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# Crude and acid oils from olive pomace as alternative fat sources in growing-finishing pigs

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ABSTRACT

The inclusion of crude and acid oils from olive pomace can lead to more unsaturated meat products and, especially in the case of olive pomace acid oil, achieve a more economically and environmentally sustainable swine production. The objective of this trial was to study the effect of dietary supplementation with crude and acid oils from olive pomace, which are rich in monounsaturated fatty acids (**FAs**) and have differing free FA content, on growth performance, digestibility, carcass parameters and FA profile of *Longissimus* muscle (**LM**) and backfat in growing-finishing pigs compared to the conventional crude palm oil. A total of 224 male and female pigs [(Landrace × Large White) × Duroc] were randomly distributed into 48 pens according to initial BW (58.7 ± 9.71 kg, mean ± SD) and sex. Four experimental treatments were randomly assigned ($n$ = 12 pens/treatment; 4–5 pigs/pen) for the growing (0–42 days) and finishing (40–62 days) phases. Treatments consisted of a basal diet supplemented with 5% (as-fed basis) palm oil (**PO**), olive pomace oil (**O**), olive pomace acid oil (**OA**) or a mixture (**M**) of PO and OA at 50/50. No differences were found in the growth performance results between PO, O or M, but animals fed OA showed a lower gain to feed ratio than M ($P$ = 0.008). No differences were found in apparent ileal digestibility among treatments, however, animals fed O and OA showed the highest values of total FA apparent total tract digestibility, while those fed PO had the lowest values, and M had intermediate values ($P$ < 0.001). No differences were observed in carcass composition among treatments. In relation to backfat and the LM FA profile, O and OA treatments led to a higher unsaturated FA to saturated FA ratio and a lower content in saturated FA than PO. Moreover, O showed a higher intramuscular fat (**IMF**) content in LM than PO ($P$ = 0.037). It is concluded that olive pomace oil is an interesting alternative fat source that can be included at 5% in growing-finishing pig diets, leading to meat products with more IMF, rich in monounsaturated FA, reaching high FA digestibility values and good pig performance parameters. Alternatively, olive pomace acid oil blended with conventional palm oil did not negatively impact fat utilisation nor performance. Including these fat by-products reduced feeding costs and led to a more efficient and environmentally sustainable production.



## Implications

The use of crude and acid oils from olive pomace can increase the ratio of monounsaturated to saturated fatty acids in meat products. Moreover, the inclusion of olive pomace acid oil, by-product from the refining industry, in swine diets results in a more efficient and environmentally sustainable swine production. Our results indicate that crude and acid oils from olive pomace may be suitable alternative fat sources to commonly used saturated fats, such as palm oil. Moreover, including olive pomace oil may be a good nutritional strategy to both increase intramuscular fat content in *Longissimus* muscle and achieve good performance.

## Introduction

The inclusion of fats and oils in monogastric animal feeding is a widespread practice due to their high energetic input and their supply of essential fatty acids (**FAs**), which contribute to efficient production. Moreover, dietary fat modifies lipid quality, and the nutritional and organoleptic properties of meat, which is of partic-

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ular interest in high-fat content crossbred pigs, such as those finished with Duroc lines.

Crude olive pomace oil is obtained by extraction from olive pomace, and olive pomace acid oil is a by-product generated from the soapstocks obtained during the chemical refining of the crude olive pomace oil. The FA profile of these two oils is rich in monounsaturated FA, particularly in oleic acid (C18:1 n-9; 55–83%), which consumption has been widely linked to many beneficial health traits (Isabel et al., 2004; Foscolou et al., 2018). The growing trend towards healthy meat products makes olive oil and its by-products interesting for use in pig feeding, as they can lead to high quality meat products, such as loin or cured ham with a lower saturated fat content and enriched in oleic acid. Olive pomace acid oil is rich in free FA (50–70%). Although it is well known that the degree of saturation, chain length and positional distribution in the triglycerides of the dietary FA affect their digestibility (Cho and Kim, 2012; Vilarrasa et al., 2015), there is some controversy in relation to the effects of dietary free FA content. Thus, while some authors have reported negative effects of free FA on digestible energy, which can impair performance (Powles et al., 1993; Wiseman et al., 1998; Jørgensen and Fernández, 2000), other authors have observed no effects on either digestible energy, FA digestibility or the performance of pigs (DeRouchey et al., 2004; Rojas-Cano et al., 2014; Vilarrasa et al., 2015) when including sources rich in free FA in pigs' diets.

Current animal production is expected to be efficient and environmentally sustainable. In this context, using food-chain fat by-products as alternative fat sources in swine feeding could be a good opportunity to reduce both the feeding costs and the environmental impact. Therefore, the aim of the present study was to research the potential of using crude and acid oils from olive pomace, rich in monounsaturated FA and differing in free FA content, as fat sources in growing-finishing pig diets. This was assessed by studying the effect of dietary supplementation with crude olive pomace oil and olive pomace acid oil on growth performance, digestibility, carcass parameters and the FA profile of the L*ongissimus* muscle (**LM**) and backfat in growing-finishing pigs compared to conventional crude palm oil as a conventional dietary fat.

## Material and methods

### *Experimental fats*

Crude olive pomace oil and olive pomace acid oil were supplied by RIOSA S.A. (Jaén, Spain), and crude palm oil was provided by bonÀrea Agrupa (Guissona, Spain). All samples were analysed in duplicate for FA composition, lipid class composition, moisture, impurities and unsaponifiable matter as described by Varona et al. (2021a).

### *Experimental design and diets*

The study was performed at the animal experimental facilities of bonÀrea AGRUPA (Nial farm, Guissona, Lleida, Spain). All animal housing and husbandry were in accordance with the European Union Guidelines (2010/63/EU). The experiment was planned to cover the BW range from ~60 to 130 kg BW. Therefore, the feeding programme consisted of two diets (in pelleted form): a grower diet (from ~60 to 103 kg average BW; from 0 to 40 days of the experimental period) and a finisher diet (from ~103 to 130 kg BW; from 41 to 62 days of the experiment). The ingredients of the experimental diets are shown in Table 1. Basal diets were formulated to meet or exceed requirements (FEDNA, 2013) and to minimise basal fat levels. Silicate (Ibersil D-100 M; IQESIL S.A., Zaragoza, Spain) was added to the diets (2.74% as-fed basis) to increase the amount of hydrochloric acid-insoluble ash as an inert digestibility marker. Four experimental treatments were obtained as the result of adding, to the same basal diet, 5% (as-fed basis) of different fat sources: crude palm oil (**PO**), crude olive pomace oil (**O**), olive pomace acid oil (**OA**) and a mixture (**M**) of PO + OA 50/50. Thus, 12 replicates per treatment were obtained, six per sex and four per block of BW.

