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The Effects of Excluding Animal Products from the Diet on Sensory Properties of Pork from Pigs Grown in New Zealand as Assessed by Singaporean Panelists

Jasmine Leong[1,2,] *, Roger W. Purchas[1], Patrick C. H. Morel[1] and Brian H. P. Wilkinson[1]

[1] Massey University, Institute of Food, Nutrition and Human Health, PN 452, Private Bag 11 222, Palmerston North, New Zealand

ABSTRACT : Sensory analyses of pork samples from leg muscles of female pigs raised in New Zealand (n = 17) were conducted using trained and untrained Singaporean panelists. The New Zealand pigs included three dietary groups, with one diet including animal products (NZA), and two containing plant products only (NZP & NZP+), with the NZP+ diet containing a supplement (0.614%) containing conjugated linoleic acid (CLA), selenium, and vitamin E. The New Zealand pork was also compared with Indonesian pork as local reference samples (n = 6). Pork samples from the NZA group had the highest score for mutton flavour and aftertaste, and the lowest score for brothy aroma, brothy flavour, meaty flavour, lightness and juiciness by trained sensory panels. Samples from NZP and NZP+ were similar except the NZP+ group had a stronger stale flavour than the NZP group (1.34 vs. 0.57 on a 100-point scale; $p<0.05$). The first and second functions of a discriminant analysis based on trained-panel scores for 14 attributes accounted for 95.4% of the variance, with function 1 (83.7%) being related mainly to mutton aroma, mutton flavour and aftertaste. Based on a 20-member untrained panel, the NZA pork had the highest mutton aroma and mutton flavour intensities ($p<0.01$) and aroma and flavour that was less acceptable than that from the NZP group ($p<0.05$). The acceptability scores of Indonesian pork were not significantly different from those of New Zealand pork, but its scores for mutton aroma and mutton flavour were significantly lower than NZP. Overall acceptability was positively associated with acceptability of aroma (r = 0.906), juiciness (r = 0.888), and tenderness (r = 0.904), but negatively associated with intensities of mutton aroma (r = -0.478) and flavour (r = -0.551). (**Key Words** : Pork Flavour, Discriminant Analysis, Mutton-flavour, Conjugated Linoleic Acid)

INTRODUCTION

Pork is a popular meat consumed by non-muslim Singaporeans with about 87,000 tonnes being consumed per year (Kanagalingam, 2005). Currently, Singapore imports its pork from several countries, but Australian and Indonesian pork is consumed most widely due to its ready availability at supermarkets and wet markets. Fresh pork is obtained from pigs raised in Indonesia but slaughtered at Singapore abattoirs, while chilled pork is mainly imported from Australia and is widely known as "Air Pork". Singaporean consumers are aware of the origin of pork from packaging labels. Results of a recent survey showed that Singapore consumers associate non-Indonesian pork with the presence of an unpleasant mutton-like off-flavour (Leong et al., 2008).

One possible cause of off-flavours in pork is by the oxidation of lipids, leading to the formation of aldehydes and short-chain fatty acids (Reindl and Stan, 1982; Devol, et al., 1988). The rate and extent of lipid oxidation depends on a number of factors, the most important being the level of polyunsaturated fatty acids (PUFA) in muscle (Allen and Foegeding, 1981). Pork contains high levels of unsaturated fatty acids relative to ruminant meat (Enser et al., 1996) and is more susceptible to oxidative deterioration of lipids and myoglobin. Feeding of PUFAs to pigs can improve the nutritional quality of pork, but may also increase the susceptibility to oxidation (Sheard et al., 2000; Kouba et al., 2003; Morel et al., 2006). There have been many reports of PUFA-rich feeds leading to increased lipid oxidation and thus off-flavour in pork (Houben and Krol, 1980; Warnants et al., 1998; Roman et al., 1995; Overland et al., 1996;

* Corresponding Author: Jasmine Leong. Tel: +65-698706164, Fax: +65-67721976, E-mail: JLeongWY@sp.edu.sg

[2] Singapore Polytechnic, School of Chemical and Life Sciences, 500, Dover Road, Singapore 139651.

