Dietary lecithin and inulin improved growth performance and eating quality of pork

5A-120

Final Report prepared for the Australasian Pork Research Institute Limited (APRIL)

By

Frank R. Dunshea [1,2], Xiying Li[1,3], Robyn D. Warner[1], Fan Liu[4], Helen Grigg[4], Ashlee Adams[4] and Henny Akit[5]

[1] School of Agriculture, Food and Ecosystem Sciences, Faculty of Science, The University of Melbourne, Parkville, VIC 3010, Australia; [2] Faculty of Biological Sciences, University of Leeds, United Kingdom [3] School of Food and Pharmaceutical Engineering, Zhaoqing University, Zhaoqing 526061, China; [4] Rivalea (Australia) Pty Ltd, JBS Australia Pork Division, Redlands Road, Corowa NSW 2646, Australia; [5] Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

July 2025

Australasian Pork Research Institute Ltd
APRIL

Executive Summary

Australian pork has historically been considered tough, dry, and of poor flavour compared to other meats, which are attributed to the high prevalence of boar taint, low intramuscular fat (IMF) content, and pork typically being overcooked. Attempts have been made to improve the eating quality of Australian pork. Previous studies have shown that IMF has a positive correlation with meat tenderness, juiciness, and flavour, while collagen content has a negative correlation with meat tenderness. Therefore, increasing the IMF and reducing the collagen content can improve the eating quality of pork.

Collagen and IMF are affected by various factors, including genetics, diet, sex and live weight of pigs. Compared to other factors, modifying diets is a convenient and simple way to alter collagen and IMF properties. Dietary supplementation with lecithin and inulin has been shown to enhance growth performance, carcass traits, and pork physical properties. Therefore, they were chosen as a dietary supplement in this study.

Lecithin is a byproduct of oilseed processing that can improve pig feed efficiency through improved fat emulsification and utilisation. Also, lecithin supplementation can reduce the collagen content and chewiness of pork *longissimus thoracis et lumborum* (LTL). However, these studies only examined the collagen content and physical properties of pork; the solubility of collagen and sensory properties of pork were not investigated. Moreover, these studies were conducted on LTL, which has a low collagen content. Other muscles, such as the biceps femoris (BF), have a higher collagen content and may respond more noticeably to lecithin. Therefore, LTL and BF were included in this study.

Inulin is a commercially available dietary fibre source that has beneficial effects on intestinal health and the metabolism of animals. Dietary supplementation with inulin increased dressing percentage, growth performance, and loin-eye area in one study. We have recently shown that dietary inulin significantly increased marbling scores of pork LTL, although IMF was not measured.

Therefore, this study aimed to 1) determine the effects of sex, dietary lecithin and inulin on growth performance and carcass traits of pigs; and 2) determine the influence of sex, dietary lecithin and inulin supplement on physicochemical and sensory properties of pork. It was hypothesized that 1) dietary supplement of lecithin improves feed efficiency and increases feed intake and weight gain in female pigs; 2) lecithin supplementation reduces collagen content in pork, resulting in higher tenderness; 3) dietary supplementation of inulin increases live weight gain and carcass weight; and 4) inulin supplementation increases intramuscular fat content and consumer likings of pork.

A total of 56 female and 56 immunocastrated male cross-bred pigs (Large White × Landrace × Duroc) were selected for the experiment at 15 weeks of age (51 ± 5.4 kg mean ± standard deviation). The animal phase experiment was conducted in a research farm in Corowa, NSW, Australia (Rivalea Australia). The pigs were individually housed and allocated to a 2×2×2 factorial arrangement of factors based on sex (female vs immunocastrated male), dietary lecithin (0% vs 0.8%), and inulin (0% vs 2%), and diets were fed for 43 days. At the end of the study, the pigs were slaughtered commercially, and samples of LTL and BF were obtained 24 h later after chilling. These samples were analysed for chemical and objective meat quality as well as consumer sensory analyses. The sensory analysis consisted of hedonic measures of eating quality (tenderness, flavour, juiciness, and overall liking) and a Check-All-That-Apply (CATA) survey where consumers choose from a list of pork-specific terms.

Dietary supplementation of 2% inulin and 0.8% lecithin to pigs had limited effects on growth performance and carcass traits, although dietary lecithin improved FCR. However, dietary inulin increased IMF content, especially in the BF, resulting in improved tenderness and flavour in both LTL and BF. Additionally, CATA results showed that LTL from immunocastrated males supplemented with inulin were less dry and fibrous. On the other hand, lecithin supplementation increased collagen solubility, mostly in LTL. Lecithin supplementation increased roasted flavour and tenderness of LTL from immunocastrated males. Dietary supplementation of inulin and lecithin has the potential to alter muscle composition and thus improve the eating quality of pork. Future studies can be conducted on the mechanism(s) of the effects of inulin and lecithin on meat quality.

As a result of the outcomes in these studies, the following recommendations have been made: 1) Further research should be conducted to determine whether the improved eating quality in response to inulin is an effect specific to inulin or whether other less expensive and more readily available

fibre sources could have similar benefits; 2) Dietary lecithin may be used as a strategy to improve the flavour eating quality of pork, and 3) The CATA method should be incorporated in future pork sensory studies.

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1. Introduction

Australian pork has historically been considered tough, dry, and of poor flavour compared to other meats, which is attributed to the high prevalence of boar taint, low intramuscular fat (IMF) content, and pork typically being overcooked (Bennett, 1997; Channon et al., 2017). Attempts have been made to improve the eating quality of Australian pork. Previous studies showed that IMF had a positive correlation with meat tenderness, juiciness and flavour, while collagen content negatively correlated with meat tenderness (Choi et al., 2019; Li et al., 2022; Li et al. 2024). Therefore, increasing the IMF and reducing the collagen content can improve the eating quality of pork.

Collagen and IMF are affected by various factors, including genetics, diet, sex and live weight of pigs (D'Souza & Mullan, 2002; Li, Ha, Warner, Lealiifano, et al., 2024). Compared to other factors, modifying diets is a convenient and simple way to alter collagen and IMF properties. Dietary supplementation with lecithin and inulin has been shown to enhance growth performance, carcass traits, and pork physical properties (Akit et al., 2018; Dunshea et al., 2024). Therefore, they were chosen as a dietary supplement in this study.

Lecithin is a byproduct of soybean and other oilseed processing, rich in linoleic acid and other unsaturated fatty acids (Soares & Lopez-Bote, 2002). Akit et al. (2018) found that dietary supplementation of 5 g/kg lecithin improved pig feed efficiency during 35 days of feeding, and that female pigs had higher weight gain and feed intake compared to immunocastrated males in the first 14 days of feeding. Also, lecithin supplementation of 4, 20 and 80 g/kg reduced collagen content and chewiness of pork *longissimus thoracis et lumborum* (LTL) (Akit et al., 2014). However, these studies only examined the collagen content and physical properties of pork; the solubility of collagen and sensory properties of pork were not investigated. Moreover, these studies were conducted on LTL, which has a low collagen content. Other muscles, such as *the biceps femoris (BF),* have a higher collagen content and may respond more noticeably to lecithin. Therefore, LTL and BF were included in this study.

Inulin is a commercially available dietary fibre source that has beneficial effects on intestinal health and the metabolism of animals (Wang et al., 2019). Dietary supplementation of 0.5% inulin increased dressing percentage and tended to increase average daily gain (ADG) and loin-eye area (Wang et al., 2019). In addition, Dunshea et al. (2024) reported that supplementation of 50 g/kg in the diet significantly increased marbling scores of pork LTL. Nevertheless, chemically analysed IMF content was not reported in these studies, and the effects of inulin supplementation on pork eating quality remained unclear.

Therefore, this study aimed to: 1) determine the effects of sex, dietary lecithin and inulin on growth performance and carcass traits of pigs; and 2) determine the influence of sex, dietary lecithin and inulin supplement on physicochemical and sensory properties of pork. It was hypothesized that 1) dietary supplementation of lecithin improves feed efficiency and increases feed intake and weight gain in

female pigs; 2) lecithin supplementation reduces collagen content in pork, resulting in higher tenderness; 3) dietary supplementation of inulin increases live weight gain and carcass weight; and 4) inulin supplementation increases intramuscular fat content and consumer likings of pork.

2. Methodology

Animals, experimental design, housing
The animal experimental procedures had prior institutional ethical approval (protocol ID:23-031) under the requirement of the New South Wales Prevention of Cruelty to Animals Act (1979) in accordance with the NH&MRC/CSIRO/Australian Animal Commission Australian Code of Practice for the Care and Use of Animals for Scientific Purposes.

A total of 56 female and 56 male cross-bred pigs (Large White × Landrace × Duroc) were selected for the experiment at 15 weeks of age (51 ± 5.4 kg body weight for mean ± standard deviation). The animal phase of the experiment was conducted at a research farm in Corowa, NSW, Australia. The pigs were allocated to a 2×2×2 factorial arrangement of factors based on sex (female vs immunocastrated male), dietary lecithin (0% vs 0.8%), and inulin (0% vs 2%). The basal diet was wheat and barley-based and was formulated to meet and exceed NRC requirements (National Research Council, 2012) (13.6 MJ/kg digestible energy and 0.8% available lysine) (Table 1). The lecithin diet was formulated by replacing 0.8% wheat with 0.8% de-oiled soy lecithin powder (Redox Ltd, Minto, Australia). The inulin diet was formulated by replacing 2% wheat with 2% inulin powder (90% purity, BENEO-Orafti, Belgium). The experimental pigs were housed individually in an enclosed, climatically controlled shed with an average ambient temperature of 20 ºC. All the pigs were fed ad libitum and had free access to water via nipple drinkers. Male pigs received the second dose of the immune-castration vaccine at 18 weeks of age.

