Determination of carcase yield, sensory and acceptance of meat from male and female pigs with dietary supplementation of oregano essential oils

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ABSTRACT

The aim was to determine the dietary supplementation of oregano essential oil (OEO) to male and female pigs on carcase performance, sensory characteristics and consumer acceptability of meat. A total of 48 pigs (Landrace × Yorkshire) of 18.5 ± 5.4 kg live weight were randomly allotted into one of four experimental diet groups each containing 12 pigs. Each group was fed a commercial diet supplemented with 0 ppm (control), 1000 ppm, 2000 ppm or 3000 ppm OEO. No difference (p > 0.05) by OEO supplementation nor by gender was observed in average daily gain (0.56 kg/d), daily feed intake (2.5 kg/d), slaughter weight (94.1 kg), and cold carcase weight (71.4 kg). Pigs receiving 2000 ppm OEO had higher (p < 0.05) cold carcase yield (77.4%) than the other treatments and it was higher in females (76.9%) than in males (74.3%). Pigs with 1000 and 2000 ppm OEO showed higher carcase length and carcase width. Loin yield was higher (p < 0.05) in pigs fed 2000 ppm (28.8%) and leg yield of pigs fed all level of OEO was lower (p < 0.05) than the control group. Females showed better values of carcase performance. Meat from pigs receiving 2000 ppm OEO was evaluated by the trained panellists as the best in colour and it also showed the highest consumer acceptability of colour, flavour, texture and overall liking. The supplementation of 2000 ppm OEO in pig diets is suggested to achieve good carcase performance and consumer acceptability.

HIGHLIGHTS

- Supplementation of pigs with oregano essential oil helps to produce better carcase performance and cut yields.
- Oregano essential oil improves meat quality and may make supplementation of pig profitable.
- The supplementation of 2000 ppm oregano essential oil in pig diets is suggested to achieve good consumer acceptability.

Introduction

Phytogenic feed additives have recently gained increasing interest, especially for use in swine and poultry. This appears to be strongly driven by the complete ban in 2006 on most antibiotic feed additives within the European Union, because of the possible risk of generating antibiotic resistance in pathogenic microbiota. The active chemical compounds of plant extracts or their essential oils are promising alternatives in protecting the health of meat animals as these supplements have antioxidant properties and also seem to act as a growth promoter comparable to antibiotic (Ri et al. 2017). There is evidence that natural oregano essential oil (OEO) can improve all aspects of the meat production chain including improvements in productive performance and carcase and meat quality (Valenzuela-Grijalva 2017). The beneficial impact of herb extracts in animal feed are due to their potential to deliver not only health benefits, but enhance appetite, optimise weight gain and improve meat production (Bahelka et al. 2011; Tan et al. 2015). The compounds of essential oils that cause these effects are eugenol, cinnamaldehyde acid, thymol and carvacrol; these are all present in oregano and in a variety of plants. Mexico ranks second in the oregano export market worldwide. The Mexican oregano (Lippia graveolens Kunth) essential oil contains carvacrol (62.2% v/v), p-cymene (6.8% v/v), thymol (5.9% v/v), trans-
caryophyllene (4.9% v/v), γ-terpinene (4.0% v/v) and α-caryophyllene (3.1% v/v) as the major components (Calvo-Irabien et al. 2009), of which thymol and carvacrol presented antimicrobial effect (Hernández-Hernández et al. 2017). OEO from different Mexican regions has showed activity against different microorganisms including pathogens (Hernández et al. 2009; Mendez et al. 2012). Supplementation with dietary OEO may be superior to supplementation with dietary vitamin E in alleviating the negative effects of transportation on pigs by improving the pigs’ antioxidant status (Zou et al. 2016). In pigs, the plant extracts significantly increased water retention and meat redness, it decreased drip loss increased the sensory quality of the fresh meat and the cooked meat (Kołodziej-Skalska 2011). Moreover, when OEO is supplemented to sows an improvement performance of their piglets has been observed, and it was attributed to the reduced oxidative stress since there is an increased systemic oxidative stress during late gestation and early lactation of sows (Tan et al. 2015). Oregano has also been used as a dietary powder in broiler chick assuming that the supplementation could also improve the growth and systemic anti-oxidative defence property of broiler chicks (Ri et al. 2017). Some reports show an increase in yellowness (b) of pork fed 250 ppm OEO (Cheng et al. 2017) without significant influence on the texture of the meat (Janz et al. 2007; Simitzis et al. 2008). The positive effects of essential oils from oregano when used alone or in combination with other essential oils to extend product shelf life by controlling lipid oxidation and improving the quality of meat and meat products, are well documented (Jayasena and Jo 2013), but there is limited information regarding changes in carcase yield and sensory quality of pork due to the effect of OEO. Therefore the objective of this work was to evaluate the effect of Mexican oregano (Lippia graveolens) essential oil as a feed additive on the carcase performance, and acceptability of pork. We hypothesised that supplementation with OEO would improve carcase and cut yields, sensory characteristics of meat and consumer acceptance.