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Leskanich et al., 1997; Wood et al., 2003). There have also been examples of off-flavours in pork arising from the direct transfer of aroma components from feed to meat, including several reports on how feeding of fish oil and high fat fish meal to finisher pigs has caused "fishy" and other off-flavours in pork products (Kjos et al., 1999; Lauridsen et al., 1999; Maw et al., 2001; Jaturasitha et al., 2002).

The current paper compares sensory assessments of the flavour of pork from the legs of pigs finished in New Zealand on three diets (Morel et al., 2008) using Singaporean panelists. The objective was to determine the extent to which dietary feed treatments received by the New Zealand pigs influenced the sensory properties of pork using trained and untrained Singaporean panels. Results of sensory analyses of pork from the loins of the same New Zealand pigs using New Zealand panelists were reported by Janz et al. (2008).

MATERIALS AND METHODS

Samples

Pork samples comprising the semimembranosus, adductor, and semitendinosus muscles were obtained from 17 female pigs (Duroc×(Large White×Landrace)) raised in New Zealand and 6 female pigs from Indonesia (Duroc cross, SG1; n = 6). The pigs from New Zealand were made up of three dietary groups, with one receiving a diet containing some animal products (NZA; n = 6), and two receiving diets containing plant products only (NZP; n = 6 and NZP+; n = 5), with the NZP+ diet containing a supplement (Sanovite^{TM}; 0.614% of the diet) of conjugated linoleic acid (CLA), selenium, and vitamin E. Details of these diets were given by Morel et al. (2008) and are shown in Table 1. All pigs were slaughtered under normal commercial conditions in a New Zealand abattoir in Wanganui for the New Zealand groups (Morel et al., 2008) and at an abattoir in Singapore for the Indonesian group, to produce carcass weights ranging from 65.2 to 87 kg for the New Zealand pigs and 60 to 70.5 kg for the Indonesian pigs. The experiment was conducted in accordance with the Massey University Animal Ethics Committee and the New Zealand Code of Practice for the Care and Use of Animals for Scientific Purposes.

Sensory evaluation

Sensory evaluation was conducted at the Food Quality and Sensory Evaluation laboratory of the Singapore Polytechnic. Quantitative descriptive analysis (QDA) which has gained acceptance for sensory evaluation of various food products (Stone and Sidel, 1998) was carried out by trained panelists who were screened based on their sensory acuity and their liking of pork. They were considered to like pork if they consumed it at least twice a week and described it as one of their favourite meats. Triangle tests using different concentrations of sucrose, sodium chloride, citric acid and caffeine were used to perform the screening and ultimately the six selected panelists participated in three training sessions over a period of two days.

Table 1. Composition of NZA, NZP and NZP+[2] diets for pigs raised in New Zealand

Ingredient (% of diet)	Treatment group	
	NZA	NZP
Barley	63.38	67.35
Broll	10	10
Soybean meal	6.5	14
Blood meal	3.00	-
Meat and bone meal	13.00	-
Tallow	3.5	-
Soybean oil	-	1.90
Linseed oil	-	0.60
Lysine	-	0.35
Methionine	0.16	0.22
Threonine	0.06	0.18
Dicalcium phosphate	-	3.20
Limestone	-	1.50
Sodium chloride	0.10	0.10
Disodium phosphate	-	0.30
Vitamin-mineral premix[1]	0.30	0.30

[1] Vitamin-mineral premix provided the following (unit kg^{-1} diet): 10,000 IU Vitamin A, 2,000 IU Vitamin D_3, 50 mg Vitamin E, 2 mg Vitamin K, 1 mg Vitamin B_1, 2.5 mg Vitamin B_2, 2 mg Vitamin B_6, 10 μg Vitamin B_{12}, 10 mg calcium pantothenate, 15 mg niacin, 10 μg biotin, 0.5 mg folic acid, 100 mg choline, 100 mg iron, 45 mg manganese, 0.5 mg cobalt, 0.3 mg selenium, 120 mg zinc, 25 mg copper, 1 mg iodine.