Pigs were weighed at the start of the feeding experiment and one day before slaughter. The feeding duration of the experiment was 43 days. Feed delivery and refusals were weighed weekly to calculate the average daily feed intake. The feed conversion ratio was calculated as the ratio between average daily feed intake and average daily gain.

All the experimental pigs were sent to a commercial abattoir (Corowa, Australia) for slaughter after being housed in a lairage for approximately 18 hours. All the carcasses were weighed according to the Australian Trim 1 standard (i.e., head on, trotters on, and visceral tissues removed). The carcass backfat thickness and loin depth were measured at the P2 site (65 mm from the midline over the last rib; Hennessy Chong's probe measurement). The dressing percentage was calculated by the ratio between the carcass weight and the endpoint liveweight.

Sample preparation and objective meat quality
Nine female and nine male carcasses from each dietary treatment were randomly selected for the subsequent meat quality evaluation after an overnight chilling process. The BF and LTL samples were taken from the left side of the selected

carcasses. Each meat sample was divided into sub-portions for measurement of meat colour, drip loss, cooking loss, shear force, IMF, collagen, and sensory evaluation.

A 25 mm thick steak was dissected from the LTL and BF muscles for meat color measurements (lightness (L*), redness (a*), and yellowness (b*)). The colour was measured in triplicate after 10 min using a chromameter (CR-400, Minolta, Osaka, Japan). The chromameter was calibrated on a white tile with D65 illumination and a 2° standard observer. Other sample portions were stored in a -20°C freezer until cooking loss and shear force measurements were taken.

A cube sample (40×40×40 mm; av. 65 g) was cut from the LTL and BF muscles for drip loss measurement. The cube samples were weighed, placed in the nylon net, and sealed in the polypropylene container. The samples were stored in the fridge at 2°C. After 24 hours, the cube samples were taken from the container, and excess moisture was absorbed using a kitchen towel before weighing. The drip loss was calculated as a ratio of moisture loss and initial weight.

The meat sample portion for cooking loss and shear force was sealed in a zip-lock bag and stored at -20 °C before analysis. A frozen portion of the meat sample (60×50×40 mm) was cooked in a water bath at 70°C for 30 min and immediately placed in ice water for 35 min. The cooked samples were dried with a paper towel before weighing. The difference between the pre-cooked and post-cooked weights was used to calculate the cooking loss. Each cooked sample was cut into six strips (40×10×10 mm) with the longitudinal direction parallel to the myofibre for the shear force measurement. The muscle strips were placed in a Warner-Bratzler attachment in shear force equipment (Mecmesin® BFG 500N, Slinfold, UK; set at 200 mm/min speed).

Chemical analyses

Total and soluble collagen content were determined using the AOAC method 990.26 (Kolar, 1990) for quantification of hydroxyproline as described by Starkey et al. (2015), with some modifications. Pork samples were freeze-dried for 3 days and then powdered using a knife. Water content was calculated using the weights before and after freeze-drying. A triplicate of 0.2 g freeze-dried powder was hydrolysed in 3.5 M H_2SO_4 for 16 h at 105 °C. For soluble collagen, 1.0 g of powder was added to 10 mL of water and heated in a water bath at 80 °C for 2 h, with vortexing every 30 min. A standard curve was plotted using a hydroxyproline solution with concentrations of 0, 1.2, 2.4, 3.6, 4.8 and 6.0 µg/ml in H_2O. A conversion factor of 7.25 was used to convert hydroxyproline content to collagen content (Colgrove et al. 2008). The total collagen content was expressed in milligrams per gram of fresh meat. Collagen solubility was expressed as the percentage of soluble collagen divided by total collagen content.

Intramuscular fat (IMF) content was determined using the AOAC method 991.36 (AOAC, 1995), with some modifications. Briefly, triplicate samples of 3.5 g freeze-dried samples were powdered and wrapped in a folded Watman no.1 filter paper. Each sample was placed in a Soxhlet apparatus using diethyl ether as extraction

solvent. Intramuscular fat content was expressed as percent fat of fresh meat weight (w/w).

Sensory evaluation

Sensory evaluation was conducted at The University of Melbourne. The project was approved by The University of Melbourne Human Ethics Committee (reference number: 30127; grant date: 13th June 2024). Two hundred and forty consumers were recruited. They were all over the age of 18, were willing to eat meat products, had eaten Australian pork in the past three months, did not have any allergies or ethical objections to pork consumption, consented to provide personal information including yearly income and consumption of the household, and did not have any coffee or strong-tasting foods within one hour of participating. All consumers had given informed consent via the statement "I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written plain language statement to keep" where they were required to sign the consent form before participating. They were able to withdraw at any time and their responses were kept confidential. All possible benefits and risks were provided to them on the plain language statement.

Sensory evaluation was conducted on 4 days with 60 consumers per day. Within each day, there were three sessions and there were 20 consumers per session. Consumers were required to attend a briefing at the start of each session where they were told the basic information about the project and the questionnaire. After the briefing, they signed the consent form and were directed to their designated booth.

All samples for sensory evaluation were thawed for 24 h at 0-2°C. On the following day, samples were taken out to a boning room (maintained at 8°C) for cutting. From each muscle, five steaks of 4.0 × 4.0 × 2.5 cm^3 were cut out. They were cut perpendicular to the muscle fibre direction. All visible fat and connective tissue were trimmed off. The pH and temperature were measured with a portable pH/temperature meter (TPS WP-80, TPS, Brendale QLD, Australia) equipped with an electrode (model TPS-121234, TPS, Brendale QLD, Australia) on three random spots of the leftover pieces. The steaks were randomised within a day across sessions. They were placed on a laminated A4 paper with their sample ID, random number codes and cooking arrangements. The steaks, together with the A4 paper, were 50% vacuum-packed (50% air was taken out) and stored at 0-2°C until cooking.

On the following day, the clamshell grill (Silex S-Tronic Single Grill, Silex, Marrickville NSW, Australia) was turned on 2 h prior to the start of the first session. The temperature was set to 160°C on both sides. While waiting, the booths were set up. Each consumer was provided with a fork, a piece of napkin, a cup of 10% apple juice (diluted with water) and a few crackers. The apple juice and crackers were used to cleanse their palate between samples. Fifteen minutes before the session started, a set of starter samples was cooked to determine the cooking time. The starter samples were random steaks cut from the leftover samples of the same size. A thermocouple was inserted into the samples to detect the internal temperature of the starter samples. The cooking time was 3 min 45s to 4 min. Then, the steaks for serving were cooked to around 68°C, rested for 30s, cut in halves and placed in a plastic sauce cup (70 ml, Genfac Plastics, Melbourne VIC, Australia) for

serving. The final temperature of the steaks was around 72°C. Each muscle gave 10 serving pieces, corresponding to 10 consumers. Each consumer was given a "Link" sample as their first sample. The "Link" sample was pork LTL from a previous project (Li et al. 2024). This sample was used to familiarise consumers with the questionnaire and was not included in the data analysis. Excluding the "Link" sample, each consumer tasted six servings.

The questionnaire (supplementary materials) consisted of two parts. The first part was the demographics questionnaire. It included gender, age, cultural heritage, household size, parent or guardian of any children aged 18 or younger, occupation of the main income earner, yearly income of the household and pork consumption frequency. The demographics of the consumers were shown in Appendix 1.

The second part was the sensory evaluation questionnaire for each sample. It included three types of questions. First, consumers assessed sensory attributes on hedonic scales from 0 to 100. The wording on the two extremes of the scale were: tenderness – 0 (not tender) and 100 (very tender); juiciness – 0 (not juicy) and 100 (very juicy); liking of flavor – 0 (dislike extremely) and 100 (like extremely); overall liking – 0 (dislike extremely) and 100 (like extremely).

Consumers were then asked whether they detected any off-flavour, and they selected either "yes" or "no". Each sample was also rated in terms of purchase intent by consumers: 1 - "I would definitely not buy it", 2 – "I would probably not buy it", 3 – "I might buy it", 4 – "I would probably buy it" and 5 – "I would definitely buy it". Consumers were also asked to rate the quality of each sample: 1 – "unsatisfactory", 2 – "good everyday", 3 – "better than good everyday" and 4 – "premium". Success was defined as when consumers selected 5 (I definitely would buy it) and 4 (I would probably buy it) in purchase intent as well as 4 (Premium) and 3 (Better than good everyday) in quality grading.

The last type of question was check-all-that-apply (CATA) where consumers selected all the words or phrases which best described the sample they just tasted. It had 21 terms, including 15 flavour terms: "faecal", "fatty", "sweet", "roasted", "tasteless", "sour", "metallic", "mushroom", "fruity", "savoury (umami)", "familiar", "clean", "buttery", "porky" and "earthy"; six textural terms "dry", "soft", "chewy", "fibrous", "juicy" and "tender". The displayed order of these terms was different on each questionnaire. These terms were selected decided with reference to Silva et al. (2023) with some modifications.

