast meat samples were collected from the carcasses immediately *post-mortem*. For each breast muscle, two similar subsamples were taken. One was stored at 4°C for evaluating technological quality traits after 24 hours *post-mortem*. And the other was kept at −80°C for later analysis of chemical composition and FA profile.

Meat quality

The pH of raw breast muscles at 15 min (pH15) and 24 h (pH24) was determined using a portable pH meter (pH-STAR, Matthäus, Germany) calibrated with standard buffer solutions of pH 4.0 and 7.0 before each measurement. The colorimetric parameters of raw breast muscle surface including lightness (L*), redness (a*) and yellowness (b*) were recorded at 24 h *post-mortem* using a portable colorimeter (CR-410, Konica Minolta, Osaka, Japan; illuminant D65) according to the method outlined by Semjon et al. (2020). Drip and cooking losses from breast samples at 24 h *post-mortem* were measured following the method of Oanh et al. (2022). Six cylinder subsamples (1.27 cm in diameter) were collected from the centre of each breast sample, aligned longitudinally with the muscle fibres, for shear force (SF) evaluation. A Warner-Bratzler blade mounted on a Mecmesin basic force gauge 500N (BFG 500N) (PPT Group UK Ltd, West Sussex, UK) was used and the average SF values (expressed as N) were obtained from six measurements on each breast sample.

Nutritional composition, fatty acid profile and cholesterol content of breast muscle

Prior to analysis, frozen breast subsamples were thawed at 4°C for 8 h. The nutrient composition of breast muscle was

analysed for dry matter, crude protein, ether extract, ash and crude fibre (AOAC 1990). Cholesterol concentration was determined using gas chromatography-mass spectrometry (GC-MS) following the procedure outlined by Derewiaka and Obiedziński (2010). A modified method of Bligh and Dyer (1959) were used to solvent-extract total lipids in 1 g of pooled feed and breast muscle, as described in detail by Nguyen et al. (2017a) and Nguyen et al. (2017b). Total lipids were extracted overnight in a single-phase solution of CH_2Cl_2:MeOH:Milli-Q H_2O (1:2:0.8 v/v), followed by phase separation with CH_2Cl_2:saline Milli-Q H_2O (1:1 v/v). The lipids were recovered by rotary evaporation at 40°C and aliquots were subsequently methylated to fatty acid methyl esters (FAME) by heating with dichloromethane (DCM), methanol and hydrochloric acid. This was extracted into an organic solvent, washed with water and centrifuged to separate phases. The organic layer was collected through repeated extractions, concentrated under a nitrogen gas stream and dissolved in DCM containing 0.1 ml of an internal standard (19:0 FAME). The FAME profiles were analysed using an Agilent 6890 plus gas chromatography system (Agilent Technologies, Palo Alto, CA, U.S.A.) equipped with a flame ionised detector and a SP®-2560 capillary column. Fatty acid proportions were expressed as percentages of the total peak area:

$$\text{FA}(\%) = (\text{area of individual FA}/\text{total FA area}) \times 100$$

Individual FA that were not detected in all samples were not reported.

Statistical analysis

Experimental data were analysed using the PROC MIXED procedure of the statistical analysis system software (SAS, v 9.4; SAS Institute, Cary, NC, U.S.A.). The statistical model included dietary treatments as fixed effects and pens and birds as random effects. For feed data, the pen was considered the experimental unit. For live weight, serum biochemical properties, carcass traits, meat quality, chemical composition and fatty acid composition, the individual animal considered the experimental unit. Multiple comparisons of means was performed using Tukey's adjustment. Orthogonal polynomial contrasts were applied to evaluate linear and quadratic effects of increasing dietary SIO levels. Results were reported as least squared means with their corresponding standard errors of the mean (SEM). Statistical significance was set at $p < 0.05$, with trends indicated when $0.05 < P < 0.10$.

Results

Fat profiles

The FA profile of the supplemental oil sources and experimental diets are shown in Table 2. The proportion of *n*-3 PUFA in SIO was approximately 18-fold higher than that in SBO. In contrast, the *n*-6/n-3 PUFA ratio in SIO was approximately 14-fold lower than that in SBO. Linoleic acid (LA) was the predominant PUFA in SBO, whereas both LA and alpha-linolenic acid (ALA) were the predominant PUFA in SIO. Among the experimental diets, the *n*-3 PUFA percentage of the CON diet was 2.02%, which was approximately 4-, 6- and 9-fold lower than that in the SI1 (7.63%), SI2 (12.85%) and SI3 (17.53%) diets, respectively. Conversely, the *n*-6/n-3 PUFA ratio in CON (17.89) was approximately four-, six- and eight-fold higher than that in SI1 (4.88), SI2 (3.08) and SI3 (2.32), respectively. The UFA/SFA ratio increased from 2.91 in CON to 5.47 in SI3, reflecting a more favourable lipid profile in diets with higher SIO inclusion.

Table 2. Fatty acid proportions of soybean oil, Sacha inchi oil and experimental diets, expressed as % of total.

Fatty acids	SBO	SIO	CON	SI1	SI2	SI3
Saturated fatty acids (SFA)	**33.00**	**8.83**	**25.59**	**22.82**	**18.53**	**15.46**
Butanoic acid (C4:0)	nd	nd	nd	0.03	nd	nd
Caproic acid (C6:0)	nd	nd	nd	0.03	nd	0.03
Octanoic acid (C8:0)	nd	nd	nd	0.05	nd	0.04
Capric acid (C10:0)	nd	nd	nd	0.04	nd	0.03
Lauric acid (C12:0)	0.08	nd	0.09	0.13	0.08	0.11
Myristic acid (C14:0)	0.54	0.02	0.46	0.53	0.32	0.30
Pentadecanoic acid (C15:0)	0.03	nd	0.04	0.05	0.04	0.04
Palmitic acid (C16:0)	27.00	5.36	19.88	16.65	13.11	10.80
Margaric acid (C17:0)	0.09	0.09	0.10	0.11	0.11	0.11
Stearic acid (C18:0)	4.27	2.81	3.56	3.55	3.17	3.16
Arachidic acid (C20:0)	0.54	nd	0.72	0.85	0.94	nd
Behenic acid (C22:0)	0.26	0.33	0.36	0.39	0.39	0.37
Lignoceric acid (C24:0)	0.12	0.19	0.33	0.36	0.38	0.42
Unsaturated fatty acids (UFA)	**67.00**	**91.17**	**74.41**	**77.17**	**81.47**	**84.54**
Monounsaturated fatty acids (MUFA)	***34.99***	***13.24***	***36.35***	***32.30***	***28.97***	***26.35***
Palmitoleic acid (C16:1)	nd	0.06	0.25	0.27	0.24	0.24
Oleic acid (C18:1n-9)	34.82	12.81	35.82	31.69	28.35	25.64
Eicosenoic acid (C20:1)	0.17	0.36	0.27	0.34	0.39	0.44
Polyunsaturated fatty acids (PUFA)	***32.01***	***77.94***	***38.06***	***44.88***	***52.50***	***58.19***
Linoleic acid (C18:2n-6, LA)	29.92	39.34	36.01	37.22	39.61	40.63
Alpha linolenic acid (C18:3n-3, ALA)	2.05	38.54	1.69	7.26	12.51	17.24
Eicosadienoic acid (C20:2n-6)	0.02	0.05	0.02	0.03	0.04	0.04
Eicosatrienoic acid (C20:3n-6)	nd	nd	0.02	nd	nd	nd
Eicosapentaenoic acid (C20:5n-3, EPA)	0.02	nd	0.09	0.11	0.09	0.08
Docosahexaenoic acid (C22:6n-3, DHA)	nd	nd	0.24	0.25	0.25	0.21
n-3 PUFA	2.07	38.54	2.02	7.63	12.85	17.53
n-6 PUFA	29.94	39.39	36.05	37.25	39.65	40.66
n-9 PUFA	34.82	12.81	35.82	31.69	28.35	25.68
n-6/n-3 PUFA	14.46	1.02	17.89	4.88	3.08	2.32
UFA/SFA	2.03	10.33	2.91	3.38	4.40	5.47