A total of 224 boars and gilts [(Landrace × Large White) × Duroc] were obtained from the swineherd of the same facility. Pigs (age of 103 ± 3 days) were individually weighed (58.7 ± 9.71 kg of BW, mean ± SD) and randomly allocated to 48 pens and two different barns according to four dietary treatments and sex. There were a total of 12 pens per treatment, six for males and six for females. Pens were classified in one of three BW blocks (light 48.4 ± 8.19 kg, medium 60.2 ± 6.18 kg, and heavy 68.3 ± 5.91 kg BW, mean ± SD, respectively) balanced within sex (boars 59.0 ± 9.39 kg and gilts 59.7 ± 8.27 kg) and treatment (PO 59.0 ± 8.43 kg, O 59.4 ± 9.35 kg, OA 58.7 ± 8.43 kg, and M 59.3 ± 9.82 kg BW, mean ± SD, respectively; according to two pens of light, medium and heavy BW per sex within each treatment). There were four pigs per pen for heavy animals and five pigs per pen for medium and light animals. Each pen (1.13 $m^2$ per animal for heavy pigs and 0.91 $m^2$ per animal for medium and light pigs) had a half slatted concrete floor, a feeder and a nipple waterer. All the animals had ad libitum access to feed and water during the entire trial. No mortality or sick animals were observed throughout the experimental period.

**Table 1**
Ingredient composition of the experimental diets (as-fed basis) for growing-finishing pigs.

| Diet composition | Experimental period | |
|---|---|---|
| | Grower (from 0 to 40 days) | Finisher (from 41 to 62 days) |
| Ingredients, % | | |
| Corn meal | 30.00 | 17.98 |
| Barley | 8.00 | 18.07 |
| Sorghum | 11.70 | 16.15 |
| Wheat | 10.00 | 10.00 |
| Soybean meal 47% | 15.95 | 10.96 |
| Wheat bran | 5.75 | 8.00 |
| Experimental fat[1] | 5.00 | 5.00 |
| Silicate | 2.74 | 2.74 |
| Cane molasses | 2.00 | – |
| Sunflower meal 30% | 5.00 | 7.04 |
| Calcium carbonate | 0.90 | 1.12 |
| Di-calcium phosphate | 0.65 | 0.64 |
| Sodium chloride | 0.55 | 0.60 |
| Vitamin and mineral premix[2] | 0.61 | 0.61 |
| DL-Methionine[3] | 0.17 | 0.13 |
| L-Lysine[4] | 0.73 | 0.74 |
| L-Tryptophan | 0.02 | 0.02 |
| L-Threonine | 0.19 | 0.18 |
| L-Valine | 0.04 | 0.02 |
| Predicted values[5] | | |
| Net energy, MJ/kg | 10.21 | 10.13 |
| CP, % | 15.81 | 15.12 |
| Standardised ileal digestible lysine, % | 0.99 | 0.92 |
| Ca, % | 0.74 | 0.81 |
| P, % | 0.50 | 0.52 |

[1] Crude palm oil (PO), crude olive pomace oil (O), olive pomace acid oil (OA) or a mixture (M) of PO + OA at 50/50.
[2] Provides per kg of feed: vitamin A, 5 995 IU; Vitamin D3, 1 497 IU; Vitamin E, 15 ppm; Fe, 100 ppm ($FeSO_4{\cdot}H_2O$); I, 0.3 ppm (KI); Cu, 18 ppm ($CuSO_4{\cdot}5H_2O$); Mn, 40 ppm ($MnO_2$); Zn, 94 ppm (ZnO); Se, 0.34 ppm (Na2SeO3).
[3] DL-2-hydroxy-4-methylthiobutanoic acid (HMTBa), the hydroxy analogue of DL-methionine.
[4] L-Lysine sulphate.
[5] Ted values from the theoretical formulation of the diets.

### Controls and sampling

Feed consumption (pen basis) and individual BW of the animals were recorded at days 0, 40 and 62 of the experiment. This was used to calculate the average daily feed intake, average daily gain and gain to feed ratio per pen for each period and for the overall study. The digestibility balance was determined from day 40 to day 62 in a subset of 64 pigs ($n$ = 16 animals/treatment). Animals selected for the digestibility balance were those closest to the average BW for each group of each sex within each treatment (at least one pig from each pen). Faecal samples were collected on the last two days of the study (days 61 and 62) from selected animals (average marketing weight of 130.00 ± 16.73 kg BW, mean ± SD) by rectal stimulation and samples were pooled immediately after the second day of collection. Then, all the animals were slaughtered (same day, at 166 ± 3 days of age), and the ileal content was collected at the slaughterhouse from the same selected animals for faces collection. All samples were immediately homogenised, freeze-dried (LyoAlpha 10/15; Telstar, Barcelona, Spain), ground (1 mm screen diameter) and kept at 5 °C until further analysis.

Backfat thickness was individually measured by ultrasound (Future-1; Inserbo, Lleida, Spain) at the midline between the last thoracic and first lumbar vertebrae (P2) at the start (5.49 ± 1.09 mm) and at the end of the study. In addition, carcass quality parameters were monitored in a subset of 100 pigs at the slaughterhouse. Animals selected for carcass quality assessment were those closest to the average BW within each group of BW (eight heavy, nine medium and eight light) for each treatment, equally for each pen (two animals per pen) and sex (in medium block of BW, five males and four females were selected). Pigs were fasted (deprived of feed but not water) for ~20 h (except in pigs selected for digestibility balance, which were not fasted), and weighed the following morning to obtain the fasted live weight. Animals were stunned with 85% $CO_2$ for 120 s and immediately exsanguinated at the commercial slaughterhouse of bonÀrea Agrupa (La Closa; Guissona, Spain). Ham fat thickness and lean meat percentage were obtained with an AutoFom III ultrasonic system (Frontmatec A/C; Herlev, Denmark). Backfat and LM samples were obtained ($n$ = 18 samples/treatment) from the dorsal midline between the last rib and the first lumbar vertebrae. Animals selected for backfat and muscle sampling were the 18 females that were closest to the average BW within each treatment (at least one from each pen). Samples were homogenised and stored at −20 °C until the chemical analyses were performed.

