The influence of carcass backfat and intramuscular fat level on pork eating quality

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Abstract: To evaluate the contribution of fatness level towards pork eating quality, carcass and meat eating quality data were analysed from 721 pigs of three genotypes (with 0, 0.25 and 0.50 Duroc inclusion level). Animals (entire male and female) were reared from 30 to 90 kg liveweight on one of seven feeding regimens which involved combinations of diet formulation and feeding level, so as to produce carcasses of widely differing fatness levels. This experimental design produced coefficients of variation for classification P_2 backfat thickness of 21.11 (mean 11.59 mm, SE 0.093) and intramuscular fat (IMF) of 63.60 (mean 13.4 g kg^{-1}, SE 0.33). The treatments also produced considerable variation for eating quality as assessed by trained sensory panel (1–8 scale) and objectively (shear force) as shown by the following coefficients of variation: shear force 22.01% (mean 334 N, SE 2.77), juiciness 16.12% (mean 4.95, SE 0.297), tenderness 19.65% (mean 5.06, SE 0.370), pork flavour 13.22% (mean 4.56, SE 0.225), abnormal flavour 34.46% (mean 2.02, SE 0.259) and overall acceptability 18.42% (mean 4.78, SE 0.328). Correlation coefficients between carcass fatness measurements and eating quality characteristics were calculated. Although shear force was significantly correlated with both classification P_2 ($r = -0.213$) and IMF ($r = -0.189$), taste panel tenderness was not significantly correlated to fatness level. Of the taste panel parameters evaluated, only juiciness showed a significant correlation ($P < 0.05$) with classification P_2 ($r = -0.086$). None of the eating quality characteristics as evaluated by taste panel correlated significantly with IMF. These results do not support the belief that fatness level *per se* has a major influence on pork eating quality.

Keywords: pigs; sensory characteristics; carcass fatness; carcass composition; intramuscular fat

INTRODUCTION

The British pig industry can be justifiably proud of its success in reducing carcass fatness (by genetic improvement and altered management practices) over the last two decades. Since a national pig carcass classification scheme was introduced in Great Britain in 1971, the national mean P_2 backfat thickness has reduced from 20 mm to 10.8 mm in 1993.[1] The level of marbling fat in pork has also reduced from 11.0 g kg^{-1} in 1975 to 8.0 g kg^{-1} in 1989.[2] Commensurate with a reduction in carcass fatness, the fat that remains in present-day pork carcasses is less saturated, with higher levels of polyunsaturated fatty acids than pork of 20 years ago.[2]

The reduction in the mean backfat thickness of pigs has shifted the distribution of P_2 depths, leading to a marked increase in the number of extremely lean pigs slaughtered. This trend towards leaner pork has been accompanied by critical comment from the meat industry, particularly retail butchers, regarding the increasing incidence of meat quality problems among the ultralean carcasses at the leading edge of the frequency distribution. The complaints are of poor cutting, presentational and processing qualities and include suggestions that the flavour, juiciness and tenderness, ie eating quality, of meat from modern lean hybrids is lower than that from pigs produced some 20–30 years ago. Such criticism (although largely unsubstantiated) has been construed by some as confirmation that a certain amount of external and intramuscular fat is essential to ensure optimal eating quality of pork. As an integral part of an extensive study investigating the influence of lean tissue growth and fatness on pork eating quality,[3] this paper presents data in a form enabling the contribution of fatness level towards pork eating quality to be evaluated.

