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Research article

Check-All-That-Apply method for sensory characterization of pork from immunocastrated male pigs fed different oil sources

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ABSTRACT: In the last decade, other quality attributes have emerged as the main aspects that impact pork consumers acceptance, such as environmentally friendly production, nutritional value, and animal welfare. This study applies a Check-All-That-Apply (CATA) questionnaire for sensory characterization of loins from genetically lean immunocastrated male pigs fed diets containing either a standard commercial diet with 1.5 % soybean oil (control) or 3 % oil from either soybean oil (SO), canola oil (CO), or fish oil (FO) during the growing-finishing phases. Twenty CATA attributes for loin samples were generated. We interviewed 101 consumers to select all the CATA terms that they considered suitable to characterize sensory attributes of *longissimus lumborum* muscle samples of pigs from each dietary treatment. The CATA results indicated differences among pork loin samples depending on the source and inclusion level of dietary oil. Loins from pigs fed 3 % SO were characterized by a higher frequency of the "juicy texture" attribute ($p < 0.05$) and a lower frequency of the "dry texture" attribute ($p < 0.05$) compared to loins from 3 % FO-fed pigs. Moreover, loins from pigs fed 3 % SO had a lower citation frequency of the "tasteless" attribute ($p < 0.05$) compared to loins from 3 % FO-fed pigs. The attributes "cooked pork meat-like taste", "juicy texture", "tender texture", and "brightness" were placed close to the overall liking. "Tender texture", "juicy texture", "pork meat-like" (odor and taste), and "cooked pork meat-like taste" attributes were considered drivers of liking. Feeding genetically lean immunocastrated male pigs with diets containing 3 % SO may be advisable from a pork sensory quality perspective.

Keywords: CATA, dietary oil source, immunologic castration, sensory profile, pork meat

Introduction

The most common attributes that influence consumers' decision to purchase pork are linked to visual appearance, particularly backfat depth and color of meat as well as its eating quality characteristics, including tenderness, juiciness, and flavor (Garmyn, 2020; Ngapo and Gariépy, 2008). Over the last decade, other quality attributes, such as environmentally friendly production and animal welfare, have emerged as the main aspects for pork consumers acceptance (Burnier et al., 2021). Therefore, given the concerns expressed by consumers regarding the surgical castration of piglets without pain relief, immunocastration has become a more welfare-friendly alternative management practice for pig husbandry (Di Pasquale et al., 2020). Studies have indicated that meat from immunocastrated pigs has the same sensory profile as pork from surgically castrated pigs (Jeong et al., 2011) and that immunological castration provides acceptable dry-cured meat products to consumers (Żakowska-Biemans et al., 2021).

Nutrition is one of the most influential factors for pork quality, affecting mainly tenderness, juiciness, and flavor (Miller, 2020). Previous data have shown that loins from genetically lean immunocastrated pigs fed diets with either 3 % soybean oil (SO) or canola oil (CO) had more significant tenderness compared to loins from pigs fed a standard commercial diet with 1.5 % SO (Almeida et al., 2021). The potential of dietary fat/oil on pork quality is well documented in the literature (Apple et al., 2009; Bertol et al., 2013; Park et al., 2012); however, data are scarce on the effects of different sources of dietary oil on sensory traits and consumers' acceptance of meat from immunocastrated male pigs.

Among the approaches to assess consumers' acceptance of meat and meat products, the Check-All-That-Apply (CATA) method is a versatile multiple-choice questionnaire that has gained importance regarding consumers' perceptions (Saldaña et al., 2021). In the CATA questionnaire, the participants are presented with a list of terms and must check all attributes that apply to describe a sample (Ares and Jaeger, 2015). Although CATA questions have been reported in many food products (Ares and Jaeger, 2013; Saldaña et al., 2018), little information is available on their application to fresh pork from immunocastrated pigs. This study was conducted to assess the sensory attributes of pork loins from genetically lean immunocastrated male pigs fed diets containing different oil sources by applying the CATA questionnaire.