### Chemical analysis

Analytical determinations of the feeds were performed according to AOAC International (2005) methods: DM (Method 934.01), ash (Method 942.05), CP (Method 954.01), ether extract (Method 920.39) and crude fibre (Method 962.09). The gross energy was determined with an adiabatic calorimeter (Parr 6300 Calorimeter, Parr Instrument Company, Moline, IL, USA) according to the Standard UNE-EN ISO 9831:2004. Lipid class composition was analysed by size exclusion HPLC with refractive index detection, following the method described by Varona et al. (2021a). The FA content of feed, ileal content and faeces were analysed following the method described by Sukhija and Palmquist (1988). Backfat and LM FAs were analysed by gas chromatography following the method described by Carrapiso et al. (2000). Nonadecanoic acid (C19:0; Sigma-Aldrich Chemical Co.; St. Louis, MO, USA) was added as internal standard. The final extract obtained was injected in a gas chromatograph (HP6890, Agilent Technologies; Waldbronn, Germany) following the method conditions described by Cortinas et al. (2004). The intramuscular fat content (**IMF**) of the LM minced and homogenised samples was determined by near infrared transmittance spectroscopy (FoodScan TM; Foss Analytical, Hillerød, Denmark), previously validated (Font-i-Furnols et al., 2012), at wavelengths between 850 and 1048 nm. Hydrochloric acid-insoluble ash was determined in feeds, ileal content and faeces according to the methods of the European Commission Regulation no. 152/2009.

### Calculations

The apparent digestibility of a particular FA (X) was calculated as follows:

$$\%\ apparent\ digestibility\ of\ X = \{1 - [(Xf/Mf)/(Xd/Md)]\} \times 100$$

where $Xf$ is the concentration of a particular FA in faeces or ileal content, $Mf$ is the concentration of the inert marker in faeces or ileal content, $Xd$ is the concentration of a particular FA in the diet, and $Md$ is the concentration of the inert marker in the diet. The digestible energy of feeds was calculated from the product of energy apparent digestibility and its corresponding feed gross energy.

### Statistical analysis

The normality of the data and homogeneity of variance were verified using the CAPABILITY procedure of SAS (version 9.4, SAS Inst. Inc.; Cary, NC, USA). Performance parameters were analysed using the MIXED procedure of SAS. Diet, block and sex were defined as the main factors and room was defined as a random effect. Digestibility coefficients, FA composition of LM and backfat, carcass composition and IMF were analysed by using the GLM procedure of SAS. For digestibility balance, diet and sex were defined as the main factors. For carcass composition and IMF, diet, sex and block were defined as the main factors. For FA composition of LM and backfat, diet was defined as the main factor. No interactions between diet, sex and block were observed for any of the variables studied. For the performance parameters, the experimental unit was the pen. For digestibility balance, FA composition, carcass parameters and IMF, the experimental unit was the individual. For all statistical analyses, differences between means were tested using Tukey's adjust correction for multiple comparisons. The results in the tables are reported as least square means. For all statistical analyses, significance was declared at $P < 0.05$ and tendencies were discussed at $0.05 > P > 0.10$.

## Results

### Experimental fats and diets

Composition of the experimental fats is presented in Table 2. Crude olive pomace oil and olive pomace acid oil were rich in monounsaturated FA, in particular in oleic acid (70.5 and 65.0%, respectively), while crude palm oil was composed mainly of palmitic (42.4%) and oleic (41.6%) acids in similar proportions. Both crude palm oil and crude olive pomace oil, as crude oils, were composed of triacylglycerols (>80%). In contrast, olive pomace acid oil, a by-product of the olive pomace oil refining process, had the highest amount of free FA (53.98%). Olive pomace acid oil had the highest moisture, impurities and unsaponifiable values (**MIU**; 12.67%), while crude olive pomace oil (4.65%) and crude palm oil (0.49%) had the lowest values. Composition of the experimental diets is presented in Table 3. All diets showed a similar content in gross energy and all macronutrients analysed. The fatty acid and lipid class composition of the experimental diets resemble those of the added fats, and M was at the midpoint between PO and OA for all analysed parameters.

**Table 2**
Composition of experimental fats[1] included in the diets of growing-finishing pigs.

| Item | Experimental fats | | |
|---|---|---|---|
| | PO | O | OA |
| Fatty acid composition (g/100 g of FA) | | | |
| C14:0 | 0.85 | – | – |
| C16:0 | 42.43 | 12.95 | 13.59 |
| C18:0 | 4.57 | 2.60 | 3.62 |
| C18:1 n-9 | 41.62 | 70.47 | 64.97 |
| C18:2 n-3 | 0.28 | 0.89 | 0.97 |
| C18:2 n-6 | 9.73 | 12.03 | 15.03 |
| C20:0 | 0.32 | 0.41 | 0.56 |
| C20:1 n-9 | 0.13 | 0.32 | 0.29 |
| C22:0 | – | – | 0.45 |
| C24:0 | – | – | 0.44 |
| Saturated FA | 48.25 | 16.14 | 18.67 |
| Monounsaturated FA | 41.75 | 70.79 | 65.25 |
| Polyunsaturated FA | 10.01 | 12.93 | 16.00 |
| Unsaturated FA to Saturated FA ratio | 1.07 | 5.19 | 4.35 |
| Lipid class composition (g/100 g of FA) | | | |
| Triacylglycerols | 86.67 | 82.36 | 23.98 |
| Diacylglycerols | 8.36 | 8.25 | 19.76 |
| Monoacylglycerols | 0.63 | 0.56 | 2.29 |
| Free FA | 4.34 | 8.82 | 53.98 |
| MIU (g/100 g of fat) | | | |
| Moisture | 0.14 | 0.28 | 1.27 |
| Impurity | 0.13 | 0.79 | 7.84 |
| Unsaponifiable | 0.22 | 3.58 | 3.56 |

Abbreviations: PO = crude palm oil; O = crude olive pomace oil; OA = olive pomace acid oil; FAs = fatty acids; MIU = moisture, impurities and unsaponifiable.
[1] All samples were analysed in duplicate.

*Performance and feed intake*

The effects of the dietary fat sources on growth performance are shown in Table 4. No differences were observed among dietary treatments during the grower period (from day 0 to day 40 of the experiment; 59.3 ± 8.74–104 ± 10.92 kg BW) in any performance parameter ($P > 0.10$). During the finishing period (from day 40 to day 62 of the experiment; 104 ± 10.92–131.7 ± 12.67 k g BW), animals fed M showed a higher average daily gain than those fed OA ($P = 0.005$). Concerning the entire experimental period (from 0 to 62d), animals fed OA showed a lower average daily gain than those fed M or PO ($P = 0.006$). In addition, the gain to feed ratio in animals fed OA was lower than in those fed M ($P = 0.008$), and tended to be lower than in those fed O ($P = 0.074$) or PO ($P = 0.076$). No differences were observed in the final BW or in the global average daily feed intake among treatments ($P > 0.10$). Regarding sex, gilts showed a lower BW, average daily gain and gain to feed ratio than boars considering the entire experimental period ($P < 0.001$). Concerning block of BW, differences between heavy, medium and light animals were maintained throughout the experimental period for BW, average daily feed intake and gain to feed ratio ($P < 0.001$). However, no differences between blocks of BW were observed on the average daily gain when considering the entire experimental period ($P = 0.807$) although heavy animals showed a higher average daily gain than light animals in the growing period (from 0 to 40 days; $P = 0.022$).