MATERIALS AND METHODS

Animals and trial design

The study was carried out at the Meat and Livestock Commission's (MLC) Stotfold Pig Development Unit. Entire male and female pigs with 0, 0.25 and 0.50 Duroc genes were produced by mating Large White sires to Fl Large White × British Landrace and Fl hybrid (Duroc × Large White × British Landrace)

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Treatment	Feeding regime	Diet[a]
1	*Ad libitum* 30–90 kg	CEP
2	Restricted 30–90 kg (80% *ad lib)*	CEP
3	*Ad libitum* 30–60 kg Restricted 60–90 kg (80% *ad lib)*	CEP
4	*Ad libitum* 30–60 kg Restricted 60–90 kg (90% *ad lib)*	CEP
5	*Ad libitum* 30–90 kg	HELP
6	Restricted 30–60 kg (80% *ad lib*) *Ad libitum* 60–90 kg	CEP
7	Restricted 30–75 kg (80% *ad lib*) *Ad libitum* 75–90 kg	CEP

Table 1. Trial dietary treatments

[a] CEP, conventional energy and protein density; HELP, higher energy and low protein density.

females and Duroc sires to Fl Large White × British Landrace hybrid females respectively. A total of 10 Duroc boars and 20 Large White boars was used on 188 sows to produce the pigs. Breeding stock was purchased from a cross-section of British Breeding Companies. Matings and farrowings occurred over a 25 week period, with approximately eight litters being produced weekly. Seven feeding regimens were devised (Table 1) using combinations of diet formulation and feeding level, to achieve different rates of lean and fat tissue gain during two growth periods. The first growth period was between 30 and 60 kg liveweight and the second between 60 and 90 kg liveweight for each treatment, except treatment 7 where the growth periods were 30–75 and 75–90 kg liveweight respectively. Two diets were formulated to be of a conventional energy (14.2 MJ kg^{-1} digestible energy) and protein (205 g kg^{-1} crude protein, 10.5 g kg^{-1} total lysine) density (CEP) or high energy (14.7 MJ kg^{-1} digestible energy) and low protein (166 g kg^{-1} crude protein, 7.0 g kg^{-1} total lysine) density (HELP). The calculated analyses of the two diets used in this study are shown in Table 2. Diets were based on wheat, barley and soya bean meal and contained 400 g t^{-1} copper sulphate, giving 100 mg kg^{-1} added copper as a growth promoter. Raw materials and formulations were held constant throughout the trial and therefore any raw materials which may have varied in supply throughout the year were excluded. The diets were manufactured and fed in the form of a dry meal. A total of 721 pigs was allocated to experimental treatments, on the basis of random selection tables using individual ear notch numbers, to give balanced numbers of the three genotypes and two sexes. Thus there was a minimum of 96 pigs per dietary treatment.

Table 2. Calculated analyses of trial diets (calculated on an 'as-received' basis)

	CEP	HELP
Digestible energy (MJ kg^{-1})	14.2	14.7
Protein (g kg^{-1})	205	166
Oil (g kg^{-1})	55.6	57.7
Fibre (g kg^{-1})	40.3	24.3
Ash (g kg^{-1})	51.8	44.4
Moisture (g kg^{-1})	115.3	117.5
Lysine (g kg^{-1})	10.5	7.0
Available lysine (g kg^{-1})	9.0	5.9
Available methionine (g kg^{-1})	2.7	2.1
Available methionine + cystine (g kg^{-1})	5.7	4.9
Available threonine (g kg^{-1})	6.1	4.6
Saturated fatty acids (g kg^{-1})	16.8	15.7
Unsaturated fatty acids (g kg^{-1})	30.2	34.0
Unsaturated/saturated fatty acids	1.80	2.17

Test procedure

Prior to the start of test, animals were reared in accordance with normal unit protocol using standard procedures. Following allocation to test, animals were housed and fed in single-sex full sib pairs in pens with a lying area of approximately 1 m × 2 m, giving an area of 1 m^2 per animal, and a dunging area of 0.5 m^2 per animal. A feed trough (1 m wide) was located at the front of each pen. Room temperature was maintained at approximately 20 °C throughout the study by a combination of central heating and fan ventilation. For *ad libitum* feed treatments, meal was available in the troughs at all times. Restricted feed animals were fed twice per day. All feed additions and removals were recorded. Levels of restriction were calculated as a percentage of estimated *ad libitum* intake. A preliminary study was carried out utilising 126 animals of representative genotypes to provide an estimate of *ad libitum* intake from which the restricted feeding regime was derived for use in the main study. Meal was fed dry and water was available constantly from nipple drinkers in each pen. Each pair of animals started test on reaching a combined weight of 56 kg or more. Pigs approaching the end test weight were weighed once per week and allocated for slaughter on a pen basis when the average weight reached a minimum of 85 kg for *ad libitum* fed pigs and 88 kg for those on restricted regimens.