Material and methods

Animal and treatments

A total of 48 pigs (Landrace × Yorkshire) were randomly assigned to one of four experimental groups during the finishing period (the last of the three production stages: nursery, growing and finishing). The weight of the pigs at the beginning of the trial was 18.3 ± 1.25 kg. There were 12 pigs per group (six females and six males), and each group was divided into two subgroups of six animals each (three females and three males) in order to have two replicates per pen/diet. Each group was fed a commercial diet supplemented with 0 ppm (control), 1000 ppm, 2000 ppm or 3000 ppm OEO until they reached approximately 90 kg live weight. The diets (Table 1) were adjusted weekly according to the nutrient demands of pigs during the different production phases. The oregano oil was extracted by steam distillation from flowers and leaves of Mexican oregano (Lippia graveolens); containing carvacrol (62.2% v/v), p-cymene (6.8% v/v), thymol (5.9% v/v), trans-caryophyllene (4.9% v/v), γ-terpinene (4.0% v/v) and α-caryophyllene (3.1% v/v) as the major components (Calvo-Irabien et al. 2009). At the end of the experiment animals were fasted for 16–20 h and transported to an abattoir. The pigs were electrically stunned and slaughtered by exsanguination in a commercial abattoir using conventional methods.

Carcase and cut yields

The carcase characteristics and the yield or cuts were evaluated at 24 h post mortem following the recommendations of Boggs et al. (1998). The yield was calculated as a percentage of the cold carcase weight. The M. longissimus dorsi was sliced (2 cm) frozen using a band saw, and the slices of a given segment vacuum packaged together and returned to the freezer at −25°C until required. At 24 h prior to grilling, the slices were partially thawed at 4°C for 18 h followed by 2 h at room temperature. M.

### Table 1. Ingredients, chemical and energetic composition of diets.

| Ingredients | Nursery | Growing | Finishing |
|-------------|---------|---------|-----------|
| Corn | 563.0 | 666.0 | 756.0 |
| Soybean meal | 376.0 | 283.0 | 208.0 |
| Vegetal plant oil | 30.0 | 17.0 | 10.0 |
| Calcium carbonate | 8.0 | 12.0 | 9.0 |
| Dicalcic phosphate | 13.0 | 6.0 | 5.0 |
| DL-Methionine | 3.00 | 2.67 | 1.96 |
| Sodium chloride | 2.5 | 6.5 | 5.0 |
| Vitamin and mineral premix | 4.5 | 7.0 | 5.0 |
| Oregano essential oil; ppm | – | – | 1000, 2000 or 3000 |

Composition:

| Ingredient | Nursery | Growing | Finishing |
|-----------|---------|---------|-----------|
| CP (g/kg) | 190 | 160 | 140 |
| CF (g/kg) | 40 | 35 | 30 |
| Fat (g/kg) | 65 | 55 | 50 |
| Ash (g/kg) | 78 | 70 | 65 |
| NE (Mcal/kg) | 4.2 | 3.3 | 3.1 |
| Lysine; calculated value (%) | 1.10 | 0.98 | 0.83 |

Nutrient content of diets based on dry matter. CP: crude protein; CF: crude fibre; NE: net energy.
longissimus dorsi was isolated from surrounding muscle and fat. The slices were cooked on a grill to a final core temperature of 72 °C. The slices were halved, and each half placed in a glass Petri dish, covered and held at 60 °C until evaluation.