*Digestibility balance*

Feed digestible energy and FA apparent ileal (**AID**) and total tract (**ATTD**) digestibility values are presented in Table 5. Regarding dietary treatments, no significant differences were observed in AID ($P > 0.10$); however, pigs fed O showed a tendency to have higher values than PO in the AID of total FA ($P = 0.078$), monounsaturated FA ($P = 0.066$) and oleic acid ($P = 0.071$). In addition, M showed a tendency to have higher values than PO in the AID of palmitic acid ($P = 0.092$). Regarding ATTD, OA and M showed a higher DE than PO ($P = 0.001$). In addition, O and OA showed the highest values for total FA ($P < 0.001$). OA had the highest values in the ATTD of monounsaturated FA and polyunsaturated FA, while PO had the lowest ($P < 0.001$). M showed higher values for saturated FA ATTD than O ($P = 0.032$). Concerning individual FA, OA showed the highest ATTD values for palmitic, oleic and linoleic acids ($P < 0.001$). However, very low values were obtained in the ATTD of stearic acid, which were even negative in the case of O and OA. In terms of sex, no differences were obtained in the AID ($P > 0.10$), but higher values were obtained for ATTD of monounsat-

**Table 3**
Analysed[1] macronutrient content and fatty acid and lipid class composition of the experimental diets of growing-finishing pigs.

| Item | Grower diets | | | | Finisher diets | | | |
|---|---|---|---|---|---|---|---|---|
| | PO | O | OA | M | PO | O | OA | M |
| Macronutrient content (g/100 g of feed) | | | | | | | | |
| DM | 88.43 | 87.28 | 87.75 | 87.40 | 89.25 | 88.85 | 89.07 | 89.04 |
| CP | 16.05 | 15.53 | 15.61 | 16.65 | 15.60 | 15.33 | 15.11 | 15.45 |
| Ether extract | 6.55 | 6.32 | 6.63 | 6.43 | 6.79 | 6.29 | 6.44 | 6.44 |
| Crude fibre | 4.45 | 4.15 | 4.13 | 4.31 | 4.65 | 4.84 | 4.33 | 4.67 |
| Ash | 6.38 | 6.66 | 7.06 | 6.77 | 6.59 | 6.74 | 6.10 | 6.67 |
| Gross energy (MJ/kg) | 17.28 | 16.97 | 16.89 | 17.03 | 17.18 | 17.12 | 17.33 | 17.27 |
| Fatty acid composition (g/100 g of FA) | | | | | | | | |
| C16:0 | 30.02 | 13.68 | 13.24 | 23.07 | 30.56 | 15.11 | 14.40 | 24.27 |
| C18:0 | 4.05 | 2.74 | 2.99 | 3.60 | 3.86 | 2.78 | 2.97 | 3.55 |
| C18:1 n-9 | 35.21 | 46.51 | 46.00 | 39.03 | 34.10 | 45.94 | 44.96 | 38.86 |
| C18:2 n-6 | 27.43 | 31.62 | 32.33 | 29.97 | 27.83 | 30.58 | 31.91 | 28.59 |
| C18:3 n-3 | 1.42 | 1.87 | 1.86 | 1.66 | 1.66 | 2.04 | 2.09 | 1.72 |
| Minor fatty acids | 1.87 | 3.58 | 3.58 | 2.67 | 1.99 | 3.55 | 3.67 | 3.01 |
| Saturated FA | 34.97 | 17.50 | 17.55 | 27.71 | 35.38 | 18.93 | 18.72 | 29.19 |
| Monounsaturated FA | 36.19 | 49.01 | 48.26 | 40.65 | 35.14 | 48.45 | 47.28 | 40.50 |
| Polyunsaturated FA | 28.85 | 33.49 | 34.19 | 31.64 | 29.49 | 32.62 | 34.00 | 30.31 |
| Lipid class composition (g/100 g of FA) | | | | | | | | |
| Triacylglycerols | 83.69 | 70.72 | 49.26 | 68.21 | 81.19 | 67.13 | 44.77 | 64.37 |
| Diacylglycerols | 8.89 | 11.12 | 14.90 | 11.77 | 9.55 | 11.91 | 15.05 | 12.39 |
| Monoacylglycerols | 0.93 | 1.27 | 1.66 | 1.27 | 1.09 | 1.40 | 1.63 | 1.54 |
| Free FA | 6.49 | 16.88 | 34.19 | 18.75 | 8.17 | 19.56 | 38.55 | 21.70 |

Abbreviations: PO = crude palm oil; O = crude olive pomace oil; OA = olive pomace acid oil; M = mixture of PO + OA at 50/50; FAs = fatty acids.
[1] All samples were analysed in duplicate.

**Table 4**
Performance parameters in growing–finishing pigs fed different dietary fat sources.

| Item[1] | Dietary treatments | | | | SEM[2] | *P*-values | | |
|---|---|---|---|---|---|---|---|---|
| | PO | O | OA | M | | Diet | Sex[3] | Block[4] |
| From 0 to 40 days | | | | | | | | |
| BW at 0d (kg) | 59.0 | 59.4 | 58.7 | 59.3 | 0.89 | 0.942 | 0.175 | <0.001 |
| Average daily feed intake (g) | 2 593 | 2 561 | 2 594 | 2 581 | 37.00 | 0.930 | 0.487 | <0.001 |
| Average daily gain (g) | 1 151 | 1 130 | 1 098 | 1 121 | 28.79 | 0.257 | <0.001 | 0.022 |
| Gain to feed ratio (g/kg) | 444 | 443 | 424 | 436 | 1.19 | 0.178 | <0.001 | <0.001 |
| From 40 to 62 days | | | | | | | | |
| BW at 40d (kg) | 105.1 | 104.5 | 102.6 | 104.1 | 1.69 | 0.633 | 0.009 | <0.001 |
| Average daily feed intake (g) | 3 168 | 3 115 | 3 045 | 3 114 | 170.70 | 0.491 | 0.016 | 0.002 |
| Average daily gain (g) | 1 235[ab] | 1 185[ab] | 1 155[b] | 1 273[a] | 51.53 | 0.005 | <0.001 | 0.056 |
| Gain to feed ratio (g/kg) | 391 | 386 | 380 | 412 | 0.96 | 0.110 | <0.001 | <0.001 |
| From 0 to 62 days | | | | | | | | |
| BW at 62d (kg) | 133.0 | 131.5 | 128.8 | 133.5 | 4.69 | 0.119 | <0.001 | <0.001 |
| Average daily feed intake (g) | 2 802 | 2 737 | 2 785 | 2 768 | 72.53 | 0.748 | 0.352 | <0.001 |
| Average daily gain (g) | 1 181[a] | 1 154[ab] | 1 119[b] | 1 186[a] | 51.18 | 0.006 | <0.001 | 0.807 |
| Gain to feed ratio (g/kg) | 422[ab] | 423[ab] | 403[b] | 429[a] | 1.02 | 0.008 | <0.001 | <0.001 |

Abbreviations: PO = crude palm oil; O = crude olive pomace oil; OA = olive pomace acid oil; M = mixture of PO + OA at 50/50.
[a,b]Values within a row with different superscripts differ significantly at $P < 0.05$.
[1] Values of average daily feed intake and gain to feed ratio expressed as-fed basis.
[2] $n = 12$.
[3] Boars vs gilts.
[4] Three blocks of BW: light 48.37 ± 8.19 kg, medium 60.22 ± 6.18 kg, and heavy 68.33 ± 5.91 kg BW, mean ± SD of initial BW.