Slaughter procedure and carcass quality assessment

All pigs were slaughtered at Dalehead Foods Ltd, Linton (approximately 50 km distance from Stotfold), each Monday morning for 25 consecutive weeks. The trial design aimed to despatch balanced numbers of sex and genotype pairs each week, comprising two pairs of each of the seven feeding regimens. Animals were transported and slaughtered in accordance with the MLC Blueprint for Pork specifications.[4] Pigs were weighed before being despatched for slaughter and held in lairage for a period of at least 1 h prior to slaughter. Slaughter and carcass handling and chilling were carried out in accordance with normal factory

procedures. Carcasses were split within 45 min of slaughter and were conventionally chilled at 1–5 °C for at least 16 h. Carcass classification measurements, ie cold carcass weight (kg) (hot carcass weight minus rebate for weight loss hot to cold) and P_2 fat depth (mm), were taken on the slaughter line by MLC staff. Classification P_2 involved a measurement of subcutaneous fat and rind depth 45 min after slaughter using a Fat-o-Meter (SFK UK Ltd, Liverpool, UK) inserted at a point 6.5 cm from the dorsal mid-line, level with the head of the last rib. A subjective score (0 = none to 3 = heavy marbling, courtesy of Dr Paul Warriss, University of Bristol, UK) of the level of marbling in the foreloin was also taken at this time.

Sample removal

Samples for shear force measurement (10 cm boneless foreloin joint cut immediately anterior to the last rib), sensory evaluation (two 2 cm thick boneless, rindless mid-loin chops) and chemical analysis (2 cm thick boneless, rindless mid-loin chop) were removed from the left side of all 721 pigs 5 days following slaughter. All samples were vacuum packaged, blast frozen and subsequently stored at −40 °C until required.

Intramuscular fat analysis

A frozen 20 mm thick boneless loin chop from each of the 721 animals was analysed for intramuscular fat content. Intramuscular fat was estimated as the free fat content, determined by the petroleum spirit (40–60 °C) method in accordance with BS 4401 (part 5).

Shear force measurement

Frozen loin joints were removed from the deep-freeze 24 h prior to assessment and allowed to defrost for 24 h in a chiller held at 3 °C. The same groups of seven samples evaluated in the taste panel sessions were tested contemporaneously. Joints were cooked in the vacuum pack by immersion in a water bath held at 90 °C for 45 min to an internal joint temperature of approximately 78 °C. Each joint was then immediately plunged into cold running water for 15 min. Joints were removed from their vacuum pack and four 2 cm diameter cores were taken by boring vertically through the subcutaneous fat into the *longissimus dorsi* (LD) muscle. Each core was trimmed of backfat and cut to a length of 2 cm. Cores were then measured for peak shear force (recorded in Newtons) within 1 h of removal from the joint using a JJ Lloyd machine (JJ Lloyd Instruments, Southampton, UK) with Warner-Bratzler jaws. A mean value was taken for the four cores.

Sensory evaluation

Loin chops were evaluated for eating quality characteristics by the MLC's trained sensory panel. Two chops from each of seven animals were evaluated at each tasting session, with samples being randomly allocated to a session from within each treatment group such that each of the seven treatments was represented, with samples balanced in a structured manner for sex and genotype. A minimum of six panellists was used for each testing session. Frozen samples were thawed for 24 h at 3 °C. The chops were trimmed to a uniform thickness of 20 mm and cooked in a Stot Benham Supergrill 600 (London, UK) gas grill set at its highest temperature. The chops were grilled for 5 min on the first side, rotating the grill through 60° every 25 s. The chops were then turned over in place and the process was repeated for the second side. The objective of this method was to cook the chops to a point where they were just turning from pink in the centre and were at an internal temperature of 63–64 °C when removed from the grill. Chops were weighed before and after cooking to estimate cooking loss (recorded in grams). The lean of each chop was separated from the backfat and cut into pieces about 2 cm^3, wrapped in aluminium foil and held at 54 °C prior to tasting. Fat from samples was not tasted, although odour assessments of fat were made. The backfat was placed in a sealed container and stored on a hot plate to maintain the temperature of the fat prior to evaluation by the panellists.