Growth performance

The experimental broilers remained in good health and showed no visible signs of disease throughout the 56 d trial period. Bird growth performance was shown in Table 3. There were no significant differences ($p > 0.05$) in LBW and ADG among the dietary treatments at any of the time points (d 1, 14, 28, 42 and 56) and throughout the experimental period. Broiler FI was significantly influenced by dietary treatment only during the initial two weeks, where those fed the CON diet had higher FI (101.4 g/bird/d) compared to the other treatments (linear, $p = 0.030$). However, no differences in FI were observed during later growth phases (d 15–28, 29–42 and 43–56) or over the entire period (d 1–56; $p > 0.05$). There was a similarity in FCR among treatments across all growth phases, except for the 15–28 d period, during which an increased trend for FCR with inclusions of 3.0% and 4.5% SIO was observed (linear, $p = 0.051$). Overall, replacement of SBO with SIO at different inclusion levels had a minimal impact on growth performance parameters in broiler chickens over the 56-day experimental period.

Dietary supplementation with SIO significantly influenced some serum biochemical parameters of the slow-growing broilers (Table 4). In particular, a significant reduction was observed in ALT (total and linear, $p < 0.01$), where birds fed SI2 and SI3 diets had lower levels compared to the CON diet. Serum creatinine and triglyceride levels were significantly reduced in SIO containing diets compared to the control diet ($p < 0.05$). Additionally, a significant decrease in LDL was observed (total and linear, $p < 0.05$) with increasing SIO levels. These results suggested that dietary SIO positively modulated lipid metabolism markers, particularly by lowering ALT, creatinine, triglyceride and LDL concentrations in broiler chickens. No significant effects were found for AST, total protein, albumin, urea, total cholesterol and HDL ($p > 0.05$).

Carcass, meat, organs and tissues

Carcass traits and organ yields are presented in Table 5. No significant effects ($p > 0.05$) were observed among treatments for LBW, carcass weight or the weights of

Table 3. Production performance of broilers fed different oil supplemented diets.

		Treatment			P-value		
Item	CON	SI1	SI2	SEM	T	L	Q
Day 1	1746	1749	1756	83.5	0.989	0.781	0.882
Day 14	2093	2094	2090	138.1	0.996	0.830	0.903
Day 28	2417	2405	2382	164.3	0.905	0.548	0.740
Day 42	2730	2717	2681	196.8	0.856	0.631	0.589
Day 56	2935	2929	2899	198.4	0.923	0.734	0.685
Days 1–14	24.8	24.6	23.9	4.15	0.940	0.538	0.987
Days 15–28	23.2	22.3	20.8	2.00	0.421	0.302	0.273
Days 29–42	22.4	22.3	21.4	2.61	0.805	0.922	0.476
Days 43–56	14.7	15.1	15.6	1.60	0.928	0.645	0.652
Days 1–56	21.3	21.1	20.4	2.09	0.758	0.535	0.542
Days 1–14	101.4[a]	97.3[b]	89.7[c]	7.15	0.105	0.030	0.481
Days 15–28	104.8	107.9	107.9	8.91	0.635	0.238	0.911
Days 29–42	127.7	123.4	119.8	13.27	0.884	0.874	0.484
Days 43–56	108.0	115.8	115.2	10.74	0.611	0.258	0.665
Days 1–56	110.5	111.1	108.1	7.67	0.638	0.908	0.478
Days 1–14	4.3	4.1	4.0	0.42	0.407	0.193	0.292
Days 15–28	4.5	4.8	5.2	0.24	0.192	0.051	0.482
Days 29–42	5.7	5.6	5.6	0.22	0.949	0.731	0.705
Days 43–56	7.4	7.6	7.6	0.41	0.927	0.544	0.955
Days 1–56	5.5	5.5	5.6	0.16	0.767	0.314	0.993

Note: CON: basal diet containing 4.5% soybean oil (SBO), SI1: basal diet containing 3.0% SBO and 1.5% Sacha inchi oil (SIO), SI2: basal diet containing 1.5% SBO and 3.0% SIO, SI3: basal diet containing 4.5% SIO; SEM: Standard error of the mean; T: total effect; L: linear, Q: Quadratic. Values with different letters in the same row demonstrate statistical differences ($p < 0.05$).

Table 4. Serum parameters of slow-growing broilers fed supplemented diets.

		Treatment					P-value	
Item	CON	SI1	SI2	SI3	SEM	T	L	Q
AST (U/L)	221.8	216.1	216.7	227.0	6.78	0.379	0.466	0.125
ALT (U/L)	22.7[a]	16.7[ab]	13.3[b]	13.7[b]	1.61	0.008	0.002	0.074
Total bilirubin (μmol/L)	0.8	0.6	0.6	0.8	0.09	0.177	0.960	0.037
Total protein (g/L)	48.2	43.8	48.2	47.9	2.07	0.093	0.536	0.136
Albumin (g/L)	15.2	14.5	14.1	16.1	1.16	0.509	0.636	0.191
Urea (mmol/L)	0.4	0.5	0.4	0.5	0.05	0.683	0.565	0.961
Creatinine μmol/L	31.2[a]	26.5[b]	26.4[b]	26.8[b]	0.98	0.021	0.015	0.029
Triglyceride (mmol/L)	7.0[a]	3.0[b]	3.9[b]	3.8[b]	0.75	0.004	0.008	0.007
TCH (mmol/L)	3.1	2.8	2.8	2.7	0.19	0.311	0.085	0.625
HDL (mmol/L)	1.1	1.2	1.2	1.2	0.15	0.649	0.306	0.519
LDL (mmol/L)	1.6[a]	1.2[b]	1.1[b]	1.1[b]	0.17	0.022	0.009	0.079

Note: $n = 8$; CON: basal diet containing 4.5% soybean oil (SBO), SI1: basal diet containing 3.0% SBO and 1.5% Sacha inchi oil (SIO), SI2: basal diet containing 1.5% SBO and 3.0% SIO, SI3: basal diet containing 4.5% SIO. AST: Aspartate aminotransferase, ALT: Alanine aminotransferase, TCH: total cholesterol, HDL: high-density lipoprotein, LDL: low-density lipoprotein, SEM: Standard error of the mean, T: total effect, L: linear, Q: Quadratic. Values with different letters in the same row demonstrate statistical differences ($p < 0.05$).

thigh and breast. The weights of head, shank and internal organs including gizzard, heart, gall bladder, liver, spleen, lung and abdominal fat, as well as meat cuts and organ weights did not differ significantly among treatments ($p > 0.05$). Carcass yield remained stable (73.9–74.4%) and the proportions of thigh, breast and most edible cuts showed minimal variation. Overall, the inclusion of SIO in broiler diets did not significantly affect carcass traits.