**Table 5**
Feed digestible energy (MJ/kg) and fatty acid apparent digestibility (%, ileal and total tract) in finishing pigs fed different dietary fat sources.

| Item | Dietary treatments | | | | SEM[1] | *P*-values | |
|---|---|---|---|---|---|---|---|
| | PO | O | OA | M | | Diet | Sex[2] |
| Apparent ileal digestibility | | | | | | | |
| Digestible energy, MJ/kg | 12.55 | 12.32 | 11.82 | 12.04 | 0.34 | 0.319 | 0.489 |
| Total FA | 76.21 | 83.07 | 81.56 | 82.50 | 2.11 | 0.078 | 0.922 |
| Saturated FA | 54.19 | 58.50 | 60.63 | 66.94 | 4.27 | 0.177 | 0.926 |
| Monounsaturated FA | 85.56 | 90.29 | 89.38 | 90.06 | 1.50 | 0.066 | 0.991 |
| Polyunsaturated FA | 80.56 | 86.36 | 82.19 | 87.01 | 3.13 | 0.336 | 0.749 |
| C16:0 | 61.13 | 68.93 | 70.25 | 71.33 | 3.36 | 0.092 | 0.866 |
| C18:0 | 22.64 | 23.69 | 19.44 | 41.96 | 8.62 | 0.236 | 0.405 |
| C18:1 n-9 | 86.13 | 90.43 | 89.56 | 90.30 | 1.40 | 0.071 | 0.964 |
| C18:2 n-6 | 82.38 | 87.14 | 83.56 | 87.63 | 2.85 | 0.421 | 0.685 |
| C18:3 n-3 | 87.25 | 92.25 | 88.29 | 89.69 | 1.19 | 0.233 | 0.997 |
| Apparent total tract digestibility | | | | | | | |
| Digestible energy, MJ/kg | 13.88[b] | 12.32[ab] | 14.20[a] | 14.20[a] | 0.06 | 0.001 | 0.097 |
| Total FA | 79.63[c] | 87.94[a] | 89.31[a] | 85.26[b] | 0.54 | <0.001 | 0.237 |
| Saturated FA | 51.81[ab] | 50.56[b] | 54.19[ab] | 58.81[a] | 2.08 | 0.032 | 0.222 |
| Monounsaturated FA | 93.81[c] | 95.94[b] | 96.94[a] | 94.63[c] | 0.25 | <0.001 | 0.031 |
| Polyunsaturated FA | 96.66[c] | 97.56[b] | 98.19[a] | 97.50[b] | 0.12 | <0.001 | 0.026 |
| C16:0 | 60.75[c] | 73.50[b] | 81.13[a] | 69.31[b] | 1.37 | <0.001 | 0.003 |
| C18:0 | 2.31[a] | −26.79[b] | −49.31[b] | 0.94[a] | 6.56 | <0.001 | 0.551 |
| C18:1 n-9 | 94.13[d] | 96.19[b] | 97.19[a] | 95.06[c] | 0.24 | <0.001 | 0.045 |
| C18:2 n-6 | 96.50[c] | 97.44[b] | 98.13[a] | 97.50[b] | 0.12 | <0.001 | 0.002 |
| C18:3 n-3 | 100.00 | 100.00 | 100.00 | 100.00 | . | . | . |

Abbreviations: PO = crude palm oil; O = crude olive pomace oil; OA = olive pomace acid oil; M = mixture of PO + OA at 50/50; FAs = fatty acids.
[a–d]Values within a row with different superscripts differ significantly at $P < 0.05$.
[1] $n = 16$.
[2] Boars vs gilts.

urated FA and polyunsaturated FA in females ($P < 0.05$). When considering individual FA, females had a higher ATTD for palmitic acid (C16:0; $P = 0.003$), oleic acid (C18:1 n-9; $P = 0.045$) and linoleic acid (C18:2 n-6, $P = 0.002$).

*Carcass quality and intramuscular fat*

The effects of dietary treatments on carcass yield, composition and LM IMF are shown in Table 6. No differences were observed in carcass weight, yield and lean percentage or ham and backfat thickness among dietary treatments ($P > 0.10$). However, some differences were found in terms of BW block. As expected, heavy animals (140.8 ± 15.5 kg BW) had the highest carcass weight while light animals (119.2 ± 12.0 kg BW) had the lowest (111.2 vs 90.0 kg carcass weight for heavy and light animals, respectively; $P < 0.001$). Moreover, in contrast to light animals, heavy animals showed a greater ham fat thickness (13.29 vs 10.93 mm of ham fat thickness for heavy and light animals, respectively; $P = 0.004$)

**Table 6**
Carcass yield, composition and *Longissimus* muscle intramuscular fat of fattening pigs according to different dietary fat sources.

| | Dietary treatments | | | | | *P*-values | | |
|---|---|---|---|---|---|---|---|---|
| Item | PO | O | OA | M | SEM[1] | Diet | Sex | Block |
| Carcass weight (kg) | 101.7 | 99.9 | 100.4 | 102.2 | 2.52 | 0.900 | 0.230 | <0.001 |
| Carcass yield (%) | 73.59 | 73.95 | 73.90 | 72.71 | 0.91 | 0.743 | 0.109 | 0.555 |
| Carcass lean percentage (%) | 60.26 | 60.78 | 61.45 | 61.06 | 0.57 | 0.495 | 0.734 | 0.916 |
| Backfat thickness[2] (mm) | 10.85 | 10.77 | 9.93 | 10.80 | 0.72 | 0.198 | 0.223 | 0.053 |
| Ham fat thickness (mm) | 12.84 | 11.95 | 11.80 | 12.18 | 0.58 | 0.585 | 0.845 | 0.004 |
| Intramuscular fat[3] (%) | 1.78[b] | 2.21[a] | 2.15[ab] | 2.07[ab] | 0.107 | 0.037 | <0.001 | 0.844 |

Abbreviations: PO = crude palm oil; O = crude olive pomace oil; OA = olive pomace acid oil; M = mixture of PO + OA at 50/50.
[a,b]Values within a row with different superscripts differ significantly at $P < 0.05$.
[1] $n = 25$. For intramuscular fat, $n = 18$.
[2] Backfat thickness measurement made by ultrasound between the last thoracic and first lumbar vertebrae (P2) in live pigs.
[3] Measured by near infrared transmittance spectroscopy (FoodScan TM; Foss Analytical, Hillerød, Denmark).

and tended to have a thicker backfat thickness (11.10 vs 10.03 mm of backfat thickness for heavy and light animals, respectively; $P = 0.053$). Animals fed O showed a higher IMF value than those fed PO ($P = 0.037$). In addition, a sex effect was observed, since females showed a higher IMF level (2.27 mm) than males (1.88 mm; $P < 0.001$).