Each sample was assessed on a scale of 1–8 for the following variables.

Evaluation of lean

- Juiciness (1 = extremely dry, 8 = extremely juicy).
- Tenderness (1 = extremely tough, 8 = extremely tender).
- Pork flavour (1 = extremely weak, 8 = extremely strong).
- Abnormal flavour (1 = extremely weak, 8 = extremely strong).
- Overall acceptability (1 = extremely unacceptable, 8 = extremely acceptable).

Evaluation of fat

- Pork odour (1 = extremely weak, 8 = extremely strong).
- Abnormal odour (1 = extremely weak, 8 = extremely strong).
- Boar odour (1 = extremely weak, 8 = extremely strong).

Statistical analysis

Statistical analysis was carried out using Minitab PC (version 9) (Minitab Statistical Software, State College PA, USA). Pearson product moment[5] correlations were calculated. For analysis of fatness measurement differences, among shear force, tenderness, juiciness and overall acceptability groups, samples were ranked by each respective trait into seven equal groups. Each group contained 103 samples, with group 1 having the highest score and group 7 the lowest score. The various fatness measurements were then analysed using one-way analysis of variance with group as the classification variable. This

Table 3. Summary of growth rates and carcass fatness levels (721 animals)

Variable	Mean	SE of mean	Minimum	Maximum	CV (%)
Overall DLWG (g day^{-1})	817	*0.38*	469	1194	*12.56*
Classification P_2 (mm)	11.59	*0.09*	6.00	21.00	*21.11*
Marbling score	0.65	*0.03*	0.00	3.00	NA
IMF LD (g kg^{-1})	13.4	*0.33*	1.40	92.9	*63.60*

process was repeated after dividing and ranking the 721 respective fatness characteristics of IMF and classification P_2. Each of eight groups contained 90 samples, with those in group 1 having the lowest level for each respective fatness trait, and those in group 8 containing samples with the highest levels. Analysis of variance was then calculated for shear force, taste panel tenderness, juiciness and overall acceptability using fatness group as the classification variable.

RESULTS

The main objective of the various nutritional treatments imposed was not to investigate the treatments *per se*, but to produce variation over the whole population (721 animals) in growth rates and carcasses of widely differing fatness levels. The treatments were very successful in this respect, as is illustrated by the summary of growth rates and carcass fatness (raw means) shown in Table 3. To compare the variability of each growth and fatness characteristic, coefficients of variation (CV) are included.

The variations achieved in growth and carcass characteristics, from the treatments, genotypes and sexes imposed, led to much variation for the attributes of eating quality when assessed by trained sensory panel and objectively as described by Blanchard *et al.* [3] In this previously reported main data set, treatment differences for carcass fatness traits were not significant for sex effects, nor were there significant treatment × sex interactions for eating quality. Therefore data for both sexes have been pooled for the analysis reported in this paper.

Calculated correlation coefficients between carcass fatness measurements and eating are shown in Table 4. The highest correlations found in this analysis were those between classification P_2 and shear force, suggesting that as backfat thickness increases, so does tenderness as measured objectively. However, correlations were low and non-significant between P_2 measurements and sensory panel tenderness. Marbling score and intramuscular fat also correlated significantly with shear force but not with taste panel tenderness. Fatness measurements were generally not correlated with juiciness. Flavour scores were not correlated with fatness measurements. Neither marbling score nor intramuscular fat correlated significantly with any eating quality parameters as assessed by trained sensory panel.