Materials and Methods

Animals and dietary treatments

All experimental protocols were approved by the Animal Care and Use Committee of the Luiz de Queiroz College of Agriculture (University of São Paulo, Piracicaba, Brazil, Protocol number CEUA 2018-28) and complied with the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 2010).

Animals, housing, experimental design, and dietary treatments for this study have been previously described in detail (Almeida et al., 2021). Briefly, 96 genetically lean immunocastrated male pigs (Large White sires × Large White dams; 28.44 ± 2.95 kg of average body weight; 71 ± 1.8 days of age) were blocked by initial body weight and randomly allotted to one of four treatments in a 98-day feeding study. There were six replicate pens per treatment and each pen contained four pigs. Treatments consisted of corn-soybean-meal based diets supplemented with 1.5 % SO (control) or 3 % oil from either SO, CO, or fish oil (FO).

Sampling procedure

On day 98, three pigs from each pen (n = 72; 18 pigs per treatment) were euthanized by electrical stunning followed by exsanguination. The carcasses were split longitudinally and chilled overnight at 4 °C. At 24 h *postmortem*, the loins (*L. lumborum* muscle) were removed from the left side of each carcass, sliced into 2.5-cm-thick chops, and then individually stored at –20 °C until the sensory analyses.

Sensory analyses

Frozen loin chops were thawed at 4 °C overnight before cooking on an electric grill flat plate (SSE-50) to an internal endpoint temperature of 71 °C. Chops were flipped halfway through cooking when they reached an internal temperature of 35 °C. The internal temperature was monitored by a hand-held digital thermometer (HM-600) inserted into the geometric center of each chop. No oil was used to grease the grill. All secondary muscles and subcutaneous fat were trimmed. We randomly selected six chops per treatment and cooked chops were cut into 2-cm^3 cubes, which were mixed, wrapped in aluminum foil, and labelled with randomly established three-digit blinding codes. A consumer sample represented one cube per treatment provided in a serving boat. The samples were kept in an oven at 60 °C to maintain the temperature prior to the sensory test (less than 5 min).

Consumers

The study comprised 101 participants (60 female; 40 male, and 1 other; aged 18 to 65 years old), who were randomly recruited from students and staff of Luiz de Queiroz College of Agriculture, University of São Paulo. The complete characteristics of the participants are given in Table 1. All participants declared themselves to be regular consumers of pork meat and filled out a consent form, which was previously approved by the Ethics Committee of Luiz de Queiroz College of Agriculture (Protocol number CAAE 04352718.6.0000.5395).

Check-All-That Apply (CATA) question

Before the test, participants were familiarized with the Compusense software. Additionally, an introductory description of both the experimental protocol and the sensory attributes in the CATA questionnaire was verbally given to each participant prior to sample evaluations. Consumers were allocated to individual sensory booths under an artificial white light environment. Sessions lasted approximately 30 min and consumers remained at least 2 m apart to avoid interaction. The samples were placed in 50 mL disposable plastic cups and served in sequential monadic order, according to a design based on Williams Latin Square. Samples were rated for overall liking using a nine-point hedonic scale described by Almeida et al. (2021). Then, consumers were asked to complete

Table 1 – Demographic characteristics of participants (n = 101).

	Count	Percent
Gender		
Female	60	59.41
Male	40	39.60
Other	1	0.99
Age (years)		
18 – 25	60	59.41
26 – 35	31	30.69
36 – 45	3	2.97
45 – 65	7	6.93
≥ 66	0	0.00
Educational status		
Unschooled	0	0.00
Partial primary school education	0	0.00
Primary school	1	0.99
Partial high school incomplete	0	0.00
High school	13	12.87
Partial university education	44	43.56
University degree	4	3.96
Partial postgraduate education	22	21.78
Postgraduate degree	17	16.83
Pork consumption frequency		
Daily	0	0.00
Six to four times a week	0	0.00
Three to one time a week	32	31.68
Twice a month	34	33.66
Once a month	20	19.80
Seldom	15	14.85

a CATA questionnaire with 20 sensory attributes, which were selected by trained and experienced assessors in sensory testing of food products from the Laboratório de Qualidade e Processamento de Carne at Luiz de Queiroz College of Agriculture, University of São Paulo. Filtered water and unsalted crackers were served as palate cleansers between samples.