Statistical analysis

Animal growth performance and carcass quality data were analysed by linear mixed model for the effects of sex, lecithin, inulin and their interactions (SPSS statistics 26.0, IBM, Armonk, NY, USA).

The pH and chemical data were analysed using R (R Core Team, 2021) in RStudio (Posit, PBC, Boston, US). Data was analysed using a linear mixed-effects model with packages "lme4", "jtools" and "emmeans". The fixed model was muscle + sex + lecithin + inulin + muscle × sex + muscle × lecithin + muscle × inulin + sex × lecithin + sex × inulin + lecithin × inulin and the random model was slaughter day + hot

carcass weight. The predicted means and *P* values were recorded, and the standard errors of differences were calculated.

Sensory data were also analysed using R. For line scale data, data was analysed by a linear mixed-effects model with the fixed model was muscle + sex + lecithin + inulin + muscle × sex + muscle × lecithin + muscle × inulin + sex × lecithin + sex × inulin + lecithin × inulin and the random model was day/participant + carcass. The probability of normal (no off-flavour), the probability of success in purchase intent, and CATA data were analysed by a generalized linear mixed-effects model with logarithmic transformation for the probability and binomial distribution. The fixed and random models were the same as that of line scale data. The CATA data was also visualized using correspondence analysis using the package "FactoMineR" and "factoextra" in RStudio.". A P-value of 0.05 was considered significant.

3. Outcomes

3.1 Results

The effects of inulin and lecithin supplementation on growth performance and carcass traits of pigs are shown in Table 2. While there were very few main effects of Inulin or lecithin on these parameters, Inulin supplementation did reduce loin depth (52.7 vs 50.3 mm, P<0.05) while Lecithin supplementation tended to reduce feed conversion ratio (2.45 vs 2.38, P<0.10) and dressing percentage (76.6 vs 76.0%, P<0.10). As anticipated, immunocastrated male showed higher final live weight (98.6 vs 99.1 kg, P<0.05), average daily gain (1.11 vs 1.13 kg/d, P<0.05), hot carcass weight (74.8 vs 75.1 kg, P<0.05), average daily feed intake (2.58 vs 2.63 kg/d, P<0.05) and and lower dressing percentage than females (75.8 vs 75.1%, P<0.05) (Table 2).

Inulin supplementation reduced drip loss (6.70 tovs 5.99%,, P<0.05) especially in immunocastrated males (6.85 vs 5.53%) as indicated by an interaction between inulin treatment and sex (P<0.10) (Table 3). Inulin supplementation reduced cooking loss (31.3 vs 29.0%, P<0.05) especially in immunocastrated males (34.2 vs 29.5%) as indicated by an interaction between inulin treatment and sex (P<0.05). Inulin tended to reduce redness (a*) in the LTL of immunocastrated male, and inulin tended to have opposite effects on redness of LTL between sexes. Lecithin supplementation tended to reduce WBSF in castrated males. Pork from immunocastrated males exhibited higher cooking loss (28.5 vs 31.9%, P<0.01) and WBSF (49.2 vs 54.5 N, P<0.01) than pork from females. The BF exhibited lower drip loss (4.22 vs 8.59%, P<0.01) and lightness (L*) (45.9 vs 50.1, P<0.01), but higher redness (a*) (10.0 vs 5.75, P<0.01), yellowness (b*) (3.15 vs 2.66, P<0.01) and WBSF (56.7 vs 47.1, P<0.01) than LTL (Table 3).

Inulin and lecithin supplement had different effects on the chemical properties of the two muscles. In BF, inulin supplementation increased IMF content (1.54 vs 1.33%, P<0.05) and tended to increase collagen solubility (9.55 vs 10.1%, P<0.10) particularly in immunocastrated males (8.94 vs 10.9%) as indicated by the significant

interaction (P<0.05) between sex and In (Table 4). In the LTL, lecithin increased collagen solubility (8.26 vs 9.00%, P<0.001) and tended to decrease collagen content in females (4.59 vs 4.22 mg/g) as indicated by the interaction (P<0.05) between sex and inulin. Without lecithin, inulin tended to increase IMF content (0.88 vs 1.12%) as indicated by a trend towards an interaction (P<0.10) between Le and IN. Immunocastrated males had higher collagen content (4.81 vs 4.40 mg/g, P=0.001) and lower collagen solubility (8.14 vs 9.11%, P<0.001) than female pigs.

As for sensory evaluation, inulin increased flavour score (46.1 vs 49.7, P<0.05) and tended to increase tenderness (41.0 vs 45.1, P<0.10) and overall liking scores (45.4 vs 48.9, P<0.10) in BF (Table 5). Inulin supplementation also increased probability of success (quality grading) in BF (0.207 vs 0.296, P<0.05) (Table 6). Lecithin increased flavour score in the LTL of immunocastrated males (41.4 vs 51.9, Table 4) as indicated by the sex x Le (P<0.05) and Le x In (P=0.05) interactions. Without inulin, lecithin increased flavour score in LTL (46.7 vs 51.0). In BF, females showed higher flavour scores than immunocastrated males (49.9 vs 45.9, P<0.05)), while in LTL, immunocastrated males had higher scores in tenderness (51.3 vs 46.7, P<0.05) and juiciness (48.7 vs 45.0, P<0.05).

The CATA results showed that the control samples were dry (Fig. 1). Pork from pigs with lecithin supplementation was sour and clean. Pork from pigs with inulin in their diets was savoury. Pork from pigs with supplementation of both lecithin and inulin 2% was tender. In individual muscles, inulin supplementation decreased the probability of selected for “fibrous” (0.392 vs 0.257, P<0.05) and increased that of “savoury (umami)” (0.0003 vs 0.0009, P<0.05) and “tender” (0.176 vs 0.256, P<0.05) in BF (Table 7). The BF from immunocastrated male pigs with lecithin supplementation was more “familiar” than those without lecithin supplement (0.106 vs 0.161), but lecithin had an opposite effect on female BF (0.174 vs 0.117) as indicated by the Sex x Le interaction (P<0.05). In LTL, pork from pigs fed on diets with inulin was more “tender” (0.258 vs 0.343, P<0.05)) and less “clean” (0.346 vs 0.239, P<0.05). Inulin also reduced the probability of selected for “dry” (0.245 vs 0.170) and “fibrous” (0.243 vs 0.160) in LTL of immunocastrated male pigs as indicated by the Sex x In interactions (P<0.05 and 0.01, respectively). The LTL from immunocastrated males with lecithin supplementation was more “roasted” (0.169 vs 0.252) and “tender” (0.310 vs 0.404) as indicated by the Sex x Le interactions (both P<0.05). Without lecithin, inulin supplementation reduced the probability of selected for “tasteless” in LTL (0.119 vs 0.060) as indicated by the In x Le interactions (P<0.05).

3.2 Discussion

The main findings of this study were that 1) inulin and lecithin supplementation had little effects on growth performance and carcass traits; 2) inulin supplementation reduced drip loss in both sexes and cooking loss in immunocastrated males; 3) inulin supplementation increased IMF content in BF, while lecithin increased collagen solubility in LTL; 4) the BF from pigs with the inulin supplement showed higher scores in flavour and was regarded as more savoury, tender and less fibrous; 5) the LTL from pigs fed on diets with inulin was less clean and more tender, while lecithin supplementation increased flavour scores in LTL of immunocastrated male.

Therefore, hypotheses 1) and 3) were rejected and hypotheses 2) and 4) were partly accepted.

In the present study, inulin supplementation reduced loin depth and had little effects on growth performance. The effects of inulin on growth performance and carcass traits varied in previous studies. Dunshea et al. (2024) reported that feeding pigs with 50 g/kg dietary inulin for 35 days increased average daily gain, leading to an increase in carcass weight. However, a meta-analysis suggested that inulin supplementation had little effects on average daily gain (Metzler-Zebeli et al., 2017). Wang et al. (2019) found that supplementation of 5 g/kg inulin for 96 days increased carcass weight and dressing percentage and tended to increase loin eye area. The authors suggested that as a dietary fibre source, inulin played a critical role in regulating intestinal health and microbiota (Jha & Berrocoso, 2015). Dietary inulin increased serum Insulin-like growth factor-I and insulin levels, resulting in elevated muscle growth (Wang et al., 2019; Yano et al., 1999). The lack of effects of dietary inulin on growth performance and carcass traits in the present study may be due to the small amount added into the diet and (or) a shorter feeding period.