DISCUSSION

Despite a vast body of literature examining the relative importance of fatness level to the eating quality characteristics of pork (particularly tenderness), the conclusions drawn by the different authors are somewhat conflicting. To identify a relationship between carcass fatness level and pork eating quality, correlation coefficients were calculated and are shown in Table 4. The highest correlations found in this analysis were those between classification P_2 and shear force (-0.213), suggesting that as backfat thickness increases, so does tenderness. Such correlations between backfat thickness and shear force are in close agreement with those of Hiner,[6] Wood *et al*[7] and Lo *et al.* [8] Correlations were, however, low and non-significant between classification P_2 and sensory panel tenderness, similar to the findings of Wood *et al*[9] and DeVol *et al.* [10] Marbling score and intramuscular fat showed higher correlations with shear force than with sensory panel tenderness. Essen-Gustavsson *et al*[11] suggested that up to 56% of variation in the shear force of pork can be explained by IMF concentration. Lo *et al*[8] showed that shear force explained 54% of the variability in taste panel tenderness scores for pork, which suggested a much stronger relationship between these two traits than found in the present study, where the correlation between shear force and taste panel tenderness was -0.30.

In agreement with Cameron[12] and Purchas *et al*,[13] fatness measurements were generally not correlated with juiciness; however, others have shown significant positive correlations between juiciness and carcass fatness level.[8,14,15] In general agreement with Camer-

Table 4. Correlations between carcass fatness measurements and eating quality characteristics (n=721)

	Juiciness	Tenderness	Pork flavour	Abnormal flavour	Overall acceptability	Pork odour	Abnormal odour	Boar odour	Shear
Classification P_2 (mm)	**−0.086**	0.040	0.034	0.000	0.028	**0.087**	0.047	0.099	**−0.213**
Marbling score	−0.015	0.037	0.040	−0.024	0.044	0.062	0.005	0.003	**−0.186**
IMF LD (g kg^{-1})	0.050	0.069	0.045	0.066	0.068	0.016	0.002	−0.008	**−0.189**

Correlations greater than 0.073 are significant ($P<0.05$) and are shown in bold.

Table 5. Fatness measurements (adjusted means) for seven shear force groups

Shear force group	*Shear force range (N)*	*Mean shear force (N)*	*Classification P_2 (mm)*	*Marbling score*	*IMF LD ($g kg^{-1}$)*
1	405–735	468[a]	10.60[a]	0.37[a]	11.06[a]
2	364–405	384[b]	11.37[b]	0.64[b]	12.81[b]
3	336–364	351[c]	11.50[b]	0.56[b]	12.39[ab]
4	309–336	323[d]	11.60[bc]	0.63[b]	12.54[ab]
5	290–309	300[e]	11.99[c]	0.53[b]	12.94[b]
6	264–290	278[f]	11.64[bc]	0.83[c]	14.73[c]
7	186–264	238[g]	12.39[d]	1.0[d]	16.98[d]
Pooled SE		*1.64*	*0.244*	*0.08*	*0.81*
Significance		***	***	***	***

*** Significant difference ($P<0.001$).

Table 6. Fatness measurements (adjusted means) for seven taste panel tenderness score groups

Tenderness group	*Tenderness range*	*Mean tenderness score*	*Classification P_2(mm)*	*Marbling score*	*IMF LD ($g kg^{-1}$)*
1	6.0–7.17	6.345[a]	11.65	0.63	13.72
2	5.67–6.0	5.817[b]	11.89	0.75	14.96
3	5.33–5.67	5.465[c]	11.78	0.71	13.60
4	5.0–5.33	5.181[d]	11.15	0.65	12.72
5	4.67–5.0	4.879[e]	11.72	0.64	13.28
6	4.17–4.67	4.474[f]	11.31	0.60	12.68
7	1.0–4.17	3.216[g]	11.54	0.58	12.24
Pooled SE		*0.025*	*0.248*	*0.08*	*0.85*
Significance		***	NS	NS	NS

*** Significant difference ($P<0.001$); NS, not significant.

on[12] and Purchas *et al*,[13] flavour scores were not correlated with fatness measurements. Of particular note is the lack of significant relationships between either marbling score or intramuscular fat and any eating quality parameters. Cooking losses had low or non-significant correlations with fatness measurements in agreement with Lundstrom *et al.*[16] Others[17,18] have shown significant negative correlations between cooking losses and fatness measurements.