The following 20 sensory attributes were used in the CATA questionnaire: "brightness", "dry meat-like appearance", and "fiber meat-like appearance" for appearance category; "pork meat-like taste", "cooked pork meat-like taste", "chicken meat-like taste", "sweet taste", "sour taste", "salty taste", "tasteless", "off-flavor", and "monosodium glutamate taste" for flavor/taste category; "pork meat-like odor" and "chicken meat-like odor" for odor/aroma category; and "tender texture", "tough texture", "fiber texture", "juicy texture", "crumbly texture", and "dry texture" for textural category. All selected attributes and definitions are shown in Table 2.

Statistical analysis

Data were analyzed using XLSTAT 2015 software. The frequency of each sensory attribute term in the CATA questionnaire was determined by counting the number of consumers that used that term to describe each loin chop sample. The Cochran's Q test was performed to identify differences ($p < 0.05$) among loin chop samples from pigs fed different oil sources for each attribute included in the CATA questionnaire. When there were differences between loin samples for a given attribute, the post-hoc multiple pairwise comparisons were performed using the Wilcoxon signed-rank test ($p < 0.05$). The correspondence analysis, based on chi-square distance (Vidal et al., 2015), was used to obtain the relationships between the loin chop samples from pigs fed different oil sources and CATA attributes. The principal coordinate analysis was carried out to display the relationship between overall liking and CATA attributes. Finally, the penalty analysis was performed on CATA data using overall liking to identify positive and negative drivers of liking (Meyners et al., 2013).

Results and Discussion

Twenty sensory attribute terms were included in the CATA questionnaire to describe loin chop samples. The Cochran's Q test revealed that consumers perceived and identified six of these attributes differently ($p < 0.05$) due to the oil source added to pig diets, including one appearance attribute (dry meat-like appearance), two taste/flavor attributes (sour taste and tasteless), and three textural attributes (firm, juicy, and dry) (Table 3). The most frequently chosen attributes were "pork meat-like odor", "cooked pork meat-like taste", "pork meat-like taste", and "tender texture"; however, none of these attributes showed differences ($p > 0.05$).

Table 2 – Definition of the sensory attributes used on Check-All-That-Apply (CATA) study.

Attribute	Definition[1]
Appearance	
Brightness	Intensity of light reflection
Dry meat-like appearance	Visible moisture on meat surface
Flavor/Taste	
Fiber meat-like appearance	Visible fiber on meat surface
Pork meat-like taste	A total pork taste with a balance of bitter, sweet, and acidulous taste
Cooked pork meat-like taste	Aromatic taste sensation associated to cooked pork meat
Chicken meat-like taste	Aromatic taste sensation associated to chicken meat
Sweet taste	Taste associated to sucrose
Sour taste	Taste associated to citric acid (monohydrate)
Salty taste	Taste associated to sodium chloride
Tasteless	Absence of taste (insipid)
Off-flavor	Atypical flavor associated to product deterioration or transformation
Monosodium glutamate taste	Taste associated to monosodium glutamate
Odor/Aroma	
Pork meat-like odor	Intensity of total pork odor perceived by sniffing
Chicken meat-like odor	Intensity of total chicken odor perceived by sniffing
Texture	
Tender texture	Easy effort required to convert the sample into a swallowable state
Tough texture	Big effort required to convert the sample into a swallowable state
Fiber texture	Fiber perception during chewing
Juicy texture	Degree of juice released during chewing the meat
Crumbly texture	Description of size and shape of particles in the mouth
Dry texture	Free from moisture perception

[1]Definitions of sensory attributes adapted from Byrne et al. (2001), Saldaña et al. (2018), and González-Mohino et al. (2021).