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Table 1. Diet Formulations

	Control	Lecithin	Inulin	Lecithin + Inulin
Ingredients, %				
Wheat	68	67	66	68
Barley	10	10	10	10
Millrun	5	5	5	5
Canola meal	11.5	11.5	11.5	11.5
Tallow	1	1	1	1
Salt	0.4	0.4	0.4	0.4
Limestone	1.2	1.2	1.2	1.2
DL-Methionine	0.05	0.05	0.05	0.05
Lysine-HCl	0.5	0.5	0.5	0.5
Threonine	0.18	0.18	0.18	0.18
Isoleucine	0.02	0.02	0.02	0.02
Soy lecithin	-	0.8		0.8
Inulin	-		2.0	2.0
Premix [1]	0.15	0.15	0.15	0.15
Calculated nutrients, %				
Dry matter				
Digestible energy (MJ/Kg)	13.6	13.7	13.4	13.6
Crude protein	15.5	15.4	15.3	15.5
Ether extract	3.0	3.4	3.0	3.0
Fibre	3.4	3.4	3.4	3.4
Ash	4.2	4.2	4.2	4.2
Available Phosphorus	0.37	0.38	0.38	0.37
Available Calcium	0.58	0.57	0.58	0.58
Available Lysine	0.84	0.84	0.83	0.84

[1] Supplied per kilogram of diet: vitamin A, 8420 IU; vitamin D3, 1579 IU; vitamin E, 26 IU; vitamin K, 1.1 mg; vitamin B1, 1.1 mg; vitamin B2, 4.3 mg; vitamin B6, 1.6 mg; vitamin B12, 10.6 mg; niacin, 15.8 mg; pantothenic acid, 36.8 mg; biotin, 0.1 mg; iron, 63 mg; iodine, 0.5 mg; manganese, 63 mg; selenium, 0.3 mg; zinc, 126 mg; cobalt, 0.32 mg; chromium, 0.2 mg; copper, 21 mg

Table 2. Effect of sex, inulin and lecithin supplementation on carcass traits.

	Castrate				Female					
Lecithin (Le)	0		0.80%		0		0.80%		SE	Significance
Inulin (In)	0	2%	0	2%	0	2%	0	2%		
Days, entry-slaughter	36.9	42.5	41.5	41.6	44.3	45.5	41.3	47.0	2.7	Sex*
Live weight, Day 0, kg	51.2	51.1	52.2	51.7	51.4	50.9	51.8	49.6	1.47	
Backfat (P2 site), Day 0, mm	7.9	7.7	7.9	7.5	8.3	8.5	8.4	8.2	0.39	Sex*
Live weight, slaughter, kg[1]	98.1	98.5	99.9	99.8	96.2	93.1	93.3	97.4	2.01	Sex*
Average daily feed intake, kg/d[1]	2.7	2.6	2.7	2.5	2.5	2.4	2.3	2.5	0.103	Sex*
Average daily gain, kg/d[1]	1.13	1.13	1.14	1.13	1.03	0.97	1.00	1.05	0.033	Sex*
Feed Conversion Ratio[1]	2.5	2.4	2.4	2.3	2.4	2.5	2.4	2.4	0.071	Le^{+}
Dressing percentage, %[1]	75.3	75.4	75.6	74.4	77.8	77.9	76.9	77.0	0.48	Le^{+}
Hot standard carcass weight, kg[1]	75.5	74.8	75.9	74.2	74.2	71.5	72.3	74.1	1.18	Sex*
Carcass backfat (P2 site), mm[1]	13.5	12.6	13.5	13.0	11.8	12.5	11.8	12.4	0.66	Sex*
Loin depth, mm[1]	49.3	51.5	53.7	49.4	54.1	49.7	51.7	52.9	1.40	In*

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, $^{+}P < 0.10$

[1]Covariates appearing in the model are evaluated at the following values: Wgt. Day 0 = 51.4 kg, P2 Day 0 = 8.1 mm, Days 0-Slaughter = 43.3

Table 3. Effects of sex, inulin and lecithin on meat quality of *longissimus thoracis et lumborum* (LTL) and *biceps femoris* (BF).

	Muscle	Castrate				Female				SE	Significance[1]
Lecithin (Le)		0		0.80%		0		0.80%			
Inulin (In)		0	2%	0	2%	0	2%	0	2%		
Drip loss, %	BF	4.5	3.5	4.6	3.8	4.0	4.7	4.9	3.8	0.67	Muscle**, In*, sex × in+
	LTL	9.1	7.5	9.2	7.3	8.9	8.5	8.4	8.8		
Colour L*	BF	45.3	44.4	44.8	44.3	43.8	45.0	44.9	45.6	0.72	Muscle**
	LTL	49.6	50.3	50.8	50.9	49.5	49.2	50.2	50.0		
Colour a*	BF	9.4	10.1	9.9	10.4	10.5	10.2	10.1	9.4	0.32	Muscle**, Muscle × sex × in*
	LTL	6.2	5.5	5.6	5.4	6.2	5.9	5.6	5.6		
Colour b*	BF	3.0	3.3	3.0	3.1	3.2	3.2	3.3	3.1	0.26	Muscle**
	LTL	2.7	2.6	2.7	2.5	2.6	2.7	2.7	2.8		
Cook loss, %	BF	31.5	28.1	38.6	27.5	28.8	28.5	27.7	28.1	1.91	Sex**, In*, Sex × In*,
	LTL	33.5	30.5	33.2	31.9	29.2	29.3	28.2	28.3		
WBSF[2], N	BF	57.4	60.8	57.9	60.3	53.2	53.4	56.2	54.0	3.4	Muscle**, Sex**, Muscle × Le+
	LTL	50.8	55.1	46.0	48.0	44.1	49.0	41.7	42.1		

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, $^{+}P < 0.10$

[1] Hot standard carcass weight (73.1 kg) was used as a co-variate.

[2] WBSF = Warner-Bratzler shear force

Table 4. Chemical properties of pork *biceps femoris* (BF) and *longissimus thoracis et lumborum* (LTL) from pigs of two sexes fed different diets.

	Castrate				Female					*P* values[2]					
Lecithin (Le)	0		0.8%		0		0.8%		SED[1]						
Inulin (In)	0	2%	0	2%	0	2%	0	2%		Sex	In	Le	Sex*In	Sex*Le	Le*In
BF															
n	6	10	8	9	12	9	9	11							
pH	5.71	5.73	5.73	5.76	5.70	5.69	5.69	5.74	0.057	0.31	0.57	0.39	0.97	0.95	0.49
IMF, %	1.42^{abc}	1.41^{abc}	1.27^{bc}	1.63^{ab}	1.24^{c}	1.67^{a}	1.41^{abc}	1.49^{abc}	0.186	0.78	**0.030**	0.69	0.73	0.67	0.80
Collagen content, mg/g	7.01^{a}	5.85^{bc}	5.61^{c}	6.69^{ab}	5.90^{bc}	6.53^{abc}	6.08^{abc}	5.70^{bc}	0.473	0.38	0.77	0.41	0.81	0.73	0.43
Collagen solubility, %	9.02^{bc}	10.08^{abc}	8.29^{c}	10.68^{ab}	9.66^{abc}	9.90^{abc}	11.22^{a}	9.67^{abc}	1.043	*0.077*	0.20	0.17	**0.012**	0.84	0.70
LTL															
n	6	10	8	9	12	9	9	11							
pH	5.53	5.54	5.53	5.50	5.51	5.54	5.50	5.53	0.039	0.74	0.67	0.62	0.32	0.79	0.66
IMF, %	0.869^{b}	0.975^{ab}	1.045^{ab}	1.059^{ab}	0.885^{b}	1.267^{a}	1.176^{ab}	1.033^{ab}	0.186	0.29	0.34	0.35	0.79	0.54	*0.083*
Collagen content, mg/g	4.60^{bc}	4.93^{ab}	4.67^{abc}	5.08^{a}	4.44^{cd}	4.75^{abc}	4.31^{cd}	4.12^{cd}	0.234	**0.001**	*0.069*	0.33	0.20	**0.031**	0.31
Collagen solubility, %	7.59^{d}	7.74^{cd}	8.57^{bcd}	8.69^{bc}	9.14^{ab}	8.57^{bcd}	9.92^{a}	8.83^{b}	0.515	**<0.001**	0.20	**0.005**	*0.070*	0.37	0.57

[1] Standard error of difference

[2] Data was analyzed by R with linear mixed effects models. Fixed model = sex + lecithin + inulin + sex * lecithin + sex * inulin + lecithin * inulin, random model = day/participant + carcass. Bold numbers are statistically significant ($P < 0.05$). Italic numbers are close to significant ($P < 0.10$).

[a, b, c, d] Data with different superscripts differ significantly.

Table 5. Sensory attributes of pork *biceps femoris* (BF) and *longissimus thoracis et lumborum* (LTL) from pigs of two sexes fed on different diets.