[2] This diet has the same ingredients as NZP with the addition of Sanovite to make up 0.614% of the total. Sanovite is a trademarked dietary supplement containing CLA, vitamin E and organic selenium.

Training under the direction of the panel leader led to the development of a common sensory language over three 1.5 hour training sessions. This relatively short training period was considered sufficient because all panelists had considerable previous experience. During the training sessions, the panelists practised scoring sensory attributes of the pork samples that were presented at least twice per session to allow panelists to re-familiarise themselves with the typical flavour associated with each attribute. The questionnaire for the trained panel included 18 items (Table 2) each of which was assessed on a 150 mm unstructured scale from "None" to "Strong".

For the trained panel, samples of the semimembranosus and adductor muscles were minced (Moulinex brand, model no.HV8) through a plate with 8 mm diameter holes at a rate of 1.6 kg/minute. For evaluation of meat aroma, 10 g of minced meat were placed in a 30 ml polypropylene bottle that was covered with a cap, and cooked for 10 min in a

Table 2. Definitions of the sensory attributes of cooked pork developed by the trained panelists during training, together with the anchor points at each end of the 150 mm scale

Sensory attribute	Interpretation	Anchor points
Aroma and odour attributes		
Meaty aroma	Aromatics associated with cooked meat[1]	None/Strong
Brothy aroma	Aromatics associated with pork cooked in water[1]	None/Strong
Metallic aroma	Aromatics associated with presence of iron ions[1]	None/Strong
Acidic aroma	Aromatics associated with presence of citric acid[2]	None/Strong
Mutton aroma	Aromatics associated with presence of mutton[1]	None/Strong
Stale odour	A typical aroma generally associated with rancidity of meat and its fat[1]	None/Strong
Flavour and taste attributes		
Meaty flavour	Sensations associated with cooked meat[1]	None/Strong
Brothy flavour	Sensations associated with pork cooked in water[1]	None/Strong
Metallic flavour	Sensations associated with the presence of iron ions[1]	None/Strong
Acidic taste	Taste on the tongue associated with citric acid[2]	None/Strong
Mutton flavour	Sensations associated with cooked mutton[1]	None/Strong
Stale flavour	Atypical taste generally associated with rancidity of meat and its fat[1]	None/Strong
Bitter taste	Taste on the tongue associated with caffeine[2]	None/Strong
Aftertaste	Sensation of lingering taste on the tongue after ingestion[1]	None/Strong
Other attributes		
Brownness	Degree of brownness[1]	Grey/Brown
Lightness	Degree of darkness/lightness[1]	Light/Dark
Juiciness	Sensation of presence of moisture or liquid exudates in the mouth[1]	None/Strong
Tenderness	Ease of breaking down of meat into fine particles when chewed[1]	None/Strong

[1] Definitions as developed by the panelists. [2] Definitions of Meilgarrd et al. (1999).

water bath at 100°C (Memmert brand; model no. W350). The bottles were capped throughout the cooking process to retain aromas and were opened by the panelists during the evaluation. For taste evaluation, 50 g of minced meat were placed into 150 ml glass jars that were capped and cooked in water (100°C) for 30 mins. During the cooking process, the minced meat was stirred to prevent clumping together. By opening and closing the jars to do the stirring, much aroma would have been lost, which is why aroma was evaluated separately as described above. Each panelist was provided with an evaluation form, napkins, a covered container for expectoration, water, and plain white bread for cleansing the palate. Each sample was tasted once in each of two sessions with 11 or 12 samples per session to give a total of four sessions. Samples were presented to the panelists randomly and one at a time.

For the untrained panel, each of the 20 untrained panelists (5 males and 15 females, aged between 18 to 45 years) assessed samples from each pig twice for aroma, flavour, juiciness, tenderness and overall acceptability on a scale from 1 to 9 where 1 was "Dislike extremely" and 9 was "Like extremely". They also assessed the intensity of mutton aroma and mutton flavour on a scale where 1 was "None" and 5 was "Intense". Both panels assessed the pork samples using normal white light at the sensory evaluation booths.