Meat quality

The physical and chemical properties of broiler breast muscle are presented in Table 6. Dietary SIO had limited impact on most meat quality parameters, with the exception of cholesterol content and redness. Cholesterol in the breast muscle was significantly reduced in all SIO-supplemented groups compared to the control (total and linear, $p < 0.01$) and trend towards a quadratic response was observed ($p = 0.071$). This indicated that cholesterol reduction may not have been dose-dependent.

No significant differences were observed among treatments for initial (15 min) or ultimate (24 h) pH, dry matter, crude protein, ash and lipid contents of the meat ($p > 0.05$). The inclusion of SIO did not result in any substantial changes ($p > 0.05$) in shear force, drip or cooking losses. In terms of colorimetric parameters, lightness (L*) and yellowness (b*) of the breast muscle were unaffected by dietary treatment ($p > 0.05$). However, redness (a*) increased with SIO inclusion (total and linear, $p < 0.05$), which suggested enhanced colour intensity.

These results demonstrated that feeding SIO can beneficially modulate the cholesterol content and colour intensity of broiler meat without adversely affecting its basic objective quality properties.

Fatty acid composition of breast muscle

Dietary inclusion of SIO significantly affected the FA proportion of breast muscle in slow-growing broilers (Table 7). Total SFA percentage decreased with increasing SIO levels (total and linear, $p < 0.01$), dropping from 48.64% in the CON to 39.96% in the SI3 group. This reduction was primarily driven by a decline in palmitic ($p < 0.05$) and stearic acid (total and quadratic, $p < 0.01$), which were the dominant SFA. In contrast, the total UFA proportion increased significantly (total and linear, $p \leq 0.001$), reaching 60.04% in samples from the SI3 group, largely due to elevated levels of PUFA ($p < 0.01$).

Both LA and ALA showed marked increases with SIO inclusion (total and linear, $p \leq 0.001$), with ALA rising from 0.30% in CON to 3.75% in SI3. Similarly, the levels of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) were significantly elevated (total and linear, $p \leq 0.01$) in samples from birds receiving SIO. As a result, the *n*-3 PUFA percentage substantially increased from 0.66% in the CON broiler meat to 4.39% for SI3 while the *n*-6/n-3 PUFA ratio dropped significantly from 14.90 in CON to 4.13 in SI3 ($p < 0.01$). Conversely, there was a significant increase in the UFA/SFA ratio when the level of SIO increased in the diets (total and linear, $p \leq 0.001$).

Discussion

The results showed that feeding broilers with SIO-containing diets did not substantially impact broiler growth performance (LBW, ADG, FI or FCR) throughout the 56 d experimental period. The findings aligned with Lopes

Table 5. Carcass variables of slow-growing broilers fed diets supplemented with various levels of Sacha inchi oil.

	Treatment					P-value		
	CON	SI1	SI2	SI3	SEM	T	L	Q
Weight (g)								
Live body	2981	3013	2996	3040	210.6	0.954	0.646	0.936
Carcass	2203	2241	2226	2255	173.9	0.955	0.647	0.950
Thigh	499.6	525.2	520.9	523.4	51.84	0.733	0.416	0.531
Breast	334.0	319.3	315.1	321.2	21.02	0.861	0.564	0.529
Head	68.7	76.1	86.9	72.7	13.88	0.310	0.471	0.134
Gizzard	57.1	61.1	58.9	59.6	2.93	0.773	0.685	0.545
Heart	16.1	16.7	15.3	15.7	2.80	0.931	0.696	0.947
Gall bladder	3.2	3.4	3.5	3.1	0.36	0.879	0.867	0.457
Liver	50.1	48.5	47.1	48.1	2.75	0.784	0.436	0.541
Spleen	6.4	6.6	5.7	5.7	0.81	0.741	0.361	0.932
Lung	15.6	17.1	16.7	15.9	1.46	0.797	0.912	0.351
Abdominal fat	50.0	44.9	40.3	37.0	10.45	0.529	0.146	0.889
Shank	121.7	128.6	126.6	124.2	16.43	0.525	0.731	0.185
Yield (% of live body weight)								
Carcass	73.9	74.4	74.2	74.0	0.72	0.939	0.972	0.566
Thigh	22.5	23.3	23.3	23.2	0.69	0.552	0.319	0.316
Breast	15.4	14.3	14.2	14.2	0.59	0.424	0.168	0.398
Head	3.1	3.3	3.8	3.2	0.42	0.422	0.509	0.192
Gizzard	2.6	2.8	2.7	2.8	0.29	0.935	0.685	0.774
Heart	0.7	0.7	0.7	0.7	0.08	0.906	0.747	0.885
Gall bladder	0.1	0.1	0.2	0.1	0.02	0.845	0.894	0.481
Liver	2.3	2.2	2.2	2.1	0.10	0.737	0.334	0.592
Spleen	0.3	0.3	0.3	0.3	0.03	0.654	0.296	0.830
Lung	0.7	0.8	0.8	0.7	0.05	0.854	0.941	0.403
Abdominal fat	2.4	2.1	1.9	1.7	0.57	0.463	0.120	0.862
Shank	5.5	5.7	5.7	5.4	0.35	0.538	0.866	0.152

Note: $N = 16$; CON: basal diet containing 4.5% soybean oil (SBO), SI1: basal diet containing 3.0% SBO and 1.5% Sacha inchi oil (SIO); SI2: basal diet containing 1.5% SBO and 3.0% SIO, SI3: basal diet containing 4.5% SIO.

Table 6. Objective quality of the breast muscle of broilers fed diets supplemented with various levels of Sacha inchi oil.