	Castrate				Female					*P* values[2]					
Lecithin (Le)	0		0.8%		0		0.8%		SED[1]						
Inulin (In)	0	2%	0	2%	0	2%	0	2%		Sex	In	Le	Sex*In	Sex*Le	Le*In
BF															
n	59	90	80	78	120	90	89	109							
Tenderness	39.0	47.0	37.6	41.4	44.1	45.5	42.9	46.4	5.00	0.13	*0.070*	0.39	0.47	0.43	0.91
Juiciness	43.3	47.6	47.2	46.9	49.4	48.4	46.4	48.6	4.01	0.35	0.54	0.99	0.77	0.52	0.98
Flavor	41.5^{c}	47.6^{abc}	44.5^{bc}	49.9^{ab}	49.4^{ab}	52.1^{a}	49.3^{ab}	49.2^{ab}	3.37	**0.020**	**0.036**	0.71	0.19	0.22	0.57
Overall liking	41.0^{b}	46.9^{ab}	44.7^{ab}	49.6^{a}	48.6^{ab}	49.8^{a}	47.1^{ab}	49.0^{a}	4.04	0.13	*0.083*	0.61	0.36	0.32	0.99
LTL															
n	60	90	80	80	120	90	90	110							
Tenderness	39.0	47.0	37.6	41.4	44.2	45.5	42.9	46.4	4.18	**0.033**	0.69	0.23	0.89	0.62	0.59
Juiciness	43.3	47.6	47.2	46.9	49.4	48.4	46.4	48.6	3.27	**0.025**	0.85	0.92	0.91	0.81	0.78
Flavor	41.5	47.6	44.5	49.9	49.4	52.1	49.3	49.2	2.87	0.40	0.82	0.31	0.78	**0.039**	*0.051*
Overall liking	41.0	46.9	44.7	49.6	48.6	49.8	47.1	49.1	3.15	*0.098*	0.95	0.15	0.99	0.13	0.51

[1] Standard error of difference

[2] Data was analyzed by R with linear mixed effects models. Fixed model = sex + lecithin + inulin + sex * lecithin + sex * inulin + lecithin * inulin, random model = day/participant + carcass. Bold numbers are statistically significant ($P < 0.05$). Italic numbers are close to significant ($P < 0.10$).

Table 6. Probability of off-flavor and success (purchase intent and quality grading) of pork *biceps femoris* (BF) and *longissimus thoracis et lumborum* (LTL) from pigs of two sexes fed on different diets.

	Castrate				Female				*P* values[1]					
Lecithin (Le)	0		0.8%		0		0.8%							
Inulin (In)	0	2%	0	2%	0	2%	0	2%	Sex	In	Le	Sex*In	Sex*Le	Le*In
BF														
n	59	90	80	78	120	90	89	109						
Probability of no off-flavor	0.970 ± 0.0198	0.961 ± 0.0218	0.990 ± 0.0074	0.989 ± 0.0078	0.984 ± 0.0096	0.971 ± 0.0172	0.985 ± 0.0100	0.970 ± 0.0163	0.12	0.32	0.11	*0.089*	0.23	0.30
Probability of success (purchase intent)[2]	0.177 ± 0.0590	0.190 ± 0.0497	0.200 ± 0.0546	0.331 ± 0.0708	0.304 ± 0.0563	0.291 ± 0.0622	0.258 ± 0.0586	0.316 ± 0.0600	*0.056*	0.18	0.48	0.56	0.14	0.37
Probability of success (quality grading)[3]	0.156 ± 0.0510	0.304 ± 0.0596	0.183 ± 0.0483	0.301 ± 0.0627	0.226 ± 0.0452	0.270 ± 0.0553	0.249 ± 0.0537	0.271 ± 0.0515	0.50	**0.016**	0.84	0.25	0.66	0.61
LTL														
n	60	90	80	80	120	90	90	110						
Probability of no off-flavor	0.982 ± 0.0130	0.976 ± 0.0147	0.990 ± 0.0071	0.984 ± 0.0107	0.986 ± 0.0085	0.985 ± 0.0102	0.980 ± 0.0126	0.981 ± 0.0112	0.68	0.48	0.39	0.53	0.25	0.66
Probability of success (purchase intent)[2]	0.247 ± 0.0695	0.307 ± 0.0641	0.320 ± 0.0688	0.327 ± 0.0698	0.264 ± 0.0524	0.213 ± 0.0532	0.235 ± 0.0565	0.303 ± 0.0585	*0.098*	0.57	0.26	0.94	0.60	0.53
Probability of success (quality grading)[3]	0.258 ± 0.0655	0.280 ± 0.0569	0.254 ± 0.0573	0.289 ± 0.0618	0.238 ± 0.0461	0.192 ± 0.0466	0.172 ± 0.0441	0.269 ± 0.0508	*0.062*	0.43	0.99	0.74	0.96	0.14

[1] Data are expressed as mean ± standard error. Data was analyzed by R with generalized linear mixed effects models. Fixed model = sex + lecithin + inulin + sex * lecithin + sex * inulin + lecithin * inulin, random model = day/participant + carcass. Bold numbers are statistically significant ($P < 0.05$). Italic numbers are close to significant ($P < 0.10$). [2] Success – consumers selecting "4. I would probably buy it" and "5. I would definitely buy it". [3] Success – consumers selecting "3. Better than everyday quality" and "4. Premium quality".

Table 7. Probability of selected for selected check-all-that-apply (CATA) terms of pork *biceps femoris* (BF) and *longissimus thoracis et lumborum* (LTL) from pigs of two sexes fed on different diets.

	Castrate				Female				*P* values[1]					
Lecithin (Le)	0		0.8%		0		0.8%							
Inulin (In)	0	2%	0	2%	0	2%	0	2%	Sex	In	Le	Sex*In	Sex*Le	Le*In
BF														
n	59	90	80	78	120	90	89	109						
Fibrous	0.465 ± 0.0949	0.211 ± 0.0560	0.444 ± 0.0816	0.257 ± 0.0654	0.320 ± 0.0609	0.313 ± 0.0676	0.392 ± 0.0747	0.255 ± 0.0566	0.80	**0.013**	0.94	0.32	0.97	0.52
Savory (Umami)	0.0149 ± 0.0098	0.0912 ± 0.0353	0.0427 ± 0.0205	0.0941 ± 0.0371	0.0586 ± 0.0226	0.0694 ± 0.0282	0.0770 ± 0.0302	0.0772 ± 0.0285	0.15	**0.043**	0.31	0.10	0.80	0.79
Familiar	0.0863 ± 0.0379	0.121 ± 0.0367	0.120 ± 0.0394	0.208 ± 0.0561	0.155 ± 0.0390	0.156 ± 0.0432	0.0896 ± 0.0320	0.118 ± 0.0339	0.67	0.12	0.97	0.29	**0.047**	0.99
Tender	0.192 ± 0.0561	0.241 ± 0.0510	0.134 ± 0.0396	0.240 ± 0.0541	0.200 ± 0.0408	0.247 ± 0.0512	0.219 ± 0.0487	0.301 ± 0.0518	0.29	**0.026**	0.98	0.72	0.61	0.58
LTL														
n	60	90	80	80	120	90	90	110						
Roasted	0.174 ± 0.0555	0.196 ± 0.0512	0.257 ± 0.0635	0.271 ± 0.0651	0.278 ± 0.0553	0.270 ± 0.0623	0.229 ± 0.0558	0.217 ± 0.0501	0.50	0.92	0.93	0.83	**0.040**	0.75
Tasteless	0.129 ± 0.0459	0.0599 ± 0.0230	0.0756 ± 0.0290	0.0517 ± 0.0216	0.114 ± 0.0319	0.0535 ± 0.0220	0.0571 ± 0.0224	0.132 ± 0.0362	0.50	0.46	0.54	0.30	0.19	**0.049**
Dry	0.275 ± 0.0664	0.161 ± 0.0428	0.238 ± 0.0548	0.181 ± 0.0478	0.263 ± 0.0489	0.330 ± 0.0617	0.253 ± 0.0538	0.356 ± 0.0577	**0.009**	0.80	0.98	**0.037**	0.68	0.79
Fibrous	0.231 ± 0.0695	0.128 ± 0.0403	0.271 ± 0.0661	0.185 ± 0.0551	0.231 ± 0.0518	0.388 ± 0.0748	0.166 ± 0.0480	0.303 ± 0.0610	0.12	0.46	0.90	**0.002**	0.16	0.83
Clean	0.463 ± 0.0963	0.269 ± 0.0649	0.353 ± 0.0793	0.237 ± 0.0643	0.306 ± 0.0615	0.239 ± 0.0612	0.289 ± 0.0691	0.276 ± 0.0603	0.20	**0.024**	0.49	0.16	0.21	0.64
Tender	0.315 ± 0.0694	0.331 ± 0.0586	0.341 ± 0.0629	0.479 ± 0.0680	0.300 ± 0.0493	0.329 ± 0.0587	0.165 ± 0.0422	0.280 ± 0.0497	**0.009**	**0.038**	0.66	0.69	**0.012**	0.13