Using the post-hoc multiple pairwise comparisons, consumers perceived differences in pork from pigs fed diets with different oil sources (Table 3). However, no pairs were found to be different for dry meat-like appearance, even though the overall Cochran's Q test detected a significant difference. For the attributes in the taste/flavor category, "sour taste" was more frequently ($p < 0.05$) chosen for loins from control-fed pigs in comparison with loins from 3 % FO-fed pigs. Moreover, loins from pigs fed diets containing 3 % FO were characterized by a higher frequency ($p < 0.05$) of mention of "tasteless" when compared to those from pigs fed diets with 3 % SO.

No difference ($p > 0.05$) was observed for the "off-flavor" attribute across loin chops from different oil sources, which agrees with the findings reported in other studies evaluating linseed, co-extruded flaxseed, and LIPEX feeding regimen (Gonzalez et al., 2020; Juárez et al., 2011; Sheard et al., 2000). In contrast, previous studies showed that addingfish oil at relatively low levels (1 to 3 %) to pig diets led to off-flavor and odors in pig tissues and pork processed products (Leskanich et al., 1997; Øverland et al., 1996). The thiobarbituric acid reactive substances (TBARS) assay is commonly used as an indicator of lipid oxidation; thus, possibly pork loins from different oil sources in our study had thiobarbituric acid (TBA) values below a threshold of 0.5 mg malondialdehyde kg^{-1} at which consumers may detect rancidity (Gray and Pearson, 1987).

For textural attributes, "firm" was more frequently ($p < 0.05$) chosen for loins from control-fed pigs when compared to loins from pigs fed diets containing 3 % SO (Table 3). Consumers cited with a significantly higher frequency ($p < 0.05$) the "juicy texture" attribute in loins from pigs fed diets containing 3 % SO compared to the 3 % FO treatment. The results for the juiciness assessment showed that the frequency of mention of the "dry texture" attribute was significantly lower ($p < 0.05$) in loins from 3 % SO-fed pigs in comparison with loins from 3 % FO-fed pigs.

Table 3 – Frequency (%) of selection of the Check-All-That-Apply (CATA) attributes for loin chop samples from immunocastrated pigs fed different oil sources.

Attribute	Dietary treatment[1]				p-value[2]
	Control	SO	CO	FO	
Appearance					
Brightness	15	19	12	15	0.519
Dry meat-like appearance	25[a]	26[a]	37[a]	41[a]	0.017
Fiber meat-like appearance	26	31	30	32	0.735
Taste/Flavor					
Pork meat-like taste	47	53	56	48	0.487
Cooked pork meat-like taste	46	55	51	47	0.373
Chicken meat-like taste	8	7	14	15	0.112
Sweet taste	20	17	21	15	0.506
Sour taste	14[a]	8[ab]	8[ab]	3[b]	0.014
Salty taste	4	6	7	8	0.442
Tasteless	33[ab]	28[b]	37[ab]	44[a]	0.039
Off-flavor	17	8	7	13	0.068
Monosodium glutamate taste	2	6	3	2	0.297
Odor/Aroma					
Pork meat-like odor	58	71	60	59	0.114
Chicken meat-like odor	19	11	20	11	0.103
Texture					
Tender texture	48	62	49	47	0.100
Firm texture	28[a]	12[b]	19[ab]	24[ab]	0.027
Fiber texture	44	39	38	38	0.745
Juicy texture	37[ab]	51[a]	35[ab]	30[b]	0.016
Crumbly texture	9	6	5	12	0.222
Dry texture	28[ab]	22[b]	37[ab]	42[a]	0.013

[1]Immunocastraded pigs were fed either a corn-soybean meal diet containing 1.5 % soybean oil (control) or diets containing 3 % soybean oil (SO), canola oil (CO), or fish oil (FO); [2]p-values were obtained according to the Cochran's Q test ($p < 0.05$); [a,b]Post-hoc multiple pairwise comparisons were performed using the Wilcoxon signed-rank test ($p < 0.05$). Means with all different superscript letters differ in the same row ($p < 0.05$).