### Sensory characteristics

Sensory characteristics of pork were evaluated by descriptive analysis (Stone and Sidel 1993). Twelve assessors (men and women, 23–35 years old) were selected and trained in accordance with the ISO 8586:2012 standard (ISO 2012) for colour, flavour and texture of pork. Prior to analysis all assessors participated in five group discussions during which, the colour, flavour, and texture characteristics of meat samples were discussed. A final vocabulary was selected and defined and included three colour (pale, pink, brown), four flavour (pig flavour, fatty flavour, salty, raw flavour), and four texture (fibrous, tender, tough, rubbery) attributes (Stone and Sidel 1993). Meat samples were scored for each attribute on unstructured 10 cm line scales with two descriptive anchors as described in the spectrum descriptive procedure (MacFie et al. 1989). All assessments were conducted in individual booths with red (for flavour and texture) or daylight (colour). When analysing the results, the marks on the line scales are converted into numbers.

### Consumer acceptance

The evaluation of consumer acceptance of meat from all treatments was carried out at the Faculty of Animal Science with the participation of one hundred and nine students and university staff (18–65 years old) as consumer panellists. Tests were performed in a controlled temperature (20 °C) room under normal white fluorescent illumination. The tests were conducted in one single session. Samples (2.5 cm meat cube) were placed in plastic dishes, identified with a three digits random number and presented simultaneously to the consumers, but in random order to each consumer. The order of testing was defined by the inscription of the test codes on the test form. Spring water and unsalted bread were provided to consumers to cleanse their palates between tastings. Consumers were instructed to evaluate meat samples in the following order: colour, flavour, texture and overall liking. Participants rated samples on a 3-point hedonic scale, 1 (dislike extremely), 2 (neither like/nor dislike) and 3 (like extremely) (Lawless and Heymann 2010).

### Statistical analysis

The experiment followed a completely randomised design. Fixed effects were the level of oil inclusion, gender and their interaction. Data obtained for carcase traits and cut yields were subjected to the generalised linear model (GLM) procedure of SAS (SAS 2002). When the F-test for treatment effect was significant, differences between treatment means were determined using the Duncan’s multiple-range test of SAS (2002). Significance was determined at α of 0.05. Sensory data were analysed with the PROC MIXED procedures of SAS (SAS 2002) using treatment and gender as fixed effects. The least squares means ± SEM of yields and carcase characteristics of pigs supplemented with oregano essential oil are presented in Table 2.

### Table 2. Least squares means ± SEM of yields and carcase characteristics of pigs supplemented with oregano essential oil.

| Variables       | Females                   | Males                   |
|-----------------|---------------------------|-------------------------|
|                 | OEO level, ppm            |                         |
|                 | 0            | 1000 | 2000 | 3000 | 0            | 1000 | 2000 | 3000 | OEO G | OEOxG |
| Slaughter weight, kg | 0.53 ± 0.04 | 0.57 ± 0.03 | 0.59 ± 0.03 | 0.59 ± 0.04 | 0.52 ± 0.04 | 0.56 ± 0.03 | 0.58 ± 0.03 | 0.58 ± 0.04 | NS     | NS     | NS     |
| Cold carcass weight, kg | 177.9 ± 8.3   | 95.9 ± 5.0   | 88.7 ± 5.8   | 85.0 ± 8.2   | 83.1 ± 5.2   | 111.5 ± 9.9 | 91.4 ± 5.5 | 79.5 ± 9.4   | NS     | NS     | NS     |
| Cold carcass yield, % | 76.3 ± 2.4   | 72.4 ± 1.5   | 75.8 ± 1.7   | 79.9 ± 2.4   | 68.4 ± 3.1   | 76.3 ± 1.5   | 76.0 ± 2.7 | NS     | NS     | NS     | NS     |
| Carcase length, cm | 80.9 ± 5.2   | 96.8 ± 3.2   | 85.4 ± 3.7   | 97.0 ± 5.1   | 71.6 ± 6.7   | 83.9 ± 3.4   | 83.1 ± 5.9 | NS     | NS     | NS     | NS     |
| Carcase width, cm | 19.6 ± 1.3   | 24.7 ± 0.8   | 22.7 ± 0.9   | 20.4 ± 1.3   | 16.9 ± 1.7   | 19.1 ± 0.9   | 21.2 ± 0.8 | 20.1 ± 1.5 | NS     | NS     | NS     |
| Head yield, %    | 85.0 ± 8.8   | 88.0 ± 0.5   | 89.0 ± 0.6   | 91.0 ± 0.8   | 84.6 ± 0.9   | 87.2 ± 0.9   | 87.8 ± 0.9 | NS     | NS     | NS     | NS     |
| Shoulder yield, %| 270.0 ± 1.6  | 267.0 ± 1.0  | 250.0 ± 1.1  | 223.0 ± 1.6  | 270.0 ± 2.1  | 259.0 ± 0.9  | 233.0 ± 1.0 | 218.0 ± 1.9 | NS     | NS     | NS     |
| Loin yield, %    | 226.0 ± 1.1  | 252.0 ± 1.3  | 291.0 ± 1.8  | 271.0 ± 1.5  | 229.0 ± 1.0  | 253.0 ± 1.2  | 284.0 ± 1.4 | 266.0 ± 1.2 | NS     | NS     | NS     |
| Bacon yield, %   | 155.0 ± 1.2  | 163.0 ± 1.0  | 146.6 ± 1.0  | 188.8 ± 1.3  | 152.0 ± 1.1  | 162.0 ± 1.0  | 147.0 ± 1.2 | 187.0 ± 1.7 | NS     | NS     | NS     |
| Leg yield, %     | 25.7 ± 1.3   | 22.3 ± 0.8   | 22.6 ± 0.9   | 22.0 ± 1.3   | 27.7 ± 1.7   | 24.2 ± 0.9   | 24.2 ± 0.8  | 23.1 ± 1.5 | **     | *      | NS     |