It has been suggested that one explanation for the poor relationship shown between fatness measurements and eating quality characteristics, as demonstrated by the correlations presented here and those of other workers, is that a 'threshold' for fatness (particularly intramuscular fat) rather than a simple linear relationship with eating quality exists.[10,19,20] To investigate this theory, all 721 animals were divided into seven groups for each of the following traits: shear force (Table 5), sensory panel tenderness (Table 6), juiciness (Table 7) and overall acceptability (Table 8). Each of the seven groups contained 103 samples, with those in group 1 having the highest score for each respective trait, and those in group 7 containing samples with the lowest scores. Analysis of variance was then calculated on the various fatness measurements, using group as the classification variable. From this analysis it would appear that only in the case of shear force (Table 5) is there any suggestion of a threshold of fatness which significantly affects the

Table 7. Fatness measurements (adjusted means) for seven taste panel juiciness score groups

Juiciness group	*Juiciness range*	*Mean juiciness score*	*Classification P_2 (mm)*	*Marbling score*	*IMF LD ($g kg^{-1}$)*
1	5.8–6.67	6.107[a]	11.27	0.67	13.71
2	5.5–5.80	5.598[b]	11.33	0.66	13.84
3	5.17–5.50	5.294[c]	11.88	0.67	13.86
4	4.83–5.17	5.050[d]	11.54	0.68	13.32
5	4.50–4.83	4.662[e]	11.27	0.76	13.49
6	4.17–4.50	4.315[f]	11.73	0.52	12.60
7	1.83–4.17	3.624[g]	12.09	0.60	12.34
Pooled SE		*0.017*	*0.248*	*0.08*	*0.86*
Significance		***	NS	NS	NS

*** Significant difference ($P<0.001$); NS, not significant.

Table 8. Fatness measurements (adjusted means) for seven taste panel overall acceptibility groups

Overall acceptability group	*Overall acceptability range*	*Mean overall acceptability score*	*Classification P_2 (mm)*	*Marbling score*	*IMF LD ($g kg^{-1}$)*
1	5.6–6.5	5.869[a]	11.53	0.63	14.95
2	5.33–5.5	5.417[b]	11.91	0.67	13.66
3	5.0–5.33	5.169[c]	11.72	0.78	13.11
4	4.83–5.0	4.901[d]	11.46	0.71	13.58
5	4.5–4.83	4.630[e]	11.35	0.60	13.13
6	4.0–4.50	4.263[f]	11.65	0.63	12.49
7	1.17–4.0	3.156[g]	11.45	0.54	12.25
Pooled SE		*0.022*	*0.250*	*0.08*	*0.85*
Significance		***	NS	NS	NS

*** Significant difference ($P<0.001$); NS, not significant.

Table 9. Eating quality measurements (adjusted means) for eight intramuscular fat groups

IMF group	*IMF range ($g kg^{-1}$)*	*IMF mean ($g kg^{-1}$)*	*Juiciness*	*Tenderness*	*Overall acceptability*	*Shear force (N)*
1	1.4–6.9	5.73[a]	4.947	4.931	4.687	351.4[abde]
2	6.9–8.6	7.69[b]	5.058	5.055	4.835	344.8[abcde]
3	8.7–10.0	9.37[c]	4.959	5.012	4.754	333.1[bcdef]
4	10.0–11.3	10.63[d]	4.816	4.969	4.695	344.1[abcde]
5	11.3–13.0	12.07[e]	4.929	5.112	4.756	337.5[abcdef]
6	13.0–15.4	14.21[f]	5.055	5.222	4.914	324.8[cef]
7	15.4–20.0	17.59[g]	4.907	5.099	4.782	324.1[cef]
8	20.1–92.9	30.53[h]	5.091	5.251	4.919	303.7[g]
Pooled SE		*0.419*	*0.085*	*0.109*	*0.096*	*7.848*
Significance		***	NS	NS	NS	***