### *Fatty acid composition of backfat and Longissimus muscle*

The fatty acid composition of backfat and LM are presented in Tables 7 and 8, respectively. The FA profiles of backfat and LM resemble the profile of the fat sources supplemented in the feed. Animals fed O or OA had a higher unsaturated FA to saturated FA ratio than animals fed PO. In relation to backfat, animals fed PO had the highest level of saturated FA while those fed O or OA had the lowest ($P = 0.034$). Animals fed O had the highest monounsaturated FA levels and those fed PO had the lowest ($P < 0.001$). Therefore, animals fed O had the highest unsaturated FA to saturated FA ratio while animals fed PO had the lowest, and diets OA and M presented intermediate values ($P < 0.001$). In terms of individual FA, oleic acid showed the highest values for O or OA and linolenic acid showed the highest values for O, OA or M. Palmitic and stearic acid showed the highest values for PO ($P < 0.001$). No differences were observed for linoleic acid.

In relation to LM, the lowest levels of saturated FA ($P < 0.001$) were observed in animals fed O or OA. Moreover, PO showed higher values of palmitic acid than OA ($P = 0.026$) and higher values of stearic acid than O ($P = 0.001$). Animals fed O had a higher monounsaturated FA content, in particular oleic acid, than those fed PO ($P = 0.003$). No differences were observed for linoleic or linolenic acids. In terms of unsaturated FA to saturated FA ratio, the highest values were obtained with the O and OA diets, while the lowest value was obtained with the PO diet ($P = 0.001$).

## Discussion

### *Performance and feed intake*

The study results show that including crude olive pomace oil, rich in monounsaturated FA and triacylglycerols, as an alternative fat source to conventional crude palm oil did not modify the performance parameters in any phase or in the overall trial. On the other hand, the biological response obtained regarding the effects of sex and block of BW were as expected. These results are in agreement with previous studies that include olive oil in the diets of growing-finishing pigs, which are similar in FA composition to O, and which did not find differences in growth performance compared to other commonly used fat sources, such as tallow or soybean oil (Park et al., 2012). Other studies have reported no negative effects on growth performance when olive pomace cake (with an approximate content of 28% fat) was added to growing-finishing pig diets (Ferrer et al., 2020).

**Table 7**
Fatty acid composition (g/100 g of FA) of backfat from finishing pigs according to different dietary fat sources.

| | Dietary treatments | | | | | |
|---|---|---|---|---|---|---|
| Item | PO | O | OA | M | SEM[1] | *P*-value |
| C14:0 | 1.11 | 1.05 | 1.11 | 1.09 | 0.03 | 0.212 |
| C16:0 | 22.71[a] | 19.82[c] | 20.25[c] | 21.20[b] | 0.22 | <0.001 |
| C16:1 | 1.51 | 1.56 | 1.62 | 1.44 | 0.06 | 0.159 |
| C17:0 | 0.22 | 0.20 | 0.23 | 0.22 | 0.23 | 0.093 |
| C18:0 | 12.56[a] | 10.39[c] | 10.96[bc] | 11.64[b] | 0.20 | <0.001 |
| C18:1 n-9 | 42.20[c] | 46.31[a] | 44.12[a] | 43.33[bc] | 0.36 | <0.001 |
| C18:1 n-7 | 1.93[b] | 2.31[a] | 2.26[a] | 1.99[b] | 0.04 | <0.001 |
| C18:2 n-6 | 15.06 | 15.29 | 16.22 | 16.16 | 0.43 | 0.117 |
| C18:3 n-3 | 0.67[b] | 0.80[a] | 0.83[a] | 0.79[a] | 0.02 | <0.001 |
| C20:0 | 0.19 | 0.15 | 0.19 | 0.19 | 0.01 | 0.060 |
| C20:1 n-9 | 0.73 | 0.79 | 0.80 | 0.76 | 0.03 | 0.289 |
| C20:2 | 0.58 | 0.62 | 0.65 | 0.63 | 0.02 | 0.096 |
| C20:4 n-6 | 0.23[b] | 0.25[ab] | 0.28[a] | 0.28[a] | 0.01 | 0.007 |
| Saturated FA | 37.14[a] | 31.67[c] | 32.79[c] | 34.41[b] | 0.39 | 0.034 |
| Monounsaturated FA | 46.37[c] | 51.24[a] | 48.78[b] | 47.58[bc] | 0.43 | <0.001 |
| Polyunsaturated FA | 16.12 | 16.47 | 17.50 | 17.38 | 0.46 | 0.083 |
| Unsaturated FA to Saturated FA ratio | 1.68[c] | 2.14[a] | 2.01[b] | 1.89[b] | 0.04 | <0.001 |

Abbreviations: PO = crude palm oil; O = crude olive pomace oil; OA = olive pomace acid oil; M = mixture of PO + OA at 50/50; FAs = fatty acids.
[a–c]Values within a row with different superscripts differ significantly at $P < 0.05$.
[1] $n = 18$.

**Table 8**
Fatty acid composition (g/100 g of FA) of *Longissimus* muscle from finishing pigs according to different dietary fat sources.