Samples of the semitendinosus muscle were cut into strips (approximately 50 mm×30 mm×5 mm) and marinated with dark soy sauce (Tai Hua Food Industries Pte Ltd., Singapore; 1 ml of sauce per 2.5 g of pork) for 10 minutes to impart a dark brownish black colour and a slight salty note to the meat, and then simmered in a covered 3.5 litre slow cooker (Cornell brand: CSJ35) for 30 min set at 90°C, 30 min at 80°C, and then held at 60°C until served. Panelists were served with a tray of four samples (in lidded plastic containers) that they tasted individually on a flour bun (commonly known as 'Mantou'; 80×50×5 mm). Three trays of samples were evaluated per session with a total of 46 samples in four sessions over two weeks, so each panelist tasted pork from each pig twice. This method of cooking and presentation was used because it is popular with Singaporeans.

Statistical analysis

All statistical analyses were carried out using SPSS ver. 17 (SPSS Inc., Singapore). The animals were nested within feed treatment, while treatment and panelist effects were arranged in a factorial manner with samples from every animal being evaluated by every panelist. The data were analysed as a nested-factorial design.

Treatment group effects were tested against animal effects. Both panelist and panelist×treatment effects were tested against panelist×animal (within treatment). Animal within treatment and panelist×animal (within treatment) effects were tested against the overall errors.

Scale marks from QDA were converted to intensity scores from 0 to 100 for each descriptor and analysed by ANOVA (Type I Sums of Squares) at 5% level of significance using the General Linear Model (GLM) procedures to determine differences among the groups. The Sharpiro-Wilk test for normality of the data indicated that 10 of the 18 attributes in the trained panelist data and two from the untrained panel required some kind of transformation ($p<0.05$ for the Shapiro-Wilk's test). Natural logs were used for 12 attributes (acid aroma, metallic aroma, mutton aroma, stale odour, acidic taste, metallic flavour, mutton flavour, stale flavour, bitter taste, and aftertaste for the trained panel, and mutton aroma, and mutton flavour for the untrained panel). Because these 12 attributes included some zero scores, the data were analysed as $\log_e(x+1)$ where x = the untransformed value. To get the actual least-squares means, "1" was subtracted from the back-transformed least-squares means. The significance of differences between the least-squares means was assessed using the Least Significant Different test. Relationships between attributes based on animal means were evaluated

Table 3. Least-squares means showing the effects of treatments on sensory attributes of pork as determined by a trained sensory panel