Data are expressed as mean ± standard error

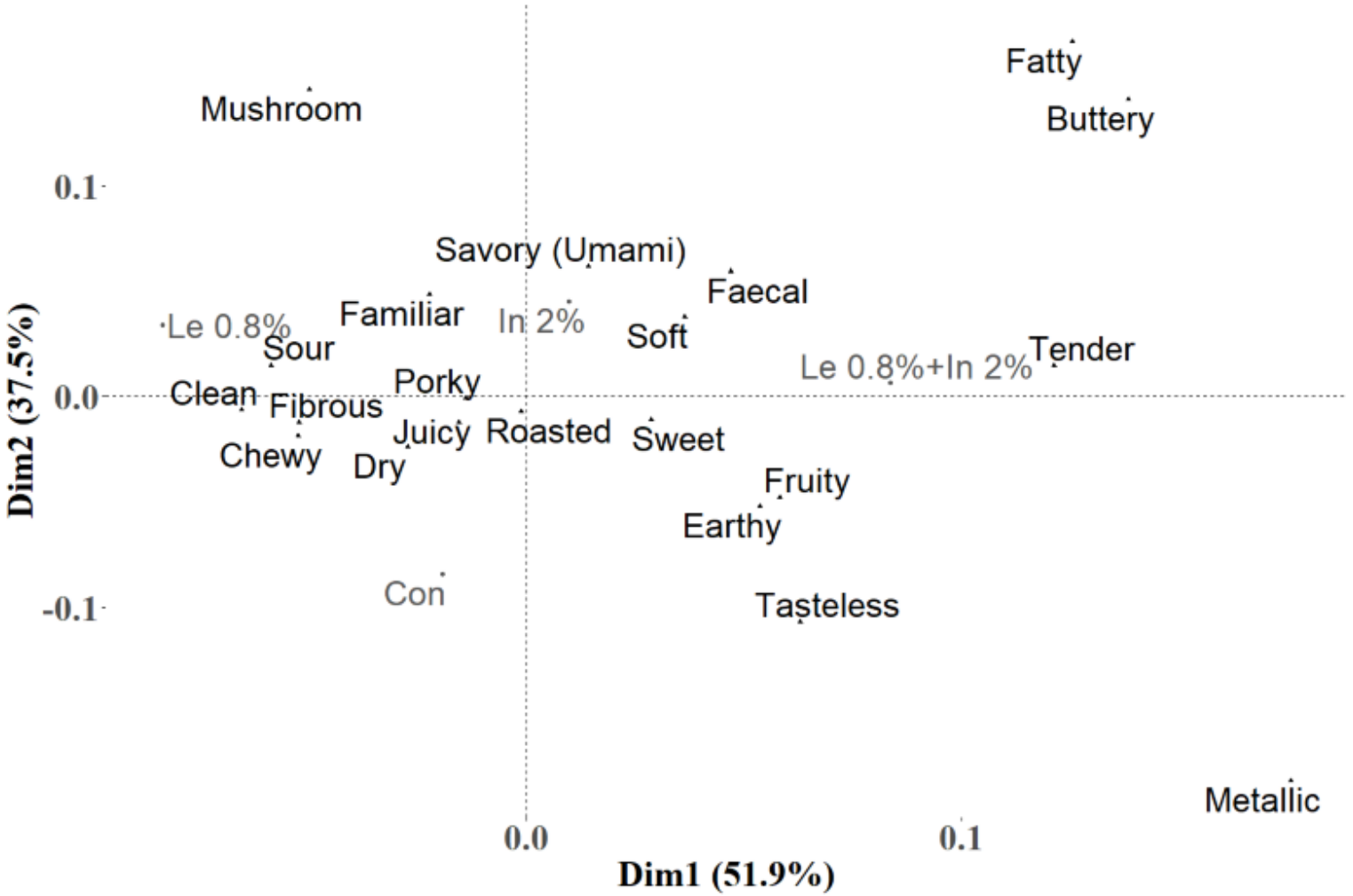


Figure 1. Correspondence analysis biplot of check-all-that-apply terms with different diet treatments. Con = control (no lecithin or inulin supplement), Le 0.8% = lecithin supplement of 0.8%, In 2% = inulin supplement of 2%, Le 0.8%+In 2% = lecithin supplement of 0.8% and inulin supplement of 2%.

The increase in IMF after inulin supplementation was as expected. Similar to this study, Dunshea et al. (2024) found that dietary supplementation of 50 g/kg inulin increased IMF content in LTL without affecting backfat thickness. Grela et al. (2021) showed that feeding pigs with diets supplemented with 40 g/kg Jerusalem artichoke, which contained approximately 50% inulin, increased IMF content of LTL, while supplementation with 20 g/kg inulin did not affect IMF content, but both treatments reduced WBSF, chewiness and hardness. The exact mechanism of inulin supplementation increasing IMF content is unknown. It is possible that inulin affects lipids and cholesterol metabolism by reducing serum lipid and cholesterol concentration (Grela et al., 2014; Kozlowska et al., 2016). The increase in IMF content improves tenderness and flavour of pork (Channon et al., 2004; Czarniecka-Skubina et al., 2010). As a result, dietary supplementation of inulin is an opportunity to increase IMF content and improve eating quality of pork.

Different from previous studies, lecithin supplementation had little effects on growth performance and carcass traits of pigs in this study. In addition, lecithin tended to improve feed conversion ratio and reduce dressing percentage. The minor effects of lecithin on feed conversion ratio and average daily gain in this study could be due to its low level of supplementation. Sun et al. (2019) showed that dietary supplementation of 0.1% de-oiled lecithin-97% improved average daily gain and gain-to-feed ratio. Similar results were reported by Kim et al. (2008) with 5% lecithin supplementation. As an emulsifier, lecithin can improve the digestibility of lipid, possibly through increasing the capacity of bile salt micelles to solubilise long chain saturated fatty acids (Jones et al., 1992; Reynier et al., 1985). Therefore, lecithin may contribute to improved feed efficiency and average daily gain by improving digestion and absorption of lipid.

In this study, lecithin supplementation increased collagen solubility, liking of flavour and tenderness in the LTL only. Similarly, D'Souza et al. (2015) found that pork LTL from pigs fed on diets containing 15 g and 75 g lecithin/kg had lower chewiness and hardness and higher linoleic acid compared to the control. Lecithin has an anti-fibrogenic effect and its active compound, polyenylphosphatidylcholine, decreases hepatic collagen accumulation in liver fibrosis (Aleynik et al., 1997). Akit et al. (2016) found that lecithin down-regulated Type I (α1) procollagen (COL1A1) and Type III (α1) procollagen (COL3A1) mRNA expression and tended to down-regulate α-subunit of prolyl 4-hydroxylase (P4H) mRNA expression, indicating a possible decrease in collagen content and cross-linking. Therefore, collagen solubility increased due to reduced cross-linking, resulting in increased tenderness in this study. On the other hand, lecithin is rich in unsaturated fatty acids, especially linoleic acid (Soares & Lopez-Bote, 2002). It changes the composition of fatty acid in IMF, which then influences the flavour of pork.

Different muscles responded differently to inulin and lecithin supplementation. Inulin had greater effects on the BF, while lecithin had greater effects on the LTL. It is possible that the reason for this difference is that the BF had higher IMF content than LTL and thus, the increase in IMF was more significant in muscles with a higher base IMF content. A higher IMF content resulted in greater effects of inulin on sensory properties of BF (Barton-Gade & Bejerholm, 1985). The LTL had lower collagen content and solubility than the BF. It is postulated that as collagen solubility is a ratio, with the same change in soluble collagen content, a smaller total collagen content resulted in greater change in collagen solubility.

Therefore, lecithin showed significant effects on collagen solubility and eating quality of LTL.

Immunocastrated males and females showed different growth performance, carcass traits and meat quality attributes, and responded differently to inulin and lecithin. The higher average daily gain, backfat depth, tenderness and juiciness of immunocastrated males were in line with previous studies (Channon et al., 2016; Grela et al., 2013). However, the higher collagen content in immunocastrated males was different from the results reported by Li, Ha, Warner, Lealiifano, et al. (2024) in which there was no difference between sex. This is possibly due to higher growth rates in immunocastrated males in this study, leading to elevated collagen synthesis. As the muscle composition, metabolism and properties differ between sexes, they reacted differently to inulin and lecithin supplementation.

4. Application of Research

Dietary inulin increased muscle IMF content and improved tenderness and flavour. Further research should be conducted to determine whether this is an effect specific to inulin or whether other less expensive and more readily available dietary fibre sources could have similar benefits.

Dietary lecithin decreased FCR, increased collagen solubility and increased roasted flavour and tenderness of pork. Dietary lecithin over the finisher phase has the potential to improve efficiency and pork quality.

The CATA method effectively differentiated between dietary treatments and muscle and indicated that the effects of dietary lecithin and inulin on eating quality are additive. The CATA method should be incorporated in future pork sensory studies.

5. Conclusion

Dietary supplementation of 2% inulin and 0.8% lecithin to pigs had limited effects on growth performance and carcass traits, although dietary lecithin improved FCR. However, dietary inulin increased IMF content, especially in the BF, resulting in improved tenderness and flavour in both LTL and BF. Also, CATA results showed that LTL from immunocastrated males with an inulin supplement were less dry and fibrous. On the other hand, lecithin supplementation increased collagen solubility, mostly in the LTL. Lecithin supplementation increased roasted flavour and tenderness of LTL from immunocastrated males. Dietary supplementation of inulin and lecithin have the potential to alter muscle composition and thus, improve eating quality of pork. Future studies can be conducted on the mechanism(s) of the effects of inulin and lecithin on meat quality.

6. Limitations/Risks

Dietary inulin is prohibitively expensive to include in commercial finisher rations, and it is unknown whether other fibre sources can replicate these effects.

This research was conducted with pigs from a single supply chain, which may not accurately replicate what might happen with pigs from a different supply chain with a different genetic background.

For the sensory study, the participants were predominantly of Asian ethnicity (see Appendix) who may be particularly discerning about pork quality. Therefore, these data may not accurately reflect the responses of a broader demographic.

7. Recommendations

As a result of the outcomes in these studies, the following recommendations have been made:

1) Further research should be conducted to determine whether the improved eating quality in response to inulin is an effect specific to inulin or whether other less expensive and more readily available dietary fibre sources could have similar benefits.
2) Dietary lecithin may be used as a strategy to improve the flavour eating quality of pork.
3) The CATA method should be incorporated in future pork sensory studies.