		Treatment					P-value	
Item	CON	SI1	SI2	SI3	SEM	T	L	Q
Chemical property								
pH at 15 min	5.7	5.6	5.9	5.9	0.13	0.414	0.140	0.765
pH at 24 h	5.6	5.6	5.6	5.6	0.03	0.303	0.308	0.162
Dry matter (%)	27.3	27.0	27.6	27.2	0.27	0.489	0.827	0.769
Crude protein (%)	89.9	89.9	88.7	90.6	0.72	0.364	0.788	0.226
Lipid (%)	4.9	4.3	4.1	4.3	0.61	0.205	0.108	0.154
Ash (%)	4.0	4.2	4.1	4.2	0.19	0.792	0.465	0.757
Cholesterol (mg/100 g fresh sample)	486.5^{a}	438.7^{b}	436.8^{b}	420.5^{b}	7.70	0.001	0.001	0.071
Physical property								
Drip loss (%)	1.9	2.1	1.9	2.2	0.35	0.916	0.743	0.825
Cooking loss (%)	12.2	13.4	13.9	13.2	0.77	0.287	0.214	0.139
Shear force (N)	17.9	17.3	16.9	16.5	1.22	0.860	0.398	0.940
Colorimetric parameter								
L*	61.5	60.4	60.1	60.5	0.69	0.520	0.312	0.275
a*	12.1^{b}	12.7^{ab}	13.7^{a}	13.9^{a}	0.51	0.049	0.007	0.706
b*	13.1	13.2	13.0	14.2	0.53	0.336	0.183	0.315

Note: $N = 16$; CON: basal diet containing 4.5% soybean oil (SBO), SI1: basal diet containing 3.0% SBO and 1.5% Sacha inchi oil (SIO), SI2: basal diet containing 1.5% SBO and 3.0% SIO, SI3: basal diet containing 4.5% SIO; SEM: Standard error of the mean, T: total effect, L: linear, Q: quadratic, values with different letters in the same row demonstrate statistical differences ($p < 0.05$).
705.

Table 7. Fatty acid proportions in the breast muscle of slow-growing broilers fed oil supplemented diets.

		Treatment					P-value	
Fatt acids (as % total)	CON	SI1	SI2	SI3	SEM	T	L	Q
Saturated fatty acids (SFA)	**48.64^{a}**	**46.33^{ab}**	**43.63^{bc}**	**39.96^{c}**	**1.067**	**0.002**	**0.001**	**0.537**
Caproic acid (C6:0)	0.11^{a}	0.09^{ab}	0.08^{ab}	0.05^{b}	0.008	0.009	0.002	0.696
Octanoic acid (C8:0)	0.11	0.11	0.12	0.08	0.023	0.434	0.349	0.272
Capric acid (C10:0)	0.09	0.05	0.05	0.04	0.022	0.597	0.282	0.594
Lauric acid (C12:0)	0.52	0.40	0.46	0.48	0.126	0.918	0.899	0.588
Myristic acid (C14:0)	1.19^{a}	1.00^{ab}	1.01^{ab}	0.94^{b}	0.088	0.279	0.087	0.547
Pentadecanoic acid (C15:0)	0.15	0.17	0.18	0.11	0.017	0.052	0.148	0.018
Palmitic acid (C16:0)	36.1^{a}	30.1^{b}	30.9^{b}	28.2^{b}	0.668	0.001	0.001	0.038
Margaric acid (C17:0)	0.45^{a}	0.35^{a}	0.0^{ab}	0.34^{ab}	0.114	0.020	0.149	0.009
Stearic acid (C18:0)	9.32^{b}	13.5^{a}	10.2^{b}	9.13^{b}	0.518	0.001	0.125	0.001
Arachidic acid (C20:0)	0.29	0.39	0.29	0.20	0.037	0.078	0.095	0.055
Behenic acid (C22:0)	0.29^{b}	0.21^{c}	0.29^{b}	0.37^{a}	0.024	0.001	0.001	0.001
Lignoceric acid (C24:0)	nd	nd	0.05	0.03	na	na	na	na
Unsaturated fatty acids (UFA)	**51.36^{c}**	**53.67^{b}**	**56.37^{ab}**	**60.04^{a}**	**0.359**	**0.001**	**0.001**	**0.538**
MUFA	***41.48^{a}***	***40.97^{ab}***	***39.13^{b}***	***37.54^{c}***	***0.45***	***0.055***	***0.009***	***0.581***
Myristoleic acid (C14:1)	0.03	0.02	0.02	0.03	0.010	0.813	0.898	0.401
Palmitoleic acid (C16:1)	1.34^{b}	1.69^{ab}	1.72^{ab}	1.94^{a}	0.101	0.035	0.007	0.574
Trans-elaidic acid (C18:1)	0.13	0.13	0.11	0.11	0.076	0.441	0.203	0.786
Oleic acid (C18:1n-9)	38.4^{a}	37.1^{ab}	35.8^{ab}	34.5^{b}	0.379	0.045	0.007	0.991
Eicosenoic acid (C20:1)	0.37	0.41	0.44	0.39	0.011	0.255	0.341	0.101
Nervonic acid (C24:1n-9)	1.26^{ab}	1.65^{a}	1.05^{ab}	0.56^{b}	0.056	0.007	0.005	0.024
PUFA	***9.88^{d}***	***12.70^{c}***	***17.24^{b}***	***22.50^{a}***	***0.337***	***0.001***	***0.001***	***0.002***
Linoleic acid (C18:2n-6, LA)	8.98^{d}	11.02^{c}	14.22^{b}	17.76^{a}	0.344	0.001	0.001	0.050
Alpha linolenic acid (C18:*n*-3, ALA)	0.30^{d}	1.19^{c}	2.23^{b}	3.75^{a}	0.216	0.001	0.001	0.135
Beta linolenic acid (C18:3n-6)	nd	nd	nd	0.03	na	na	na	na
Eicosadienoic acid (C20:2n-6)	0.14^{a}	0.10^{b}	0.15^{a}	0.16^{a}	0.012	0.001	0.004	0.002
Eicosatrienoic acid (C20:3n-6)	0.03^{b}	0.01^{c}	0.03^{b}	0.09^{a}	0.001	0.001	0.001	0.001
Eicosapentaenoic acid (C20:5n-3, EPA)	0.06^{ab}	0.03^{b}	0.09^{ab}	0.14^{a}	0.008	0.010	0.005	0.050
Docosadienoic acid (C22:2n-6)	0.08	0.04	0.12	0.07	0.017	0.338	0.716	0.897
Docosahexaenoic acid (C22:6n-3, DHA)	0.29^{c}	0.34b^{c}	0.41^{b}	0.51^{a}	0.021	0.001	0001	0.101
n-3 PUFA	0.66^{d}	1.55^{c}	2.73^{b}	4.39^{a}	0.229	0.001	0.001	0.071
n-6 PUFA	9.23^{d}	11.16^{c}	14.51^{b}	18.11^{a}	0.343	0.001	0.001	0.028
n-9 PUFA	39.75^{a}	38.85^{ab}	36.96^{ab}	35.19^{b}	0.374	0.016	0.002	0.614
n-6/n-3 PUFA	14.90^{a}	7.32^{b}	5.74^{b}	4.13^{b}	0.519	0.001	0.001	0.007
UFA/SFA	1.06^{c}	1.16^{bc}	1.29^{b}	1.50^{a}	0.050	0.001	0.001	0.246