NS: No significant; *p value < .05; **p value < .01; ***p value < .001.

abDifferent superscript in each line denotes significant differences.

SEM: Standard error of mean; OEO: oregano essential oil; ppm: parts per million.
panellist as a classificatory variable and the average of each panellist score as the responding variable. When significant differences were found Duncan’s multiple-range test of SAS (2002) was performed. The consumer test data were analysed with a chi-square test of independence for contingency tables and the results are presented as the relative frequency of the acceptability for each attribute (colour, flavour, texture and overall liking).

**Results**

**Carcase and cut yields**

The results for carcase performance and cut yields are shown in Table 2. The mean of the average daily gain was 0.56 kg and no differences were observed by treatment nor by gender ($p > 0.05$). The feed intake of finishing pigs fed with oregano oil at any of the three levels (1000, 2000 or 3000 ppm) studied was not affected by OEO nor by gender. During the finishing period the average daily intake was $2.5 \pm 0.30$ kg. The final or slaughter weight was aimed to be 90 kg but all pigs were slaughtered at the same day and weights varied from 89.1 to 101.8 kg ($p > 0.001$). The interaction between OEO level and gender was found significant ($p < 0.001$) for cold carcase weight. Pigs receiving OEO at any of the three levels (1000, 2000 or 3000 ppm), when studied showed a tendency to have higher cold carcase weight (71.4 kg) than the control (67.3 kg) and weight of females (74.3 kg) tend to be higher than those of males (68.5 kg). A significant effect ($p < 0.001$) of the interaction between OEO level and gender was found for cold carcase yield. Pigs supplemented with 2000 ppm OEO showed the highest ($p < 0.05$) cold carcase yield (77.4%) and the females presented higher ($p < 0.05$) values (76.9%) than males (74.3%). There was a significant effect of OEO level and gender on carcase length and carcase width. Pigs fed 1000 ppm and 2000 ppm had longest ($p < 0.05$) carcase compared to the control and 3000 ppm groups. Pigs from the control group had the lowest ($p < 0.05$) values of carcase width. Females had the highest values ($p < 0.05$) for carcase length (85.3 cm) and carcase width (21.8%). No difference ($p > 0.05$) was found in head yield, but significant differences ($p < 0.001$) were found in yields of shoulder, loin, bacon and leg without effect ($p > 0.05$) of gender on primal cut yields. Shoulder yield of pigs of the control group (27.4%) and 1000 ppm OEO group (26.4%) had the highest ($p < 0.001$) values compared to those of 2000 ppm OEO (24.1%) and 3000 ppm pigs (21.7%). The highest ($p < 0.001$) loin yield was observed in pigs fed 2000 ppm (28.8%) and the lowest in the control group (22.6%), whereas the highest ($p < 0.001$) bacon yield was found in pigs fed 3000 ppm (18.6%) and the lowest in the 2000 ppm group (14.6%).

The leg yield of pigs fed all level of OEO was lower ($p < 0.05$) than the control group (26.2%) with no difference ($p > 0.05$) between OEO levels (23.1, 23.5 and 23.1% for 1000, 2000 and 3000 ppm, respectively).
Males showed higher ($p < .05$) leg yields (24.7%) than females (23.2%).