Juiciness is greatly influenced by the amount of saliva each consumer produces; thus, confounding the overall sensory perception of meat tenderness (Findlay, 2017). Although loins from 3 % SO-fed pigs showed higher citation frequency for the "juicy texture" term in comparison with the FO treatment, no differences ($p > 0.05$) were found in the "tender texture" attribute across dietary treatments using the CATA method. This is an interesting result given that, in our previous study, loins from pigs fed diets with either 3 % SO or CO showed decreased Warner-Bratzler shear force compared to loins from control-fed pigs (Almeida et al., 2021). Instrumental measurements of pork loin tenderness, such as Warner-Bratzler shear force and texture profile analysis, accounted for less than 20 % of the variability in sensory evaluation (Choe et al., 2016).

The biplot of correspondence analysis shows the differences in the sensory map across the loin chop samples from pigs fed different dietary oil sources (Figure 1). The two first dimensions explained 85.97 % (53.87 % for dimension 1 and 32.10 % for dimension 2) of the total variance. Loin samples were in different quadrants, showing a distinct sensory map. More specifically, loins from 3 % CO- or FO-fed pigs were located in the same quadrant and mainly related to "tasteless", "dry texture", "fiber meat-like appearance", "dry meat-like appearance", "chicken meat-like taste", and "salty taste" attributes. In contrast, those from 3 % SO-fed pigs were more linked to "tender texture", "pork meat-like odor", "pork meat-like taste", "juicy texture", "cooked pork meat-like taste", and "brightness" attributes. The attributes that best described loins from control-fed pigs were "fiber texture", "sweet taste", "chicken meat-like odor", "off-flavor", as well as "firm texture". Therefore, based on the set of CATA terms selected by the consumers, loin samples could be separated into the following three groups: 1) control, 2) 3 % SO, and 3) 3 % CO and FO. These findings indicate that different sensory attributes are perceived depending on the source and inclusion level of dietary oil for pigs.

The nine-point hedonic scale is the most useful sensory method to measure product liking and preference, which ranges from 1 = Dislike extremely to 9 = Like extremely (Stone et al., 2020). As we reported above, adding 3 % SO (5.98 ± 0.21) to pig diets resulted in loin chops that were rated higher for overall consumer liking when compared with chops from pigs fed the control diet (5.30 ± 0.21) or diet with 3 % FO (5.24 ± 0.21), whereas the addition of 3 % CO (5.78 ± 0.19) to pig diets had similar consumer overall liking score than chops from all other diets (Almeida et al., 2021).

Considering the principal coordinate analysis (Figure 2), overall liking (lower right quadrant) seemed to be positively correlated with attributes that were linked to loin samples from 3 % SO-fed pigs in the