Note: $N = 8$; CON: basal diet containing 4.5% soybean oil (SBO), SI1: basal diet containing 3.0% SBO and 1.5% Sacha; inchi oil (SIO), SI2: basal diet containing 1.5% SBO and 3.0% SIO, SI3: basal diet containing 4.5% SIO; SEM, Standard error of the mean, T: total effect, L: linear, Q: quadratic, nd: not detected, na: not available; values with different letters in the same row demonstrate statistical differences ($p < 0.05$).

et al. (2013), who found that partially or fully replacing SBO with linseed oil (LSO) in the diet had no influence on LBW, ADG and FCR in broiler chickens. Similarly, Lucas et al. (2011) observed no significant effects on LBW and FCR in broilers fed 5% SIO compared to those receiving 5% conventional fat. A previous study (Oanh et al. 2022) demonstrated no differences in ADG, FI and FCR when 2% SBO was replaced with 2% SIO in H × LP broilers. Similar results were reported by Rahbari et al. (2025), who replaced vegetable oil with salmon oil (rich in *n*-3 PUFA) at levels of up to 3% in Ross 308 broiler diets. The similarity in growth performance was attributed to the isonitrogenous and isocaloric levels among dietary treatments. These studies involved partial or complete oil substitutions in diets with similar metabolisable energy and crude protein levels, the two most essential nutritional factors influencing growth performance (Geng et al. 2023). Other studies have reported that ALA enriched diets were linked to improved growth

and/or FCR in certain growing periods (González Sepúlveda et al. 2024; Kanakri et al. 2017). The contradiction among these studies indicated that the impact of fat on growth performance depends on the type, profile and levels of the sources, as well as the age of the chickens (Attia et al. 2020). The broilers receiving SIO had a decreased trend for FI during the initial 14 d period, which was attributed to early palatability or adaptation issues, as previously reported for PUFA-rich oils (Schumacher et al. 2022; Selim et al. 2021). Therefore, the majority of studies suggested that dietary SIO is not deleterious to broiler growth performance.

Serum biochemical parameters serve as indicators of nutrient metabolism and, in particular, immune and antioxidant status, thereby indirectly reflecting the overall health of the bird. Among these, serum levels of AST and ALT are valuable markers of organ health and are associated with the quality of the diet (Geng et al. 2023). In the current study, the lack of differences in total protein, albumin and urea contents among diets indicated that the SIO replacement did not affect the diet quality and the protein metabolic status within the body. Additionally, low serum urea content reflected optimal protein metabolism. Increasing SIO inclusion led to a reduction in serum triglyceride and LDL levels. A decrease in serum triglycerides was reported by Zamora et al. (2025) who fed laying hens with a diet containing 3% SIO for 8 weeks, compared to those fed a negative control diet. The benefits of SIO on triglyceride and LDL may have been due to its high content of non-saponifiable components, including sterols and tocopherols (Lu et al. 2025; Selim et al. 2021). These bioactive compounds facilitate the formation of HDL transporter proteins, which subsequently enhances anabolic steroid hormone levels, resulting in reduced concentrations of LDL and triglycerides (Qassim et al. 2022).

Carcass characteristics are critical indicators in poultry production because they reflect nutrient deposition in the body and enable meat yield evaluation (Aprianto et al. 2023). Srikha et al. (2024) concluded that key measures, such as dressing percentage, organ-to-LBW ratios and edible meat yield, provide valuable insights into nutrient utilisation, meat yield and quality and the overall health status of birds. This ensures high-quality products and optimisation of production systems. Factors influencing these carcass traits include LBW and the size of non-carcass components, such as head, shank, internal organs and abdominal fat (Bai et al. 2022). In the current study, dietary inclusion of SIO did not cause differences in any carcass characteristics. These findings agreed with previous studies (Oanh et al. 2022; Srikha et al. (2024), who found no impact on the carcass traits when feeding slow-growing native broilers diets containing SIO and black soldier fly larvae oil, respectively. This was attributed to the similarity in BLW in the current study, as Park et al. (2021) reported that carcass characteristics were closely related to LBW at slaughter. Meat quality is a key factor influencing both nutritional and economic value of meat products (Srikha et al. 2024). Mhlongo and Mnisi (2023) identified three indicators, including physical, biological and chemical characteristics, in determining meat quality. Together, these properties affect the overall acceptability and appeal of meat products, contributing to market demand and consumer preferences (Xie et al. 2022). Although the meat pH at 24 h *post-mortem* (5.58 – 5.60) observed in this study was slightly lower than the normal ultimate pH range for chicken breast (5.7 and 6.1 (Beauclercq et al. 2022); they were similar among treatment groups. Substitution of dietary SBO with SIO did not negatively affect meat quality properties, which indicated that SIO inclusion did not compromise the quality of meat products. In agreement with these findings, supplementation of 2% SIO in H × LP broiler diet had no influence on quality properties but significantly reduced the cholesterol content of breast meat (Ivanova et al. 2022; Selim et al. 2021) who fed broilers with diets to compare SIO with flaxseed oil and rice bran oil, respectively. The absence of dietary effects on these characteristics was attributed to the similar muscle pH values across the treatment groups in these studies, given the established significant correlation between muscle pH and these quality traits (Beauclercq et al. 2022; Mhlongo and Mnisi 2023). Choi et al. (2023) showed that the difference in pH levels at 24 h *post-mortem* could significantly affect the lightness, shear force and cooking loss of breast meat. In addition, broilers a fed diet supplemented with SIO exhibited increased muscle redness (a*) values, which was attributed to the capacity of PUFA-rich SIO to slow myoglobin oxidation (Long et al. 2020). Thus, the presence of bioactive compounds in SIO, including tocopherols and sterols, was expected to enhance the overall meat quality (Mhlongo and Mnisi 2023).

It is accepted that FA profiles of broiler meat are influenced by the dietary profile (Aprianto et al. 2023; Oanh et al. 2022; Verge-Mèrida et al. 2022). Mirshekar et al. (2021) stated that the ALA significantly increased the total *n*-3 PUFA level in broiler meat. Based on this, many studies have been conducted to modify the FA composition of meat from the diet to produce healthier animal products for human nutrition (Alagawany et al. 2022; Choi et al. 2023; Ivanova et al. 2022). In the present study, substitution of SBO with SIO produced healthier FA profiles in breast muscle. The results showed that fully replacing SBO with SIO over 56 days increased *n*-3 PUFA proportion in breast meat approximately sevenfold, while *n*-6 PUFA proportion roughly doubled. The improvement in *n*-3 PUFA content of the H × LP broilers fed 2% SIO diets was reported in a previous study (Oanh et al. 2022). Similarly, Zamora et al. (2025) demonstrated that increasing the inclusion of SIO up to 4% in hens' diets led to a higher total *n*-3 PUFA content in eggs. When adding 3.0% flaxseed oil to male Ross 308 broiler diets for 42 d, Ivanova et al. (2022) found that levels of PUFA increased drastically in both breast and thigh meat. Such increases in *n*-3 PUFA and *n*-6 PUFA were attributed to the higher concentrations of ALA and LA in SIO compared to SBO. Mirshekar et al. (2015) suggested that the increased PUFA content in broiler meat fed plant-based oil diets resulted from the rapid and direct absorption of ALA that escaped gut biohydrogenation. Another possible explanation is that the rise in PUFA levels could stem from enhanced *de-novo* synthesis of these FA (Mirshekar et al. 2021). The current findings revealed that SIO could be successfully incorporated into broiler diets to increase health-beneficial *n*-3 PUFA and balance the *n*-6/n-3 PUFA ratio in meat without detrimental impacts on health status, growth performance or meat quality.