**Sensory characteristics**

The sensory attribute evaluation is reported in Figure 1. In assessing the colour of the pork difference was found in the pink colour ($p < .05$), panellists observed that meat from pigs fed 2000 ppm OEO showed a more intense pink compared to the other OEO levels. According to panellists pale and brown colour showed no difference ($p > .05$) due to the level of inclusion of OEO. In the present study, the sensory test showed that meat among OEO treatments had no differences ($p > .05$) in flavour attributes (pig flavour, fatty flavour, salty or raw flavour) (Figure 1). The texture profile of meat showed no difference in attributes such as fibrous texture, soft texture and rubbery texture. However, OEO level had a tendency to increase ($p < .01$) toughness, showing the OEO 3000 ppm the highest values for tough ($p < .01$) and the control group the lowest notes for this attribute ($p < .01$). On the other hand, meat from OEO treatments (1000, 2000 and 3000 ppm) was less tender ($p < .01$) than the control which presented the highest tenderness ($p < .01$).

**Consumer acceptance**

The consumer acceptance of meat attributes is shown in Figures 2-5. The meat colour of pigs supplemented with 2000 ppm was evaluated as ‘like extremely’ by 39% of the consumers ($p < .05$), while meat colour from the other OEO treatments received a low level of acceptance ($p < .05$) as 56% evaluated the colour of the control meat as ‘dislike extremely’ (Figure 2). Consumers expressed that the meat from the 3000 ppm experimental group has the least accepted flavour ($p < .05$) (‘dislike extremely’) while the flavour of the 2000 ppm meat was evaluated as ‘like extremely’ by 41% of consumers ($p < .05$) (Figure 3). Meat from animals receiving 2000 ppm of OEO showed the most acceptable texture ($p < .05$) compared to the control which texture was evaluated as ‘dislike extremely’ ($p < .05$) by 50% of consumers (Figure 4). Meat from OEO 2000 ppm level showed very good overall liking ($p < .05$) by consumers as most of the responses were in the ‘like extremely’ category, while the level 0 ppm and 3000 ppm inclusion were less accepted ($p < .05$) with most of the answers in the ‘neither like/nor dislike’ (0 ppm) or ‘dislike extremely’ (3000 ppm) categories (Figure 5).