Sensory attribute[1, 2]	Treatment				Effects[4]	R^2(%), RSD[5]
	NZA	NZP	NZP+	SG1		
No. of animals	6	6	5	6		
Aroma and odour attributes:						
Meaty aroma	39.95	36.15	40.06	35.75	0.522	54.0, 23.63
Brothy aroma	31.41^{a}	34.31^{ab}	41.93^{b}	37.14^{ab}	0.025	56.2, 30.10
Metallic aroma[3]	1.07	1.07	1.08	1.44	0.058	64.9, 1.026
	(1.92)	(1.92)	(1.94)	(3.22)		
Acidic aroma[3]	0.596^{ab}	0.856^{ab}	0.573^{a}	0.922^{b}	0.046	71.7, 0.742
	(0.81^{ab})	(1.35^{ab})	(0.77^{a})	(1.51^{b})		
Mutton aroma[3]	2.38	2.29	1.86	1.95	0.108	60.2, 1.18
	(9.80)	(8.87)	(5.42)	(6.03)		
Stale odour[3]	0.639	0.921	0.619	0.646	0.095	73.6, 0.727
	(0.89)	(1.51)	(0.86)	(0.91)		
Flavour and taste attributes:						
Meaty flavour	47.66^{a}	55.53^{b}	53.13^{b}	54.72^{b}	0.002	77.8, 15.54
Brothy flavour	28.51^{a}	40.91^{b}	33.15^{ab}	32.93^{ab}	0.003	83.0, 14.64
Metallic flavour[3]	0.929	0.755	0.947	0.674	0.382	58.9, 0.830
	(1.53)	(1.13)	(1.58)	(0.96)		
Acidic taste[3]	0.629^{ab}	0.499^{ab}	0.860^{b}	0.439^{a}	0.027	71.2, 0.667
	(0.88^{ab})	(0.65^{ab})	(1.36^{b})	(0.55^{a})		
Mutton flavour[3]	3.42^{c}	1.96^{b}	2.17^{b}	0.897^{a}	<0.0001	67.4, 1.08
	(29.57^{c})	(6.10^{b})	(7.76^{b})	(1.45^{a})		
Stale flavour[3]	0.624^{ab}	0.448^{a}	0.849^{b}	0.343^{a}	0.001	72.2, 0.587
	(0.87^{ab})	(0.57^{a})	(1.34^{b})	(0.41^{a})		
Bitter taste[3]	1.29^{b}	1.22^{b}	1.37^{b}	0.699^{a}	<0.0001	79.7, 0.683
	(2.63^{b})	(2.39^{b})	(2.94^{b})	(1.01^{a})		
Aftertaste[3]	3.57^{c}	3.10^{b}	3.22^{b}	2.20^{a}	<0.0001	67.2, 0.733
	(34.52^{c})	(21.20^{b})	(24.03^{b})	(8.03^{a})		
Other attributes						
Colour	37.89	42.56	34.58	39.07	0.353	79.3, 15.30
Lightness	31.30	36.13	32.01	32.15	0.707	62.1, 21.77
Juiciness	50.32^{a}	55.30^{b}	52.54^{ab}	52.35^{ab}	0.031	40.0, 13.32
Tenderness	60.08	58.75	60.49	56.13	0.114	52.4, 14.79

[1] All attributes were scored on a scale of 0-100 with higher values indicating a stronger note.

[2] Means in the same row with no letters or with a common letter after them do not differ significantly ($p<0.05$) as determined by Fisher's least significance difference (LSD) mean separation test.

[3] The significance of differences (using LSD) was based on the transformed means ($\log_e$) of these attributes, and the back-transformed means are shown in brackets below the transformed means.

[4] p-values.

[5] Measures of the overall goodness-of-fit for the model include the coefficient of determination (R^2(%)) and the residual standard deviation (RSD).

Table 4. The largest five coefficients for the first two discriminant functions from the discriminant analysis based on the 14 aroma and taste attributes (Table 1) assessed by the trained panel

Discriminant function number			
1 (83.7% of variation)		2 (11.7% of variation)	
Attribute	Discriminant coefficient	Attribute	Discriminant coefficient
Mutton flavour	1.560	Stale flavour	-1.580
Meaty aroma	1.417	Meaty aroma	1.250
Brothy flavour	-0.936	Metallic aroma	-1.212
Mutton aroma	0.918	Bitter taste	-1.106
Aftertaste	0.872	Metallic flavour	0.414

using Pearson's linear correlation coefficients. Discriminant analysis was performed using the scores of 14 aroma and flavour attributes from the trained panel in order to identify combinations of variables that discriminated best among the four treatment groups.

RESULTS

Trained panel results

Results in Table 3 indicate that 8 of the 18 attributes were not significantly different among the four groups. Many of the attributes (7 out of 14) had very low scores with means less than 4 on the 100-point scale. Brothy aroma scores were significantly higher for the NZP+ than NZA groups, with NZP and SG1 being in-between. Stale odour score was higher for NZP samples than those from NZA, but neither of these differed significantly from the other two groups. Meaty flavour scores were lower for the NZA group than for the other three groups. Brothy flavour was lowest for NZA, which differed significantly from NZP, but not the other two groups. Mutton flavour showed large differences between the groups with NZA having a higher score than NZP or NZP+, and these two groups had higher scores than SG1. The mutton flavour score for NZA was more than 20 times that for SG1. Mean stale flavour score for NZP+ was significantly higher than those for NZP and SG1, but not significantly different from that for NZA. Aftertaste was significantly higher for NZA than SG1 with the other two groups in-between. Juiciness was lower for NZA than SG1. There was a significant positive correlation between acidic and metallic aroma scores (r = 0.659), both of which were highest for the NZA group although group differences were not significant. Pork samples from the NZP and NZP+ groups were similar for all attributes except stale flavour, which was higher for NZP+. This similarity was reflected in the closeness of these two groups on the Function-1 scale of the discriminant analysis plot (Figure 1).