Conclusions

This study demonstrated that the partial or entire replacement of SBO with SIO in slow-growing broiler diets improved the nutritional quality of breast meat. This was manifested as increasing *n*-3 PUFA levels such as ALA, EPA and DHA and lowering the *n*- 6/n-3 PUFA ratio and cholesterol content without compromising growth performance, carcass traits and technological meat quality. Additionally, SIO inclusion modulated selected serum biochemical markers, notably reducing triglyceride and LDL levels, which indicated a positive effect on lipid metabolism and overall health status. This suggested that SIO is a promising plant-based lipid source for producing healthier poultry meat while maintaining production efficiency.

Acknowledgments

The authors gratefully acknowledge the contributions of colleagues, project members, and undergraduate and graduate students for their support in conducting the study.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This study was funded by National Foundation for Science and Technology Development (NAFOSTED), Vietnam [08/2022/TN].

ORCID

O. Nguyen Cong http://orcid.org/0000-0001-7549-3389
J.-L. Hornick http://orcid.org/0000-0003-1831-1440
D. V. Nguyen http://orcid.org/0000-0002-4273-0672

Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

References

Alagawany, M., S. S. Elnesr, M. R. Farag, M. E. abd el-hack, A. F. Khafaga, A. E. Taha, R. Tiwari, et al. 2019. "Omega-3 and Omega-6 Fatty Acids in Poultry Nutrition: Effect on Production Performance and Health." *Animals* 9 (8): 573. https://doi.org/10.3390/ani9080573.

Alagawany, M., S. S. Elnesr, M. R. Farag, K. el-sabrout, O. Alqaisi, M. A. Awood, H. Soomro, and S. A. Abdelnour. 2022. "Nutritional Significance and Health Benefits of Omega-3, -6 and -9 Fatty Acids in Animals." *Animal Biotechnology* 33 (7): 1678–1690. https://doi.org/10.1080/10495398.2020.1869562.

Aoac. 1990. *Official Methods of Analysis*. 15th ed. Association of Official Analytical Chemists.

Aprianto, M. A., A. Kurniawati, C. Hanim, B. Ariyadi, and M. Al Anas. 2023. "Effect Supplementation of Black Soldier Fly Larvae Oil (*Hermetia Illucens* L.) Calcium Salt on Performance, Blood Biochemical Profile, Carcass Characteristic, Meat Quality and Gene Expression in Fat Metabolism Broilers." *Poultry Science* 102 (10): 102984. https://doi.org/10.1016/j.psj.2023.102984.

Attia, Y. A., M. A. al-harthi, and H. M. Abo el-maaty. 2020. "The Effects of Different Oil Sources on Performance, Digestive Enzymes, Carcass Traits, Biochemical, Immunological, Antioxidant and Morphometric Responses of Broiler Chicks." *Frontiers in Veterinary Science* 28 (7): 181. https://doi.org/10.3389/fvets.2020.00181.

Bai, H., B. Yang, Z. Dong, X. Li, Q. Song, Y. Jiang, G. Chang, and G. Chen. 2022. "Research Note: Effects of Cage and Floor Rearing Systems on Growth Performance, Carcass Traits, and Meat Quality in Small-Sized Meat Ducks." *Poultry Science* 101 (1): 101520. https://doi.org/10.1016/j.psj.2021.101520.

Beauclercq, S., S. Mignon-grasteau, A. Petit, Q. Berger, A. Lefèvre, S. Metayer-coustard, S. Tesseraud, P. Emond, C. Berri, and E. L. Bihan-duval. 2022. "A Divergent Selection on Breast Meat Ultimate pH, a Key Factor for Chicken Meat Quality, Is Associated with Different Circulating Lipid Profiles." *Frontiers in Physiology* 13:935868. https://doi.org/10.3389/fphys.2022.935868.

Birhanu, M. Y., K. Geremew, W. Esatu, W. Worku, S. Getachew, F. Unger, and T. Dessie. 2021. "Poultry Production, Marketing and Consumption in Vietnam: A Review of Literature." ILRI Research Report. access on 1 April 2025. http://cgspace.cgiar.org/server/api/core/bitstreams/6242b3b0-4263-4601-8098-33e45221d41d/content.

Bligh, E. G., and W. J. Dyer. 1959. "A Rapid Method of Total Lipid Extraction and Purification." *Canadian Journal of Biochemistry and Physiology* 37 (8): 911–917. https://doi.org/10.1139/o59-099.

Cárdenas, D. M., L. J. gómez Rave, and J. A. Soto. 2021. "Biological Activity of Sacha Inchi (*Plukenetia Volubilis Linneo*) and Potential Uses in Human Health: A Review." *Food Technology and Biotechnology* 59 (3): 253–266. https://doi.org/10.17113/ftb.59.03.21.6683.

Choi, J., B. Kong, B. C. Bowker, H. Zhuang, and W. K. Kim. 2023. "Nutritional Strategies to Improve Meat Quality and Composition in the Challenging Conditions of Broiler Production: A Review." *Animals* 13 (8): 1386. https://doi.org/10.3390/ani13081386.

Cobb-Vantress. 2018. "Broiler Performance & Nutrition Supplement. L-2114-08 EN." Arkansas, US, Cobb Vantress Inc. access on 1 April 2024. https://appec-h.com/wp-content/uploads/2023/02/Broiler-Performance-and-Nutrition-Supplement.pdf.

Dai, Q. V., M. Yabe, H. Nomura, and Y. Takahashi. 2022. "Structural Changes in Meat Consumption in Vietnam: Evidence from Household Survey Data." *Journal of Agribusiness in Developing and Emerging Economies* 13 (4): 590–612. https://doi.org/10.1108/JADEE-08-2021-0206.

d'Angelo, S., M. L. Motti, and R. Meccariello. 2020. "ω-3 and ω-6 Polyunsaturated Fatty Acids, Obesity and Cancer." *Nutrients* 12 (9): 2751. https://doi.org/10.3390/nu12092751.

Derewiaka, D., and M. Obiedziński. 2010. "Cholesterol Oxides Content in Selected Animal Products Determined by GC-MS." *European Journal of Lipid Science and Technology* 112 (10): 1130–1137. https://doi.org/10.1002/ejlt.200900238.