**Discussion**

Carcase yield was used to identify which carcases will have a higher proportion of primal cuts. Numerous studies have documented the benefits of essential oils on the performance of swine and poultry (Bahelka et al. 2011; Tan et al. 2015; Ri et al. 2017; Valenzuela-Grijalva 2017) but no reports have been found on the effects of OEO on the yield of pig carcase and primal cuts. Tan et al. (2015) demonstrated that OEO supplementation to sows’ diet improved performance of their piglets and they attributed to the reduced oxidative stress. Also, the replacement of traditional growth
promoters in experiments with broilers yielded benefits in productive performance and carcase and meat quality (Kirkpinar et al. 2014; Ri et al. 2017). Although the effects in pigs have been similar to those observed in broilers, fewer studies have been carried out in pigs, and there is a need to define the types of phytochemicals to be used and the right application time during production (Simitzis 2017). In the present study carvacrol was the major compound (62.2% v/v) of the supplemented OEO, therefore, the results observed might be attributed to carvacrol effect in pigs. Some studies on performance of OEO-
supplemented pigs showed no differences in the growth rate (Ranucci et al. 2015), however, the oregano supplementation seemed to improve the growth performance of the outdoor- but not the indoor-reared animals (Forte et al. 2017). The effect observed of OEO level on carcase yield and the interaction between OEO levels and gender might be due to the action of OEO as a growth promoter and this effect differs between OEO levels where 2000 ppm showed the best result. The use of diet × gender interaction allowed to observe a different response to the diet treatment in males and in females, with the greater effect of OEO diet found in the female pigs showing this higher efficiency with higher cold carcase yields. The differences found in width and length of carcase between male and female pigs due to the supplementation of OEO have not been reported before. The administration of OEO (1000 and 2000 ppm) in pig diets resulted in longer and wider carcasses probably because OEO has beneficial effects on animal health, which is reflected in better carcase characteristics (Ri et al. 2017). It is thought that the addition of OEO to the diet enhances animal health by improving gut flora as well as nutrient absorption and gene expression (Zhai et al. 2018) and according to the results of the present study this effect seems to be higher in female than in male pigs. Several studies have been conducted using OEO, alone or mixed with other spices and plants, to supplement the diet of weaning pigs and finishing birds, or to use it as an ingredient in meat products to add or enhance functional properties. The results are inconsistent, possibly caused by the origin of the essential oils or herb species, the quantity added to the feed, or the environmental conditions used in the trial, to name a few (Henn et al. 2010; Zeng et al. 2015). But probably one of the most important factors is the content of carvacrol in the essential oils used as it differs between oregano species (Teixeira et al. 2013; Mechergui et al. 2016). Also aromatic herbs and essential oils are often claimed to improve the flavour and palatability of feed, thus increasing voluntary feed intake resulting in improved pig performance equal to that of pigs fed antibiotics (Li et al. 2012). Carcase quality is determined by a set of factors, including body conformation, which affects carcase yield, and the characteristics of the meat and fat produced. The evaluation of the carcases allows classify them according to the muscle yield of the primal cuts with the greatest market value: the loin and leg. Zeng et al. (2015) exposed the need to investigate the detailed constituents of essential oils in order to assess their different biological effects, only in this way it would be possible to compare different essential oil products and formulate mixtures that optimise their efficacy. The biochemical mechanisms of the effect of essential oils on the improvement of animal health and on carcase and meat quality are still being studied. From these results all OEO levels (1000, 2000 and 3000 ppm) in pig diet appeared to have the best effects on carcase performance and sub-primal yields, and the OEO might have a more pronounced effect on female individuals.
Previously, we had reported the physicochemical properties of meat quality from pigs fed with OEO (Alarcon-Rojo et al. 2013); in that research meat luminosity (L*) was higher in oregano levels of 0 and 1000 ppm, such difference was not observed by the panellists of the present study when assessing the pale colour of meat. Kołodziej-Skalska (2011) investigated the effects of a plant extracts mixture including carvacrol (oregano), cinnamaldehyde (cinnamon), and capsicum oleoresin (Mexican pepper) on the meat quality of pigs. They observed that the treated meat had a higher red colour in the fresh meat. They suggested that plant extracts significantly increased the sensory quality of the fresh meat and the cooked meat. Other study showed that diet supplemented with oregano oil in birds reduced the redness of breast meat and had no difference in breast appearance (Kirkpinar et al. 2014). Some authors have reported that the addition of essential oils did not significantly affect the sensory properties of sausages (Martín-Sánchez et al. 2011; El Adab and Hassouna 2016). These controversial results might be due to the different species of the herb used in animal diet. The trend observed in toughness of meat of the present study appears to be that for high levels of OEO (3000 ppm) tough meat could be achieved. Similar reports have previously been reported measuring instrumental shear force of OEO-treated and untreated meat (Alarcon-Rojo et al. 2013). Also in the present study the panellists considered the untreated meat as the most tender. It is important to mention that in this experiment extremes in colour, flavour and texture were not found. Janz et al. (2007) considered that the inclusion of OEO could positively influence the sensory parameters to improve the quality of the fresh pork meat with a desirable flavour to consume. Many herbs and plant extracts, including oregano, have antimicrobial activities and antioxidant properties, which make them useful as natural animal feed additives. They improve the shelf life of meat products because of a reduction of the lipid oxidation degree (Viuda-Martos et al. 2009) and this antioxidant could affect the meat flavour. Park et al. (2014) used ducks investigate the effect of supplemental dried oregano powder in feed on the productivity, antioxidant enzyme activity, and breast meat quality. They suggested that diets containing oregano powder might beneficially affect antioxidant enzyme activity, improve meat cooking loss, and reduce thiobarbituric acid reactive substance values in breast meat at 5 d of storage in ducks. Oregano and other herbs and spices are also used to improve the sensory characteristics and to extend the shelf-life of frozen food. Pino et al. (2013) compared oregano and sage (0.10% dry plant) as a natural antioxidant in balls of chicken breast and stored at −20°C for 144 h. Herbs were effective in controlling the development of hexanal, an indicator of lipid oxidation. However, the oregano was more effective than sage in preventing the formation of hexanal in chicken meatballs pre-cooked. Recently, Van Haute et al. (2016) showed that the sensorial properties of the meat/fish are inevitably affected when the necessary essential oil concentrations to extend the microbial shelf life are applied. Consumers have become more critical about the use of synthetic additives to preserve food or enhance its colour and flavour; hence, there is a growing trend toward minimally processed foods (El Adab and Hassouna 2016). The use of essential oils in food preservation and their impact on functional and sensory properties will continue been studied.