8. References

Akit, H., Collins, C., Fahri, F., Hung, A., D'Souza, D., Leury, B., & Dunshea, F. (2016). Dietary lecithin decreases skeletal muscle COL1A1 and COL3A1 gene expression in finisher gilts. *Animals*, *6*(6), 38.

Akit, H., Collins, C., Fahri, F., Hung, A., D'Souza, D., Leury, B., & Dunshea, F. (2018). Dietary lecithin improves feed efficiency without impacting meat quality in immunocastrated male pigs and gilts fed a summer ration containing added fat. *ANIMAL NUTRITION*, *4*(2), 203–209. https://doi.org/10.1016/j.aninu.2018.01.008

Akit, H., Collins, C. L., Fahri, F. T., Hung, A. T., D'Souza, D. N., Leury, B. J., & Dunshea, F. R. (2014). Dietary lecithin improves dressing percentage and decreases chewiness in the longissimus muscle in finisher gilts. *Meat Science*, *96*(3), 1147–1151. https://doi.org/10.1016/J.MEATSCI.2013.10.028

Aleynik, S. I., Leo, M. A., Ma, X., Aleynik, M. K., & Lieber, C. S. (1997). Polyenylphosphatidylcholine prevents carbon tetrachloride-induced lipid peroxidation while it attenuates liver fibrosis. *Journal of Hepatology*, *27*(3), 554–561. https://doi.org/https://doi.org/10.1016/S0168-8278(97)80361-3

AOAC. (1995). *Official methods of analysis* (16th ed.). AOAC International.

Barton-Gade, P., & Bejerholm, A. C. (1985). Eating quality in pork. *Pig Farming*, *33*(12), 56–57.

Bennett, J. (1997). Eating quality assurance for pig meat. *Final Report for the Pig Research and Development Corporation. Canberra*.

Channon, H. A., D'Souza, D. N., & Dunshea, F. R. (2016). Developing a cuts-based system to improve consumer acceptability of pork: Impact of gender, ageing period, endpoint

temperature and cooking method. *Meat Science*, *121*, 216–227. https://doi.org/https://doi.org/10.1016/j.meatsci.2016.06.011

Channon, H. A., D'Souza, D. N., & Dunshea, F. R. (2017). Guaranteeing consistently high quality Australian pork: are we any closer? *Animal Production Science*, *57*(12), 2386–2397.

Channon, H. A., Kerr, M. G., & Walker, P. J. (2004). Effect of Duroc content, sex and ageing period on meat and eating quality attributes of pork loin. *Meat Science*, *66*(4), 881–888. https://doi.org/https://doi.org/10.1016/j.meatsci.2003.08.010

Choi, Y. M., Garcia, L. G., & Lee, K. (2019). Correlations of sensory quality characteristics with intramuscular fat content and bundle characteristics in bovine longissimus thoracis muscle. *Food Science of Animal Resources*, *39*(2), 197–208. https://doi.org/10.5851/kosfa.2019.e15

Colgrave, M., Allingham, P., & Jones, A. (2008). Hydroxyproline quantification for the estimation of collagen in tissue using multiple reaction monitoring mass spectrometry. *Journal of chromatography. A*, *1212*, 150–153. https://doi.org/10.1016/j.chroma.2008.10.011

Czarniecka-Skubina, E., Przybylski, W., Jaworska, D., Kajak-Siemaszko, K., & Wachowicz, I. (2010). Effect of pH24 and intramuscular fat content on technological and sensory quality of pork. *Polish Journal of Food and Nutrition Sciences*, *60*(1).

D'Souza, D. N., Blake, B. L., Williams, I. H., Mullan, B. P., Pethick, D. W., & Dunshea, F. R. (2015). Dietary lecithin supplementation can improve the quality of the M. Longissimus Thoracis. *Animals*, *5*(4), 1180–1191. https://doi.org/10.3390/ani5040405

D'Souza, D. N., & Mullan, B. P. (2002). The effect of genotype, sex and management strategy on the eating quality of pork. *Meat Science*, *60*(1), 95–101. https://doi.org/https://doi.org/10.1016/S0309-1740(01)00112-7

Dunshea, F. R., Pluske, J. R., & Ponnampalam, E. N. (2024). Dietary iron or inulin supplementation alters iron status, growth performance, intramuscular fat and meat quality in finisher pigs. *Meat Science*, *213*, 109496. https://doi.org/https://doi.org/10.1016/j.meatsci.2024.109496

Grela, E. R., Kowalczuk-Vasilev, E., & Klebaniuk, R. (2013). Performance, pork quality and fatty acid composition of entire males, surgically castrated or immunocastrated males, and female pigs reared under organic system. *Polish Journal of Veterinary Sciences*, *16*(1), 107–114. https://www.proquest.com/scholarly-journals/performance-pork-quality-fatty-acid-composition/docview/1353087332/se-2?accountid=12372

Grela, E. R., Sobolewska, S., Kowalczuk-Vasilev, E., & Krasucki, W. (2014). Effect of dietary inulin source on piglet performance, immunoglobulin concentration, and plasma lipid profile. *Journal of Veterinary Research*, *58*(3), 453–458. https://doi.org/https://doi.org/10.2478/bvip-2014-0069

Grela, E. R., Świątkiewicz, M., Florek, M., Bąkowski, M., & Skiba, G. (2021). Effect of inulin source and a probiotic supplement in pig diets on carcass traits, meat quality and fatty acid composition in finishing pigs. *Animals*, *11*(8). https://doi.org/10.3390/ani11082438

Jha, R., & Berrocoso, J. D. (2015). Review: Dietary fiber utilization and its effects on physiological functions and gut health of swine. *Animal*, *9*(9), 1441–1452. https://doi.org/https://doi.org/10.1017/S1751731115000919

Jones, D. B., Hancock, J. D., Harmon, D. L., & Walker, C. E. (1992). Effects of exogenous emulsifiers and fat sources on nutrient digestibility, serum lipids, and growth performance in weanling pigs. *Journal of Animal Science*, *70*(11), 3473–3482. https://doi.org/10.2527/1992.70113473x

Kim, W. T., Shinde, P., & Chae, B. J. (2008). Effect of lecithin with or without chitooligosaccharide on the growth performance, nutrient digestibility, blood metabolites and pork quality of finishing pigs. *Canadian Journal of Animal Science*, *88*(2), 283–292. https://doi.org/10.4141/CJAS07079

Kolar, K. (1990). Colorimetric Determination of Hydroxyproline as Measure of Collagen Content in Meat and Meat Products: NMKL Collaborative Study. *Journal of Association of Official Analytical Chemists*, *73*(1), 54–57. https://doi.org/10.1093/jaoac/73.1.54

Kozlowska, I., Marc-Pienkowska, J., & Bednarczyk, M. (2016). Beneficial aspects of inulin supplementation as a fructooligosaccharide prebiotic in monogastric animal nutrition - a review. *Annals of Animal Science*, *16*(2), 315–331. https://doi.org/10.1515/aoas-2015-0090

Li, X., Ha, M., Warner, R. D., & Dunshea, F. R. (2022). Meta-analysis of the relationship between collagen characteristics and meat tenderness. *Meat Science*, *185*, 108717. https://doi.org/https://doi.org/10.1016/j.meatsci.2021.108717

Li, X., Ha, M., Warner, R. D., Hewitt, R. J. E., D'Souza, D. N., & Dunshea, F. R. (2024). Genetic lines influenced the texture, collagen and intramuscular fat of pork longissimus and semimembranosus. *Meat Science*, *207*, 109376. https://doi.org/https://doi.org/10.1016/j.meatsci.2023.109376

Li, X., Ha, M., Warner, R. D., Lealiifano, A., Hewitt, R. J. E., D'Souza, D. N., Trezona, M., & Dunshea, F. R. (2024). Muscle, season, sex, and carcass weight affected pork texture, collagen characteristics, and intramuscular fat content. *Journal of Animal Science*, *102*(August). https://doi.org/10.1093/jas/skae231

Li, X., Hastie, M., Warner, R. D., Hewitt, R. J. E., D'Souza, D. N., Gonzalez Viejo, C., Fuentes, S., Ha, M., & Dunshea, F. R. (2024). Consumer eating quality and physicochemical traits of pork Longissimus and Semimembranosus differed between genetic lines. *Meat Science*, *218*(June). https://doi.org/10.1016/j.meatsci.2024.109631

Metzler-Zebeli, B. U., Trevisi, P., Prates, J. A. M., Tanghe, S., Bosi, P., Canibe, N., Montagne, L., Freire, J., & Zebeli, Q. (2017). Assessing the effect of dietary inulin supplementation on gastrointestinal fermentation, digestibility and growth in pigs: A meta-analysis. *Animal Feed Science and Technology*, *233*, 120–132. https://doi.org/https://doi.org/10.1016/j.anifeedsci.2017.05.010

National Research Council (U.S.). (2012). *Nutrient requirements of swine* ([11th rev.). National Academies Press. https://research.ebsco.com/linkprocessor/plink?id=dcd4d08b-6b24-33b6-ab91-7a964b429d62

R Core Team. (2021). R: A language and environment for statistical computing. In *R Foundation for Statistical Computing*. https://www.r-project.org/

Reynier, M. O., Lafont, H., Crotte, C., Sauve, P., & Gerolami, A. (1985). Intestinal cholesterol uptake - comparison between mixed micelles containing lecithin or lysolecithin. *Lipids*, *20*(3), 145–150. https://doi.org/10.1007/BF02534246

Silva, J. P. M. da, Almeida, V. V., Schinckel, A. P., Meira, A. N., Moreira, G. C. M., Pian, L. W., Campos, D. de, Gomes, J. D., Gonçales, J. L., Dargelio, M. D. B., Patinho, I., Saldaña, E., Contreras-Castillo, C. J., Coutinho, L. L., Luchiari Filho, A., Nuñez, A. J. C., & Cesar, A. S. M. (2023). Check-All-That-Apply method for sensory characterization of pork from immunocastrated male pigs fed different oil sources. *Scientia Agricola*, *80*.