Doan, B. H., N. T. Mai, N. T. Son, and N. H. Dat. 2011. *Studied Parameters in the Poultry Production in Vietnam*. Hanoi, Vietnam: Agricultural Publishing House.

European Union. 2009. "Commission Regulation (EC) No 152/2009 of 27 January 2009 Laying Down the Methods of Sampling and Analysis for the Official Control of Feed." *Official Journal of the European Union* 54 (1): 2–54. access on 1 August 2024. http://data.europa.eu/eli/reg/2009/152/oj.

Geng, A. L., Q. Q. Zhang, C. Chang, H. H. Wang, Q. Chu, J. Zhang, Z. X. Yan, and H. G. Liu. 2023. "Dietary Metabolizable Energy and Crude Protein Levels Affect the Performance, Egg Quality and Biochemical Parameters of a Dual-Purpose Chicken." *Animal Biotechnology* 34 (7): 2714–2723. https://doi.org/10.1080/10495398.2022.2114001.

González Sepúlveda, C. A., Á. M. Giraldo Mejía, and E. A. Oviedo Álvarez. 2024. "Evaluation of the Inclusion of Three Oils on Productive Parameters and Carcass Characteristics in Broiler." *Revista Facultad Nacional de Agronomía Medellín* 77 (1): 10637–10649. https://doi.org/10.15446/rfnam.v77n1.107938.

Goyal, A., B. Tanwar, M. K. Sihag, and V. Sharma. 2022. "Sacha Inchi (*Plukenetia Volubilis* L.): An Emerging Source of Nutrients, Omega-3 Fatty Acid and Phytochemicals." *Food Chemistry* 373 (March): 131459. https://doi.org/10.1016/j.foodchem.2021.131459.

Ivanova, P., P. B. Petrov, V. Gerzilov, N. Keranova, Z. Petkova, O. Teneva, G. Antova, P. Hristakieva, and I. G. Penchev. 2022. "Effect of Flaxseed Oil Supplemented Diets on Growth Performance and Meat Quality Traits in Broilers." *Bulgarian Journal of Agricultural Science* 28 (1): 101–110.

Kanakri, K., J. Carragher, R. Hughes, B. Muhlhausler, and R. Gibson. 2017. "A Reduced Cost Strategy for Enriching Chicken Meat with Omega-3 Long Chain Polyunsaturated Fatty Acids Using Dietary Flaxseed Oil." *British Poultry Science* 58 (3): 283–289. https://doi.org/10.1080/00071668.2017.1293798.

Long, S., S. Liu, D. Wu, S. Mahfuz, and X. Piao. 2020. "Effects of Dietary Fatty Acids from Different Sources on Growth Performance, Meat Quality, Muscle Fatty Acid Deposition, and Antioxidant Capacity in Broilers." *Animals* 10 (3): 508. https://doi.org/10.3390/ani10030508.

Lopes, D. C. N., E. G. Xavier, V. L. Santos, F. M. Goncalves, M. A. Anciuti, V. F. B. Roll, F. A. B. D. Pino, J. O. Feijo, and A. A. S. Catalan. 2013. "Growth Performance, Carcass Traits, Meat Chemical Composition and Blood Serum Metabolites of Broiler Chicken Fed on Diets Containing Flaxseed Oil." *British Poultry Science* 54 (6): 780–788. https://doi.org/10.1080/00071668.2013.843161.

Lu, W. C., C. S. Chiu, Y. J. Chan, A. T. Mulio, and P. H. Li. 2025. "New Perspectives on Different Sacha Inchi Seed Oil Extractions and Its Applications in the Food and Cosmetic Industries." *Critical Reviews in Food Science and Nutrition* 65 (3): 475–493. https://doi.org/10.1080/10408398.2023.2276882.

Lucas, J., E. Icochea, R. Valdivia, F. Carcelén, and J. Guzmán. 2011. "Efecto del Aceite de Sacha Inchi (*Plukenetia Volubilis*) en la Dieta de Reproductoras de Pollos de Engorde sobre el Desempeño Productivo de su Progenie." *Revista de Investigaciones Veterinarias del Perú* 22 (4): 283–289. https://doi.org/10.15381/rivep.v22i4.327.

Mai, H. C., N. C. Duy, N. P. T. Nhan, and B. G. Long. 2020. "Physico-Chemical Properties of Sacha Inchi (*Plukenetia Volubilis* L.) Seed Oil from Vietnam." *Asian Journal of Chemistry* 32 (2): 2. https://doi.org/10.14233/ajchem.2020.22233.

MARD. 2019. *Decision of the Ministry of Agriculture and Rural Development (MARD) on Special Recognition of New Medicinal Plant.* 204/QD-BNN-TT. Hanoi, Vietnam: Ministry of Agriculture and Rural Development.

Mhlongo, G., and C. M. Mnisi. 2023. "Effect of Seaweed (*Ecklonia maxima*) on Apparent Nutrient Digestibility, Growth Performance and Physiological and Meat Quality Parameters in Boschveld Cockerels." *Poultry Science* 102 (2): 102361. https://doi.org/10.1016/j.psj.2022.102361.

Mirshekar, R., F. Boldaji, B. Dastar, A. Yamchi, and S. Pashaei. 2015. "Longer Consumption of Flaxseed Oil Enhances N-3 Fatty Acid Content of Chicken Meat and Expression of FADS2 Gene." *European Journal of Lipid Science and Technology* 117 (6): 810–819. https://doi.org/10.1002/ejlt.201300500.

Mirshekar, R., B. Dastar, and M. S. Shargh. 2021. "Supplementing Flaxseed Oil for Long Periods Improved Carcass Quality and Breast Fatty Acid Profile in Japanese Quail." *Animal* 15 (2): 100104. https://doi.org/10.1016/j.animal.2020.100104.

Nájera, P. R. A., H. I. V. Lara, S. E. L. Sampedro, and H. Patricio. 2018. "Evaluation of Three Levels of Sacha Inchi Oil (*Plukenetia volubilis*) in Broilers Chicken Diet." *Revista Caribeña de Ciencias Sociales* 5: 1–24. http://www.eumed.net/rev/caribe/2018/05/dieta-pollos-engorde.html.

Nguyen, D. V., A. R. Flakemore, J. R. Otto, S. W. Ives, R. W. Smith, P. D. Nichols, and A. E. O. Malau-aduli. 2017a. "Nutritional Value and Sensory Characteristics of Meat Eating Quality of Australian Prime Lambs Supplemented with Pelleted Canola and Flaxseed Oils: Fatty Acid Profiles of Muscle and Adipose Tissues." *Internal Medicine Review* 3 (3): 1–21.

Nguyen, D. V., B. S. Malau-aduli, J. Cavalieri, P. D. Nichols, and A. E. Malau-aduli. 2018. "Supplementation With Plant-Derived Oils Rich in Omega-3 Polyunsaturated Fatty Acids for Lamb Production." *Veterinary and Animal Science* 6:29–40. https://doi.org/10.1016/j.vas.2018.08.001.