*** Significant difference ($P<0.001$); NS, not significant.

measurement. This was apparent for each of the fatness measurements evaluated. Interestingly, classification P_2 and marbling score showed clear trends with regard to increased amounts being associated with a lowering of shear force. However, IMF, although showing a similar trend at the extremes, did not demonstrate a relationship at intermediate shear force groups. There was agreement between each of the fatness measurements of a definite reduction in the level of fatness occurring between shear force groups 1 and 2 and between groups 5 and 6 and groups 6 and 7. None of the characteristics analysed in Table 5 or 7 differed significantly for tenderness or overall acceptability respectively.

To elucidate further whether extremely lean carcasses produce meat of inferior eating quality, samples from the 721 animals were divided into eight groups for each of the following fatness traits: intramuscular fat concentration in LD (Table 9) and classification P_2 (Table 10). Each of the eight groups contained 90 samples, with those in group 1 having the lowest level for each respective fatness trait, and those in group 8 containing samples with the highest levels. Analysis of variance was then calculated for shear force, taste

Table 10. Eating quality measurements (adjusted means) for eight classification P_2 groups

Classification P_2 group (mm)	*Classification P_2 range (mm)*	*Classification P_2 mean (mm)*	*Juiciness*	*Tenderness*	*Overall acceptability*	*Shear force (N)*
1	6.0–9.0	8.172[a]	5.150	4.978	4.725	366.1[a]
2	9.0–10.0	9.345[b]	4.922	4.936	4.734	342.0[b]
3	1.0–11.0	10.07[c]	5.015	5.100	4.798	340.8[b]
4	11.0–11.0	11.00[d]	4.987	5.100	4.811	322.0[c]
5	11.0–12.0	11.75[e]	5.025	5.256	4.840	339.0[b]
6	12.0–13.0	12.67[f]	4.792	5.106	4.820	321.9[c]
7	13.5–15.0	13.83[g]	4.943	5.036	4.796	322.7[c]
8	15.0–21.0	15.97[h]	4.877	5.0986	4.796	310.6[c]
Pooled SE		*0.054*	*0.085*	*0.107*	*0.952*	*7.640*
Significance		***	NS	NS	NS	***

*** Significant difference ($P<0.001$); NS, not significant.

Table 11. Eating quality measurements (adjusted means) for four subjective marbling scores

Marbling score	*Number of samples*	*Juiciness*	*Tenderness*	*Overall acceptability*	*Shear force (N)*
0	360	4.975	5.045	4.757	342.4[a]
1	217	4.932	5.094	4.799	331.5[a]
2	64	5.014	5.247	4.948	307.8
3	30	5.102	5.071	4.839	285.0
Pooled SE		*0.080*	*0.107*	*0.097*	*6.695*
Significance		NS	NS	NS	***

*** Significant difference ($P<0.001$); NS, not significant.

[a] Means within the same column with different superscripts were significantly different ($P<0.05$).

panel tenderness, juiciness and overall acceptability, using fatness group as the classification variable. Analysis of variance was also carried out for taste panel juiciness, tenderness, overall acceptability and shear force using marbling score (subjective four-point score from 0 = none to 3 = heavy marbling) as the classification variable, the results for which are shown in Table 11 (only 671 samples had marbling score evaluation). Again, the only characteristic to deteriorate significantly with lower fatness levels was that of shear force. This was demonstrated for IMF, classification P_2 and marbling score.

CONCLUSION

The consensus from previous studies would suggest that a threshold of ether-extractable IMF somewhere between 16 and 20 g kg^{-1} exists below which eating quality will be reduced.[10,19,20] Furthermore, a maximum threshold of 25 g kg^{-1} ether-extractable IMF has been identified above which tenderness has been shown to deteriorate.[21] With the exception of the findings for shear force, this theory does not appear to be confirmed here. These results do not support the belief that fatness level *per se* influences pork eating quality.

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