| | Dietary treatments | | | | | |
|---|---|---|---|---|---|---|
| Item | PO | O | OA | M | SEM[1] | *P*-value |
| C14:0 | 1.05 | 1.06 | 1.06 | 1.06 | 0.03 | 0.988 |
| C16:0 | 22.57[a] | 21.70[ab] | 21.60[b] | 22.17[ab] | 0.25 | 0.026 |
| C16:1 | 2.50 | 2.68 | 2.57 | 2.58 | 0.10 | 0.642 |
| C17:0 | 0.13 | 0.13 | 0.20 | 0.15 | 0.02 | 0.131 |
| C18:0 | 12.51[a] | 11.58[b] | 11.99[ab] | 12.04[ab] | 0.15 | 0.001 |
| C18:1 n-9 | 38.41[b] | 41.32[a] | 39.64[ab] | 40.17[ab] | 0.53 | 0.003 |
| C18:1 n-7 | 3.18[b] | 3.48[a] | 3.30[ab] | 3.27[ab] | 0.07 | 0.024 |
| C18:2 n-6 | 14.32 | 13.31 | 14.30 | 13.55 | 0.61 | 0.531 |
| C18:3 n-3 | 0.38 | 0.41 | 0.41 | 0.39 | 0.02 | 0.485 |
| C20:0 | 0.13 | 0.14 | 0.08 | 0.13 | 0.02 | 0.249 |
| C20:1 n-9 | 0.62 | 0.63 | 0.63 | 0.64 | 0.01 | 0.687 |
| C20:2 | 0.54 | 0.51 | 0.56 | 0.54 | 0.02 | 0.320 |
| C20:4 n-6 | 3.13 | 2.81 | 3.19 | 2.99 | 0.19 | 0.487 |
| C21:0 | 0.35 | 0.34 | 0.36 | 0.35 | 0.02 | 0.836 |
| Saturated FA | 36.75[a] | 34.70[b] | 35.32[b] | 35.74[ab] | 0.33 | <0.001 |
| Monounsaturated FA | 44.71[b] | 48.10[a] | 46.16[ab] | 46.69[ab] | 0.66 | 0.006 |
| Polyunsaturated FA | 18.00 | 16.52 | 17.96 | 16.85 | 0.80 | 0.442 |
| Unsaturated FA to Saturated FA ratio | 1.71[b] | 1.86[a] | 1.82[a] | 1.79[ab] | 0.03 | 0.001 |

Abbreviations: PO = crude palm oil; O = crude olive pomace oil; OA = olive pomace acid oil; M = mixture of PO + OA at 50/50; FAs = fatty acids.
[a–b]Values within a row with different superscripts differ significantly at $P < 0.05$.
[1] $n = 18$.

However, these results showed that including olive pomace acid oil, rich in monounsaturated FA and free FA, at 5% in the growing-finishing diets decreased the average daily gain and therefore reduced the gain to feed ratio. Despite this, there are few studies that assess the effect of including fat by-products rich in free FA on the growth performance of growing pigs. DeRouchey et al. (2004) observed a linear increase in average daily feed intake as the free FA concentration increased (up to 53% free FA; MIU < 3.3) when choice white grease was included in weaning pigs' diets. Rojas-Cano et al. (2014) did not find an improvement in the performance of growing pigs when the dietary energy level was increased by including increasing levels of olive acid oil up to 75 g/kg. However, Vilarrasa et al. (2015) observed no differences in the growth performance of growing pigs fed palm fatty acid distillates (53% of free FA) in contrast to palm oil added at 4%. The inconsistent results among studies that include free FA rich sources in swine diets might be explained by the high variability in the composition and quality of available fat by-products. It has been stated that the MIU value of the added acid oils and fatty acid distillates could lead to a decrease in the DE of pigs (Wiseman et al., 1992; Varona et al., 2021b). In agreement with this, the present study found the highest MIU values for olive pomace acid oil (12.67%), while crude olive pomace oil or crude palm oil had values of 4.64 and 0.49%, respectively. Although most of the studies available in the literature did not report values of MIU, it is important to highlight the significance of knowing the non-energetic fraction of dietary added fats for a correct assessment of their DE value.

The present results also show that including olive pomace acid oil at 2.5% in a blend with 2.5% crude palm oil achieved similar growth performance results as PO or O. It is well established that blending different fats and oils with different chemical compositions (differing in saturation degree, chain length or molecular structure) produces positive interactions in terms of energy and FA utilisation (Zumbado et al., 1999; Roll et al., 2018). Moreover, blending olive pomace acid oil with a high quality fat source with low MIU content, such as crude palm oil, dilutes the final MIU content of the blend. With this, the use of the fat blend did not impair performance parameters, so our results suggest that olive pomace acid oil can be included in growing-finishing swine diets, blended with conventional crude palm oil, achieving a combination of triacylglycerols and free FA and a moderate level of MIU.

*Digestibility balance*

In the present study, OA and M diets showed higher digestible energy at the faecal level than the PO diet. However, this effect was not observed in the dietary digestible energy determined at ileal level. The different results between the digestible energy measured in faeces or in ileum could be explained by the effect of microbiota present in the hindgut (Stein, 2017); therefore, the results obtained at ileal level are more representative. Although no statistical differences were observed in this study, a numerical reduction of digestible energy at ileal level for OA and M could be explained by the higher MIU content in these fat sources. Studying the effect of dietary treatments on digestibility of FA, and concerning ATTD, the present results showed that PO had the lowest FA digestibility among the dietary treatments under study. As expected, as dietary unsaturation increases, digestibility also increases (Cho and Kim, 2012; Duran-Montgé et al., 2007). Otherwise, no differences were observed between O and OA in total FA, despite the higher free FA content in the latter. There are controversial results in the literature about the effects of free FA on FA digestibility. The results from the present study are in agreement with those found by DeRouchey et al. (2004), who observed no differences in FA digestibility when free FA levels were increased in choice white grease fed to weaning pigs. In addition, Vilarrasa et al. (2015) did not obtain different results in FA digestibility when they compared palm fatty acid distillates with crude palm oil in growing-finishing pigs. On the contrary, Powles et al. (1993) concluded that the level of free FA in the diet of growing pigs appeared to be determinant for the digestible energy value of fats. It has been proposed that the negative effects of free FA on FA digestibility are related to its reaction with ionised minerals, such as calcium and magnesium, which form insoluble soaps that cause both the free FA and the mineral to become unavailable for absorption (Small, 1991). However, this effect is mainly related to long-chain saturated FA rather than to unsaturated FA, as the former has a greater ability to form insoluble soaps than the latter (Atteh and Leeson, 1985). This suggests that the negative effect of free FA on FA digestibility is restricted to saturated sources of free FA (Wiseman and Salvador, 1991).

Blending 2.5% olive pomace acid oil and 2.5% crude palm oil is a suitable option in terms of FA utilisation. In general, M showed AID and ATTD values above the arithmetically predicted values obtained from the two individual fats. This phenomenon is frequently referred to as synergism (Powles et al., 1993; Wiseman et al., 1998). First, a synergic effect occurs when unsaturated and saturated fats are blended, since long-chain unsaturated FAs are more able to form mixed micelles than long-chain saturated FAs are. Therefore, the presence of unsaturated FA can increase the capacity to take up saturated FA in the core of mixed micelles, improving their absorption (Vilarrasa et al., 2015; Rodriguez-Sanchez et al., 2019). Second, it has been suggested that increasing amounts of diacylglycerols or monoacylglycerols have a positive effect on free FA digestibility because their emulsifying effect enhances the inclusion of free FA in mixed micelles (Roll et al., 2018). In agreement with our results, Zumbado et al. (1999) described a synergistic effect on digestibility and dietary apparent metabolisable energy values of broiler chickens when unsaturated and saturated fats rich in free FA were blended. The synergic effect observed between 2.5% olive pomace acid oil and 2.5% crude palm oil could be due to it being an adequate unsaturated FA to saturated FA ratio, with the presence of monounsaturated FA from OA and a high proportion of monoacylglycerols from the lipolysis of palm triacylglycerols, capable of better solubilising free FA in the mixed micelle and facilitating its absorption.