The first and second functions of the discriminant analysis (Figure 1) accounted for 95.4% of the variance, with function 1 being related mainly to mutton aroma,

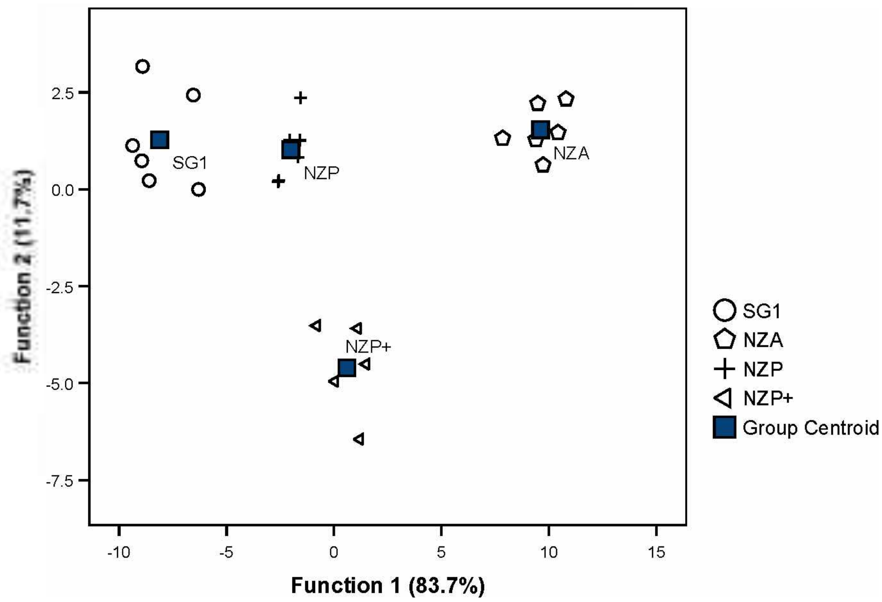

Figure 1. A plot of function 1 versus function 2 from the discriminant analysis based on the 14 aroma and flavour attributes evaluated by the trained panel (Table 1). Points are shown for the 23 individual pigs as well as the treatment group centroids.

meaty aroma, aftertaste, brothy flavour and mutton flavour, while function 2 reflected mainly meaty aroma, metallic aroma, bitter taste, stale flavour and metallic flavour (Table 4). Function 1 clearly separated the treatments into 3 clusters with little separation of NZP and NZP+, but function 2 clearly separated NZP+ from the other three groups (Figure 1).

Correlations across all 23 samples revealed positive relationships between aftertaste and acidic taste (r = 0.594; p<0.01), mutton flavour (r = 0.884; p<0.01), stale flavour (r = 0.429; p<0.05) and bitter taste (r = 0.444; p<0.01). Likewise, mutton flavour was positively related with stale flavour (r = 0.361; p<0.05), and acidic taste (r = 0.584; p<0.01), but negatively related to meaty flavour (r = -0.728; p<0.01). Meaty flavour was positively related with brothy flavour (r = 0.72).

Untrained panel results

Results of evaluations by the untrained panel (Table 5) showed no significant differences between the groups for juiciness, tenderness or overall acceptability. Both aroma and flavour of pork from the NZP group was preferred to that from the NZA group, with pork from the SG1 group having an aroma that was of similar acceptability to the NZP group, but a flavour that was significantly less acceptable than for that group. Flavour and aroma acceptability were not different between the NZP and NZP+ groups.