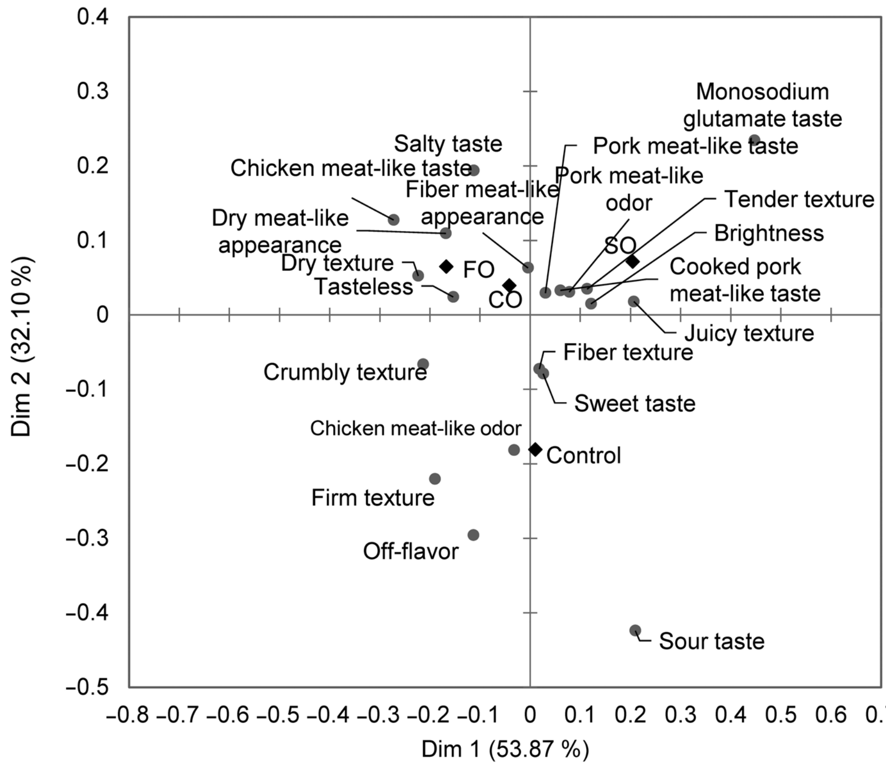

Figure 1 – Representation of the Check-All-That-Apply (CATA) attributes (●) used to describe loin chop samples from immunocastrated pigs fed four dietary treatments (◆) in the first two dimensions of the correspondence analysis performed using the CATA attributes. Dietary treatments consisted of corn-soybean-meal based diets supplemented with 1.5 % soybean oil (control) or 3 % oil from either soybean oil (SO), canola oil (CO), or fish oil (FO); Dim 1 and Dim 2 = percentage of the total variance explained.

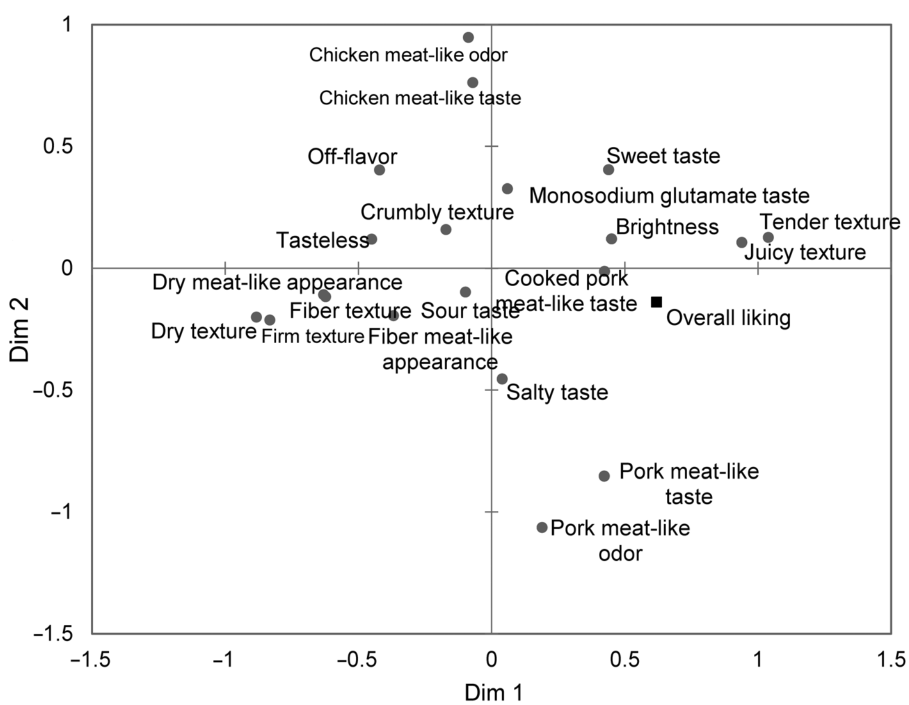

Figure 2 – Principal coordinate analysis plot of Check-All-That-Apply (CATA) attributes frequencies (●) and overall liking scores (■) for loin chop samples from immunocastrated pigs fed four dietary treatments; Dim 1 and Dim 2 = percentage of the total variance explained.

correspondence analysis. The attributes "cooked pork meat-like taste", "juicy texture", "tender texture", and "brightness" were located close to the overall liking and may have a significant influence on consumer acceptability. Consumers have demonstrated a high acceptance for the more tender and juicier fresh pork (Aaslyng et al., 2007) and particularly for increased brightness in processed pork products (Lebret and Čandek-Potokar, 2022).