In our study, ATTD showed higher values than AID for digestible energy and for all FA except for saturated FA, which means that energy and unsaturated FA that were not absorbed at the end of the ileum disappeared in the hindgut. Duran-Montgé et al. (2007) also reported higher values for unsaturated FA ATTD than the corresponding AID, and lower values for saturated FA. This effect may be explained by a biohydrogenation of oleic, linoleic and linolenic acids that are saturated by the microflora and, in part, converted into stearic acid (Jørgensen and Fernández, 2000; Duran-Montgé et al., 2007). Thus, the low values (or even negative for O and OA) obtained in the ATTD of stearic acid could be explained due to this microbial activity. Moreover, C15:0 and C17:0, which were not present in the diet, were observed in faecal samples, and were probably generated by microbial synthesis. In relation to this, the differences between sexes in the ATTD of FA obtained in the present study may be affected by these effects, since no differences were observed in any FA in the AID. Although it is generally accepted to report digestibility of fat as total tract digestibility, these findings suggest that using ileal digestibility is more accurate for the FA digestibility and estimates the nutritive value of fats better than faecal digestibility. Moreover, the interaction generated by microbial biohydrogenation of unsaturated FA in the hindgut can be avoided in this way (Stein, 2017).

*Carcass quality and intramuscular fat*

The dietary supplementation of crude and acid oils from olive pomace oils did not modify carcass weight, yield and lean percentage, or ham fat and backfat thickness. However, supplementation with crude olive pomace oil lead to an increase in IMF content in the LM. Although there is a relationship between loin and ham fatness and IMF content, the correlation is not very high, varying between 0.28 and 0.49 (Font-i-Furnols et al., 2019). Generally, a 5% increase in carcass fat corresponds only to a 1% increase in IMF (Hocquette et al., 2010) due to the lower proliferative potential or low activity levels of lipogenesis enzymes in intramuscular preadipocytes compared to subcutaneous adipocytes (Gardan et al., 2006). Consequently, changes in IMF content are difficult to note, especially in commercial lean breeds such as Landrace or Pietrain. However, in high-fat content crossbreed pigs such as Duroc, changes in IMF content may be accentuated. Samples of LM from the present study (Duroc-finished pigs) showed a higher IMF content (an average of 2.05 ± 0.65%) than other values recorded in commercial lean breeds such as Landrace or Pietrain (0.5–2.5% of wet weight; Cagnazzo et al., 2006). Higher IMF content levels have been linked with a better sensory quality of pork (Font-i-Furnols et al., 2012). The use of Duroc-finished lines in a commercial environment is an alternative for obtaining meat products with a higher IMF content and therefore fulfilling sensory acceptance by consumers.

Our results confirm that the IMF content can be modified through changes in the fat source added to growing-finishing pig diets, as supplementation of crude olive pomace oil increased the IMF content above the other diets of the study. Present results were consistent with data reported by Miller et al. (1990), who observed higher IMF levels in pigs fed diets rich in oleic acid. In addition, Isabel et al. (2004) found a higher IMF content in growing-finishing pigs when the monounsaturated FA to polyunsaturated FA ratio was increased. In the work of Gerfault et al. (2000), higher concentrations of oleic acid and lower of linoleic acid (therefore, a higher monounsaturated FA to polyunsaturated FA ratio) in porcine skeletal muscle and adipose tissue had been associated with higher lipogenic enzyme activity. In agreement with this, in the present study, O had the highest monounsaturated FA to polyunsaturated FA ratio both in the diet (1.46) and in LM (2.91) among treatments, while PO had the lowest (1.25 in the diet; 2.48 in LM), and hence the lowest IMF values. Alternatively, other nutritional strategies have been applied to reach high IMF levels in pork. Some authors have observed an increase in IMF levels when the protein to digestible energy ratio is decreased; however, this also may have a negative effect on performance (Kerr et al., 1995; D'Souza et al., 2003). Higher IMF content (+53%) has been reported when growing-finishing pigs are fed a diet deficient in vitamin A, as retinoic acid, a derivative of vitamin A, could inhibit the terminal differentiation of intramuscular adipose tissue (D'Souza et al., 2003). However, although these nutritional manipulations increased the IMF content, they also led to other detriments and disadvantages in the pigs' performance, which made their application unviable in a commercial environment. Alternatively, the work of Katsumata et al. (2005) showed that a defined lysine deficiency (about a 40% of reduction in recommended dietary lysine levels) in finishing pigs' diets was an effective way of increasing IMF without affecting performance. Our results suggest that increasing dietary monounsaturated FA by including crude olive pomace oil may be another good nutritional strategy to both increase IMF content in the LM of pigs and achieve a good performance.

*Fatty acid composition of backfat and Longissimus muscle*

The FA profile of both the backfat and LM was affected by the dietary fat, which is in agreement with the literature (Miller et al., 1990; Vilarrasa et al., 2015). In particular, the use of O or OA as an alternative to PO reduced saturated FA and increased the unsaturated FA to saturated FA in both the backfat and LM. Other studies have reported that reducing saturated FA while increasing monounsaturated FA content in meat has health benefits for consumers (Mateos et al., 2019). Specifically, it has been observed that including olive pomace cake in growing-finishing pig diets makes it possible to reduce saturated FA in porcine adipose tissue (Ferrer et al., 2020). Overall, animals fed O lead to meat products with more IMF, rich in monounsaturated FA, with high FA digestibility values and good performance parameters. Thus, this pork should result in both better sensory-perceived and healthier products. Similar effects were obtained when OA was used blended with a common saturated fat source such as PO. In addition, it is important to note that the use of fat by-products could also reduce feeding costs, as they usually have competitive prices.

In conclusion, crude olive pomace oil can be included at 5% in growing-finishing pig diets to obtain a meat rich in monounsaturated FA and low in saturated FA content with high fatty acid digestibility values and performance. Moreover, the inclusion of crude olive pomace oil lead to a higher IMF content in the *Longissimus* muscle. Another dietary strategy is to include olive pomace acid oil blended with crude palm oil in feed formulation, which did not negatively impact fat utilisation or performance. In addition, including this by-product reduced feed costs, resulting in a swine production of high-fat content crossbreeds that is more efficient and environmentally sustainable.

## Ethics approval

Not applicable. The staff at Nial farm facilities looked over the animal continuously.

## Data and model availability statement

None of the data was deposited in an official repository. Available upon request.

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## Declaration of interest

The authors declare that partial funding was received from bonÀrea AGRUPA. M. Balart and M. Verdú both work for bonÀrea AGRUPA. All authors contributed to analysing and interpreting the data and therefore declare no conflict of interest.

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