Nguyen, D. V., H. L. van, N. V. Quang, B. S. Malau-aduli, P. D. Nichols, and A. E. Malau-aduli. 2017b. "Omega–3 Long-Chain Fatty Acids in the Heart, Kidney, Liver and Plasma Metabolite Profiles of Australian Prime Lambs Supplemented with Pelleted Canola and Flaxseed Oils." *Nutrients* 9 (8): 893. https://doi.org/10.3390/nu9080893.

Oanh, N. C., N. V. Don, P. K. Dang, and J.-L. Hornick. 2022. "Effects of Dietary Sacha Inchi (*Plukenetia volubilis* L.) Oil and Medicinal Plant Powder Supplementation on Growth Performance, Carcass Traits and Breast Meat Quality of Colored Broiler Chickens Raised in Vietnam." *Tropical Animal Health and Production* 54 (2): 1–9. https://doi.org/10.1007/s11250-021-02994-8.

Park, S. Y., D. S. Byeon, G. W. Kim, and H. Y. Kim. 2021. "Carcass and Retail Meat Cuts Quality Properties of Broiler Chicken Meat Based on the Slaughter Age." *Journal of Animal Science and Technology* 63 (1): 180. https://doi.org/10.5187/jast.2021.e2.

Phuong, N. V., T. H. Cuong, and M. Mergenthaler. 2014. "Effects of Socio-Economic and Demographic Variables on Meat Consumption in Vietnam." *Asian Journal of Agriculture and Rural Development* 4 (393–2016–23934): 7–22. access on 1 April 2024. https://archive.aessweb.com/index.php/5005/article/view/1115.

Qassim, A. H. A., L. K. Ban, and F. M. Alkalan. 2022. "Effect of Using Avocado and Chia Oil and Their Mixture in Meat Broiler Diets on Some Physiological and Microbial Characteristics of Lood Plasma." *NeuroQuantology* 20 (4): 233–243. https://doi.org/10.14704/nq.2022.20.4.NQ22114.

Rahbari, S., A. Salehi, S. D. Sharifi, and S. Honarbakhsh. 2025. "Dietary Omega-3 Fatty Acids Affect the Growth Performance of Broiler Chickens Reared at High Stocking Density." *Poultry Science* 104 (1): 104468. https://doi.org/10.1016/j.psj.2024.104468.

Schumacher, M., H. Delcurto-wyffels, J. Thomson, and J. Boles. 2022. "Fat Deposition and Fat Effects on Meat Quality - A Review." *Animals* 12 (12): 12. https://doi.org/10.3390/ani12121550.

Selim, S., E. Hussein, N. S. Abdel-megeid, S. J. Melebary, M. S. al-harbi, and A. A. Aleh. 2021. "Growth Performance, Antioxidant Activity, Immune Status, Meat Quality, Liver Fat Content and Liver Histomorphology of Broiler Chickens Fed Rice Bran Oil." *Animals* 11 (12): 3410. https://doi.org/10.3390/ani11123410.

Semjon, B., D. Marcinčáková, B. Koréneková, M. Bartkovský, J. Nagy, P. Turek, and S. Marcinčák. 2020. "Multiple Factorial Analysis of Physicochemical and Organoleptic Properties of Breast and Thigh Meat of Broilers Fed a Diet Supplemented with Humic Substances." *Poultry Science* 99 (3): 1750–1760. https://doi.org/10.1016/j.psj.2019.11.012.

Shoaib, M., S. A. Bhatti, S. Ashraf, M. M. A. Hamid, M. M. Javed, S. Amir, N. Aslam, et al. 2023. "Fat Digestion and Metabolism: Effect of Different Fat Sources and Fat Mobilisers in Broilers' Diet on Growth Performance and Physiological Parameters–A Review." *Annals of Animal Science* 23 (3): 641–661. https://doi.org/10.2478/aoas-2022-0083.

Silalahi, M. 2022. "Sacha Inchi (*Plukenetia Volubilis* L.): Its Potential as Foodstuff and Traditional Medicine." *GSC Biological and Pharmaceutical Sciences* 18 (3): 213–218. https://doi.org/10.30574/gscbps.2022.18.3.0117.

Srikha, T., P. Pootthachaya, W. Puangsap, N. Pintaphrom, N. Somparn, W. Boonkum, A. Cherdthong, B. Tengjaroenkul, and S. Wongtangtintharn. 2024. "Effects of Black Soldier Fly Larvae Oil on Growth Performance, Blood Biochemical Parameters, Carcass Quality and Metabolomics Profile of Breast Muscle of Thai Native Chickens." *Animals* 14 (21): 3098. https://doi.org/10.3390/ani14213098.

Tien, V. D., V. H. Thai, N. T. Tram, and Y. Larondelle. 2019. "Evaluation and Characterization of Nutrient Value of Sacha Inchi Seeds Grown in Vietnam and the Residual Pressed Cake." The 12th Regional Conference on Chemical Engineering, Ho Chi Minh City, Vietnam, 139–141.

Torres Sánchez, E. G., B. Hernández-ledesma, and L. F. Gutiérrez. 2023. "Sacha Inchi Oil Press-Cake: Physicochemical Characteristics, Food-Related Applications and Biological Activity." *Food Reviews International* 39 (1): 148–159. https://doi.org/10.1080/87559129.2021.1900231.

Verge-mérida, G., D. Solà-oriol, A. Tres, M. Verdú, G. Farré, C. Garcés-narro, and A. C. Barroeta. 2022. "Olive Pomace Oil and Acid Oil as Alternative Fat Sources in Growing-Finishing Broiler Chicken Diets." *Poultry Science* 101 (10): 102079. https://doi.org/10.1016/j.psj.2022.102079.

Wang, Y., G. Wu, Y. Wang, A. Rehman, L. Yu, H. Zhang, Q. Jin, H. A. R. Suleria, and X. Wang. 2025. "Recent Developments, Challenges and Prospects of Dietary Omega-3 PUFA-Fortified Foods: Focusing on Their Effects on Cardiovascular Diseases." *Food Chemistry* 470:142498. https://doi.org/10.1016/j.foodchem.2024.142498.

Xie, Q., K. Xie, J. Yi, Z. Song, H. Zhang, and X. He. 2022. "The Effects of Magnolol Supplementation on Growth Performance, Meat Quality, Oxidative Capacity and Intestinal Microbiota in Broilers." *Poultry Science* 101 (4): 101722. https://doi.org/10.1016/j.psj.2022.101722.

Zamora, S. J., M. A. Arista, P. A. Fernández, L. Valle, H. Frias, E. Salvador-tasayco, Y. D. Leiva, et al. 2025. "Effect of Sacha Inchi Oil (Plukenetia Volubilis) on Productive Performance, Egg Quality and Blood Biochemistry of Laying Hens." *Journal of Applied Poultry Research* 34 (2): 100537. https://doi.org/10.1016/j.japr.2025.100537.