Soares, M., & Lopez-Bote, C. J. (2002). Effects of dietary lecithin and fat unsaturation on nutrient utilisation in weaned piglets. *Animal Feed Science and Technology*, *95*(3), 169–177. https://doi.org/https://doi.org/10.1016/S0377-8401(01)00324-8

Sun, H. Y., Yoon, S. Bin, & Kim, I. H. (2019). Growth performance, nutrient digestibility, blood lipid profile and faecal Escherichia coli and Lactobacillus counts on growing pigs fed with de-oiled lecithin emulsifier. *Italian Journal of Animal Science*, *18*(1), 1111–1116. https://doi.org/10.1080/1828051X.2019.1620140

Wang, W., Chen, D., Yu, B., Huang, Z., Luo, Y., Zheng, P., Mao, X., Yu, J., Luo, J., & He, J. (2019). Effect of dietary inulin supplementation on growth performance, carcass traits, and meat quality in growing–finishing pigs. *Animals*, *9*(10). https://doi.org/10.3390/ani9100840

Yano, K., Bauchat, J. R., Liimatta, M. B., Clemmons, D. R., & Duan, C. (1999). Down-regulation of protein kinase c inhibits insulin-like growth factor I-induced vascular smooth muscle cell proliferation, migration, and gene expression. *Endocrinology*, *140*(10), 4622–4632. https://doi.org/10.1210/endo.140.10.7035

Appendices

Table A1. Demographics of consumers

	Count	Percentage
Gender		
Male	65	27.1
Female	174	72.5
Age group	1	0.4
20 or younger		
21-30	28	11.7
31-40	161	67.1
41-50	25	10.4
51-60	5	2.1
61-70	19	7.9
70 or older	2	0.8
Cultural heritage	0	0.0
Australian		
Indigenous Australian	15	6.3
British	0	0.0
European	0	0.0
Asian	220	91.7
African	0	0
South American	0	0.0
North American	3	1.3
Other	0	0.0
Number of people in the household	2	0.8
1		
2	53	22.1
3	60	25.0
4	56	23.3
5	55	22.9
6	13	5.4
7 or more	1	0.4
Parent or guardian of any children age 18 or younger		
Yes	30	12.5
No	210	87.5
Occupation of the main income earner in the household		
Manager	25	10.4
Professionals (included health professional etc.)	46	19.2
Technicians and trade workers	12	5.0
Community and personal services worker	6	2.5
Clerical and administrative workers	9	3.8
Sales workers (includes retail sales etc.)	8	3.3
Machinery operators and drivers	3	1.3
Labourers	5	2.1

Home duties	7	2.9
Student	97	40.4
other	22	9.2
Household income		
under $25,000 per year	72	30.0
$25,000 - $50,000 per year	62	25.8
$50,001 - $75,000 per year	39	16.3
$ 75,001 - $100,000 per year	31	12.9
$100,001 - $125,000 per year	19	7.9
Over $125,000 per year	17	7.1
Pork consumption frequency		
Everyday	6	2.5
4-5 times a week	50	20.8
2-3 times a week	95	39.6
Weekly	57	23.8
Fortnightly	16	6.7
Monthly	12	5.0
Less than monthly	4	1.7
Total	**240**	**100.0**

Table A2 DEMOGRAPHICS QUESTIONNAIRE

This information is confidential and will be used for classification purposes only.

D1. Please indicate your gender. (Select one)

☐	☐	☐
Male	Female	Other
[1]	[2]	[3]

D2. In which of the following age groups do you belong? (Select one)

☐	☐	☐	☐	☐	☐	☐
20 or younger	21–30	31–40	41–50	51–60	61–70	71-80
[1]	[2]	[3]	[4]	[5]	[6]	[7]

D3. What is your cultural heritage? (Select one)

[1] ☐ Australian
[2] ☐ Indigenous Australian
[3] ☐ British
[4] ☐ European
[5] ☐ Asian
[6] ☐ African
[7] ☐ South American
[8] ☐ North American
[9] ☐ Other. Please specify:_____

D4. Including yourself, how many people are living in your household? This includes infants but does not include students living away from home. (Select one)

☐	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7 or more

D5. Are you the parent or guardian of any children age 18 or younger living in your household?
(Select one)

☐	☐

Yes	No
[1]	[2]

D6. What's the occupation of the main income earner in your household? (Select one)

- [1] ☐ Manager
- [2] ☐ Professionals (included health professional etc.)
- [3] ☐ Technicians and Trade Workers
- [4] ☐ Community and Personal Services Workers
- [5] ☐ Clerical and Administrative Workers
- [6] ☐ Sales Workers (includes retail sales etc.)
- [7] ☐ Machinery Operators and Drivers
- [8] ☐ Labourers
- [9] ☐ Home Duties
- [10] ☐ Student
- [11] ☐ Other

D7. Which one of the following ranges includes your total yearly household income, before taxes?
(Select one)

☐	☐	☐	☐	☐	☐
Under $25,000 per year	$25,000– $50,000 per year	$50,001– $75,000 per year	$75,001– $100,000 per year	$100,001– $125,000 per year	Over $125,000 per year
[1]	[2]	[3]	[4]	[5]	[6]

D8. How often do you consume pork? (Select one)

- [1] ☐ Everyday
- [2] ☐ 4-5 times a week
- [3] ☐ 2-3 times a week
- [4] ☐ Weekly
- [5] ☐ Fortnightly
- [6] ☐ Monthly
- [7] ☐ Less than monthly

Table A3 Hedonic scales empliyed

Sample No. _____ **Participant code: _____**

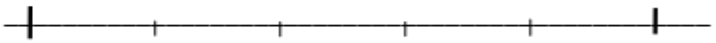
Follow the test instructions closely. You will be provided with 7 individual samples which all require a test. Each sample will have two portions.

Please inspect, smell and then eat one portion the sample provided. Once you have finished fill out the questions below in section (1).

When you have completed section (1), eat the second portion, then select all attributes that apply in section (2). Then eat some cracker, drink some water and wait for the next sample.

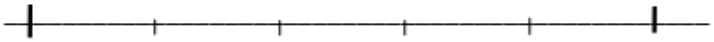
(1)

Liking of appearance



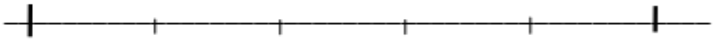
Dislike Extremely — Like Extremely

Liking of odor



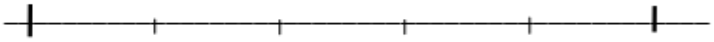
Dislike Extremely — Like Extremely

Tenderness



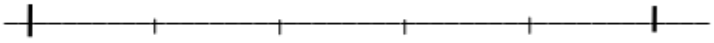
Not Tender — Very Tender

Juiciness



Not Juicy — Very Juicy

Liking of flavor



Dislike Extremely — Like Extremely

Overall Liking

Dislike Extremely — Like Extremely

Do you detect any off-flavor?

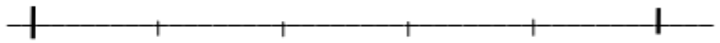
Yes [ ] [1] No [ ] [2]

To what extent would you purchase this product?

I definitely would not buy it [1] ☐
I would probably not buy it [2] ☐
I might buy it [3] ☐
I would probably buy it [4] ☐
I would definitely buy it [5] ☐

Please tick one of the following to

Rate the quality of the pork sample you have just eaten
Choose **one** only (you must make a choice).



Unsatisfactory | Good everyday quality | Better than everyday quality | Premium

(2) Please check the words or phrases about odor and texture which best describe the pork sample you have just tried.

Faecal odor	☐	Tender	☐	Sweet odor	☐
Roasted odor	☐	Chewy	☐	Dry	☐
Soft	☐	Oily odor	☐	Mushroom odor	☐

Metallic odor	☐	Fibrous	☐	Earthy odor	☐
Juicy	☐	Sour odor	☐	Fruity odor	☐
Familiar odor	☐	Porky odor	☐		

(3) Please check the words or phrases about flavor which best describe the pork sample you have just tried.

Faecal flavor	☐	Fatty flavor	☐	Sweet taste	☐
Roasted flavor	☐	Tasteless flavor	☐	Earthy flavor	☐
Porky flavor	☐	Sour taste	☐	Metallic flavor	☐
Buttery flavor	☐	Fruity flavor	☐	Mushroom flavor	☐
Clean flavor	☐	Familiar flavor	☐	Savory flavor	☐