Conversely, overall liking is mainly negatively correlated to "chicken meat-like" (odor and taste), "dry meat-like appearance", "dry texture", and "pork meat-like" (odor and taste) attributes, which were characteristics linked to loins from 3 % CO- and FO-fed pigs, and to a minor degree to the other attributes laying in the negative side of the first dimension (Figure 2). These findings reinforce the greater overall liking of consumers for loin chops from pigs fed diets that contained 3 % SO, whereas the least valued loin samples, based on their sensory attributes, were those from the 3 % FO and CO treatments.

Drivers of consumer liking reveal which attributes positively or negatively impact consumer acceptance (Kuesten and Bi, 2018). The liking mean impact plot displays the attributes with significant influence on overall liking (Figure 3). Therefore, "tender texture", "juicy texture", "pork meat-like" (odor and taste), and "cooked pork meat-like taste" attributes were drivers of liking, whereas "dry meat-like appearance", "fiber texture", "dry texture", "tasteless", and "firm texture" attributes negatively affected the overall liking mean impact, noted as drivers of disliking. The drivers of consumer liking were also observed in the correspondence analysis biplot, which were linked to loins from 3 % SO-fed pigs.

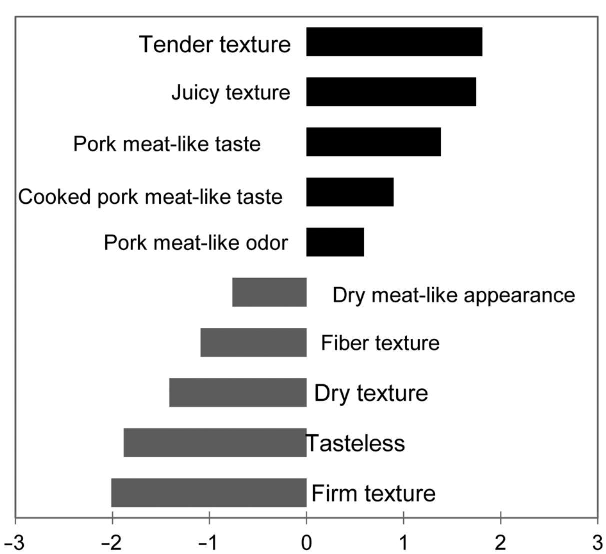

Figure 3 – Liking mean impact plot displaying the attributes identified as "drivers of liking" (black) and "drivers of disliking" (gray).

Conclusions

The CATA method may help characterize variations in pork loin sensory attributes depending on the oil source and the level added to genetically lean immunocastrated pig diets. The most appreciated loins by the consumers came from pigs fed diets with 3 % SO, which were mainly associated with textural-related attributes. Therefore, adding 3 % SO to immunocastrated pig diets is certainly relevant from a pork sensory quality perspective.

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Authors' Contributions

Conceptualization: Campos, D.; Gomes, J.D.; Gonçales, J.L.; Patinho, I.; Villa, E.M.S.; Contreras-Castillo, C.J.; Coutinho, L.L.; Luchiari Filho, A.; Cesar, A.S.M. **Data curation**: Silva, J.P.M.; Meira A.N.; Moreira, G.C.M.; Pian, L.W.; Campos, D.; Gomes, J.D.; Gonçales, J.L.; Dargelio, M.D.B.; Patinho, I.; Luchiari Filho, A. **Formal analysis**: Saldaña, E.; Nuñez, A.J.C. **Methodology**: Moreira, G.C.M.; Cesar, A.S.M. **Project administration:** Cesar, A.S.M. **Funding acquisition:** Cesar, A.S.M. **Writing – original draft**: Silva, J.P.M.; Almeida, V.V. **Writing – review & editing**: Schinckel, A.P.; Saldaña, E.; Contreras-Castillo, C.J.; Coutinho, L.L.; Nuñez, A.J.C.; Cesar, A.S.M.

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