Intensity scores for mutton aroma and flavour from the untrained panel (Table 5) were lowest for pork samples from the SG1 group and highest for the NZA group (p<0.01). Scores for the NZP and NZP+ groups were intermediate. Scores from the untrained panel indicated that higher overall acceptability scores were associated with more acceptable aroma (r = 0.906), juiciness (r = 0.888), and tenderness (r = 0.904), but with lower intensities of mutton aroma (r = -0.478) and flavour (r = -0.551).

DISCUSSION

Dietary effects on pork flavour

The relatively low acceptability and high mutton-flavour scores for pork from the NZA group may have been due to the higher protein content of the diet for that group (20.6% vs. 15.2% for NZP (Morel et al., 2008) and the fact that some of that protein came from meat and bone meal that is likely to have included meat and bone from sheep. The higher protein level would have resulted in more tryptophan being available in the hind-gut (Tuomola et al., 1996; Henry et al., 2002) for microbial degradation to form the flavourful compounds skatole and indole (Lane and Fraser, 1999; Lane et al., 2002). These indolic compounds have also been shown to be implicated in boar taint (Vold, 1970; Walstra and Maarse, 1970). The quantity of tryptophan reaching the hindgut was calculated using the NRC (1998) feedstuff gross tryptophan content and ileal digestibility coefficient. It is estimated that 20% more tryptophan would have reached the hindgut of NZA pigs relative to NZP pigs (0.53 vs. 0.44 g per kg of feed, respectively). In addition to the possible extra synthesis of

Table 5. Least-squares means for treatment effects on acceptability and intensity scores as assessed by an untrained panel

Sensory attribute [1, 2]	Treatment				Effect[3]	R^2(%), RSD[4]
	NZA	NZP	NZP+	SG1		
Measures of acceptability						
Aroma	5.68^a	6.33^b	6.01^{ab}	6.22^b	0.007	49.4, 1.65
Flavour	5.58^a	6.26^b	5.80^{ab}	5.82^a	0.030	49.7, 1.74
Juiciness	5.70	6.26	5.80	5.82	0.094	49.2, 1.74
Tenderness	5.62	6.17	5.77	5.82	0.294	51.0, 1.84
Overall acceptability	5.64	6.11	5.85	6.05	0.247	50.3, 1.70
Measures of intensity						
Mutton aroma[5]	0.414^c (1.73^c)	0.298^b (1.52^b)	0.261^{ab} (1.47^{ab})	0.199^a (1.32^a)	0.005	48.8, 0.443
Mutton flavour[5]	0.670^c (2.21^c)	0.335^b (1.59^b)	0.387^b (1.66^b)	0.186^a (1.29^a)	<0.0001	52.1, 0.449

[1] All acceptability scores were on a scale of 1-9 where 1 is "Dislike extremely" and 9 is "Like extremely", while intensity scores were on a scale of 1-5 where 1 is "None" and 5 is "Intense".

[2] Means in the same row with no letters after them or with a common letter after them do not differ significantly (p<0.05) as determined by Fisher's least significance difference (LSD) mean separation test.

[3] p-values.

[4] Measures of the overall goodness-of-fit for the model include the coefficient of determination (R^2(%)) and the residual standard deviation (RSD).

[5] The significance of differences (using LSD) was based on the transformed means ($\log_e$) of these attributes and the back-transformed means are shown in brackets below the transformed means.

skatole and indole in the hind-gut of pigs in the NZA group, it is also likely that these compounds would have been present in the diet as they are present in sheep meat and fat (Young et al., 1997; Young et al., 2002; Schreurs et al., 2007; Schreurs et al., 2008), and appear to be at least partly responsible for mutton flavour (Hoffman and Meijboom, 1968; Brennand and Linsay, 1982; Young et al., 2003). These flavourful compounds may have been transferred to the pork, as has been reported for fish odours in several studies (Kjos et al., 1999; Lauridsen et al., 1999; Maw et al., 2001; Jaturasitha et al., 2002).