In this study the meat from pigs fed 2000 ppm OEO was rated the highest consumer acceptability score with respect to colour, flavour, texture and overall liking. The literature on the effects of feeding essential oils, herbal extracts and spices in pigs on the sensory characteristics of the meat is scarce. When supplemented animal feeds with oregano essential oils interesting results were obtained by Forte et al. (2017) who showed that dietary oregano essential oil can be effective in reducing performance losses due to the outdoor-rearing system, increasing the oxidative status of the animal and oxidative stability of the meat, without modifying the meat quality traits and improving consumer perceptions of the meat quality. Similarly Cheng et al. (2017) reported that dietary OEO enhanced the sensory attributes and anti-oxidative status of pork meat by improving IMF and n-3 PUFA proportion and antioxidative capacity. The study of Janz et al. (2007) showed that panellists detected no difference in aroma and flavour of meat from pigs fed essential oils containing oregano. It is generally accepted that meat lipids provide flavour and aroma volatiles that impact on meat flavour, yet the effect of OEO in the sensory quality of pork is far from being understood. Texture was the only attribute showing different results between panellist and consumers. Protein oxidation increases meat product toughness but essential oils of oregano and Rosemary can protect the thiol in pork patties and reduce the disulphide cross-links of the myosin heavy chains avoiding the toughness of meat (Nieto et al. 2013). In general, meat from the 2000 ppm OEO treatment was the best rated from the sensory and consumer point of view. Previous studies of supplementation of pigs with oregano (Ranucci et al. 2015) showed that the meat samples of animals fed
oregano oil, received higher scores for colour, taste and overall liking. OEO has also been added directly to meat products. Van Haute et al. (2016) reported that baking increased the odour acceptability of EO-treated meat and fish, which could be partly due to the volatile nature of EOs, and partly because of the mixing of scents of EOs with meat aromas, which occurs during heat processing. Boskovic et al. (2017) found that thyme essential oil (0.3%) gave a characteristic, desirable odour to minced meat being the odour scores at the limit of acceptability when added at the concentration of 0.6% and unacceptable at the level of 0.9%. The study of Ghabraie et al. (2016) about the antimicrobial effect of essential oils in combinations against five bacteria and their effect on sensorial quality of ground meat has shown that an EO level of 0.05% was the highest organoleptically acceptable. Another report on the potential of chitosan as a possible booster of the antimicrobial activity of OEO showed that chitosan combined with OEO boosts its antimicrobial activity and shows a potential for application in industrial production of fresh pork in modified atmosphere packaging, to achieve shelf-life extension, control of *Listeria monocytogenes* growth, stability of colour and protective effect from oxidation, with low sensory impact (Paparella et al. 2016).

**Conclusions**

The present study contributes to a better understanding of the efficacy of OEO in pig diets to improve carcase performance and consumer acceptability of meat. From these results it can be concluded that supplementation of pigs with 1000, 2000 and 3000 ppm OEO helps to produce better carcase performance and cut yields. Particularly the addition of 2000 ppm OEO in diet led to higher carcase yield in females and higher loin yield in both genders. This study has revealed, that using essential oil can influence sensory properties and consumer acceptance. Meat from pigs fed 2000 ppm OEO, which was perceived by the trained panellists as having an intense pink colour was rated the highest consumer acceptability score with respect to colour, flavour and texture. The meat industry can benefit substantially by taking into account the importance of measuring sensory characteristics of meat particularly when pigs have been supplemented with essential oils. Therefore, our results suggest that OEO, particular at 2000 ppm, can be included in pig feed as a natural supplement to achieve good carcase performance, sensory characteristics and consumer acceptability. Also, the potential effects of OEO on meat quality may make it profitable to supplement pig feed with this essential oil.

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**Ethical approval**

All procedures have been conducted in accordance with the guidelines set out by the Universidad Autónoma de Ciudad Juarez in the Code of Practice for the Care and Use of Animal for Experimental Purposes and were reviewed and approved by the Ethics Committee on Use of Animal for Research of the Universidad Autónoma de Ciudad Juárez.

**Disclosure statement**

The authors declare that they have no interest or benefit arising from the direct applications of this research.

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