Although not directly comparable because of differences in the cut used, cooking procedures, and the flavour attributes evaluated, it is noteworthy that a trained New Zealand panel did not detect any significant differences between loin samples from the three groups of New Zealand pigs that were assessed in Singapore (Janz et al., 2008) These results suggest that the Singaporean panelists may have been more sensitive to some of the flavour characteristics, possibly due to the low consumption and poor acceptability of sheep meat in many Asian countries (Prescott et al., 2001), including Singapore (Yeo, 1998), which may mean that mutton-like flavours are less acceptable and more apparent than in New Zealand (Pliner, 1982; Crandall, 1985). Prescott et al. (2001) indicated that the low acceptability of sheep meat in Japan was also related to a low level of consumption in that country. In China, consumers describe the hedonically negative cooking odour of sheep meat as *soo,* meaning sweaty or sour (Wong et al., 1975).

Effects of nutrient supplements on pork flavour

The supplements of CLA, vitamin E and selenium that were present in the diet of pigs in the NZP+ group did not lead the pork to have significant differences in most of the sensory characteristics assessed by the Singapore panels, or by a New Zealand panel (Janz et al., 2008). The only significant difference ($p<0.05$) was a higher stale flavour score for the NZP+ pork relative to the NZP pork, but the mean scores of 1.34 and 0.57, respectively, on the 100-point scale were very low (Table 3). This result and the assessment by the New Zealand trained panel (Janz et al., 2008) of a slightly more frequent rancid odour for NZP+ compared to NZP, is in agreement with other reports indicating that incorporating CLA into finishing diets of pigs has no appreciable effects on the sensory quality of cooked pork and pork products (Dugan et al., 1999; Wiegand et al., 2002; Corino et al., 2003, Teye et al., 2006). It is unlikely that the duration of feeding the supplement was too short to have an effect as it was fed from weaning to slaughter (Morel et al., 2008), but it may be that the amount of CLA added was not enough to cause an extensive oxidative reaction. Martin et al. (2008) also demonstrated that CLA supplementation at doses lower than 1% in the diet of pigs did not affect lipid oxidation in loins.

The low levels of stale flavours in NZP+ (1.34) pork as well as NZP (0.57) pork in the current study and that of Janz et al. (2008) may be partly attributable to the antioxidant properties of vitamin E and selenium that were included in the diet. Vitamin E can stabilise the membrane-bound lipids against metmyogloblin/H_2O_2-initiated oxidation (Monahan et al., 1990; Asghar et al., 1991; Monahan et al., 1992).

Comparison of New Zealand and Indonesian pork

Differences reported here between the locally obtained Indonesian pork and that from New Zealand cannot be interpreted in any depth because there were a number of uncontrolled factors involved. These include the genetic makeup of the pigs, the diet they received, the composition of the pork (Purchas et al., 2009), and the exact nature of the ways in which the pork was treated post mortem. The results indicate, however, that the Singapore panels detected significantly stronger mutton aroma and flavour (untrained panel); and mutton flavour but not aroma (trained panel), in the New Zealand samples, and particularly from pigs that received animal products in their diets (the NZA group).

CONCLUSIONS

Trained and untrained sensory panels in Singapore were able to detect differences in some flavour and aroma characteristics of pork from pigs raised on different diets in New Zealand with the pork from pigs with some animal products in their diet generally being less acceptable and having a stronger mutton flavour. It is suggested that these differences could be caused by the diet of NZA pigs which contained more protein and possibly some meat and fat from sheep.

The Singapore panels detected differences between pork from the three New Zealand groups that were not detected by a New Zealand panel, but there were some confounding factors in this comparison. These results, however, support previous evidence that sensory results from one population may not necessarily apply for populations in other countries even when trained panelists are involved.

Results showed that dietary supplementation with CLA (conjugated linoleic acid) increased the stale note in pork, but this effect was small, possibly because of the antioxidant effects of the additional vitamin E and selenium present.

Relative to locally-produced Indonesian pork the pork from New Zealand did not differ significantly in overall acceptability, but did have more intense mutton-like flavour attributes.

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