Effect of fat score on the quality of various meat products

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Abstract

In the larger Swiss abattoirs the fat score (FS) is determined by default as an indicator of fat quality. The FS refers to the iodine number and is related to the degree of unsaturation of the outer layer of backfat. In a feeding trial with Large White gilts, the FS was determined in 47 carcasses. Meat and fat tissues were prepared for the production of salami (SAL), raw-cured bacon (RCB), pork hamburger (PHB) and Vienna sausage (VIS).
In the different meat products, the FS was closely related to the percentage of saturated (SFA: r = -0.49 to -0.79) and polyunsaturated fatty acids (PUFA, r = 0.36 to 0.79) for RCB, SAL and PHB ($p \leq 0.05$), but not for VIS. For RCB, significant correlations with FS were seen for the meat:fat ratio (r = 0.39), fat firmness (r = -0.31) and one fat-oxidation marker (1-octen-3-ol: r = 0.51). The texture (r = -0.60), a_w-value (r = 0.63) and one fat-oxidation marker (1-octen-3-ol: r = 0.46) were significantly correlated with FS in SAL. On the whole, only a few variables correlated significantly with FS for SAL and RCB and the corresponding relationships were always linear. No significant correlation between FS and any of the technological and sensorial parameters were found for VIS or PHB.

Keywords: fat score, fat quality, pig, processing, sensory, texture, oxidation, volatiles, meat products, salami, cured bacon, Vienna sausage, pork hamburger

1. Introduction

During recent decades, breeding strategies were aimed at increasing the lean meat to fat-ratio in pig carcasses. Because of the close relationship between the intake and the concentration of polyunsaturated fatty acids (PUFA) in porcine adipose tissue, both, lower fat deposition and dietary PUFA-intake, are often followed by increased PUFA concentrations in body fat (Gläser, Wenk, & Scheeder, 2002; Madsen, Jakobsen, & Mortensen, 1992; Warnants, Van Oeckel, & Boucqué, 1999; Wenk, Häuser, Vogg-Perret, & Prabucki, 1990). On the one hand, increased PUFA levels are associated with a higher occurrence of possible oxidation and rancidity as well as, together with monounsaturated fatty acids (MUFA), a soft, greasy and oily texture of the fat (Wenk *et al.*, 1990). Both of these characteristics are of great importance for the meat processing industry (Prabucki, 1991). On the other hand, fat with a lower degree of saturation is often associated with superior health properties (Hugo & Roodt, 2007a). These aspects illustrate the great dilemma between technology and (human) health, that the meat producers and the meat industry have to deal with (Wood *et al.,* 2003).
In larger Swiss abattoirs, fat quality is characterised by the fat score (FS, which originates from the German expression “Fettzahl”) per batch of delivered pigs in order to fulfil the

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requirements of the industry on meat and meat product quality. The FS is a measure of the number of double bounds in the outer layer of the backfat. Its analytical determination refers to the iodine value (Margosches, 1924), which includes the attachment of iodine to the double bounds of the fat. The method has been modified by Prabucki (1991) to enable an automated titration of the residual iodine in order to reduce the complexity and cost of routine analysis (Scheeder, Bossi, & Wenk, 1999). One meat company has recently introduced a method to determine the FS using NIRS (near-infrared spectroscopy). which has also been tested for additional fat parameters in backfat, recently (Müller, Wenk, & Scheeder, 2008). The carcass fat quality recommended by Prabucki (1991) and since then demanded by the larger abattoirs is a FS below 62. Pig producers not meeting these requirements are given reduced payments. That is why the FS-threshold is still the subject of intense discussion between pig producers and the meat industry in Switzerland. Variations in pig fat composition are also an important issue for meat producers and processors all over the world (Hugo & Roodt, 2007b; Madsen *et al.*, 1992; Nishioka & Irie, 2006).

Because there has been no study investigating the possible effects of the FS-level on quality traits of meat products up to now, the aim of this work was to determine these effects on different quality criteria such as nutrient composition, fatty acid profiles, sensory characteristics, texture, and secondary oxidation products of four different meat products.

2. Material and methods

2.1. Animals

Due to the fact, that FS can only be determined from fat samples taken just after slaughter and that fat samples are taken from a batch of animals and not from an individual pig in the abattoirs, the establishment of an experimental design with an equal number of pigs per FS-level was not possible in advance. Therefore, meat and fat tissue of 47 Large White gilts from the trial of Bee (2005) were used additionally in our experiment. In the study of Bee (2005), the effects of different levels of PMI (PUFA-MUFA-index = 1.3×MUFA + PUFA; Bee, 2004; Stoll, 2004; Stoll & Bee, 2002) in two different finisher diets (standard diet: 2.18 vs. optimised diet: 1.38 g PMI per kg digestible energy (DE)) on FS, fatty acid profile, growth and dressing parameters during the fattening period (63-115 kg body weight) were tested. The two finisher diets, which were isoenergetic (15.0 MJ DE per kg dry matter) and isoproteic (153 g protein per kg dry matter), were fed restrictedly to 12 full-sibling groups of four animals each (one animal died during the trial) by four different feeding modes (change from the standard diet with 32.2 g MUFA and 52.4 g PUFA per 100 g fatty acids to the optimised diet with 31.5 g MUFA and 42.3 g PUFA per 100 g fatty acids at 44, 29, 16 or 0 days prior to slaughter, respectively). The animals were reared in individual pens and fed a standard grower diet from 22 to 63 kg body weight during 63 days. They were grown in two independent lots of 24 animals each (six full-sibling groups of four animals) during the same time span. Based on the chosen experimental design of the trial of Bee (2005), large variations in the FS were also expected.

Table 1
Distribution of animals to the individual fat score classes

Fat score class	Lot 1	Lot 2	Fat score class	Lot 1	Lot 2
< 58.0	-	1	63.6 – 64.0	-	-
58.1 – 59.0	1	-	64.1 – 64.5	1	1
59.1 – 60.0	5	2	64.6 – 65.0	-	3
60.1 – 61.0	5	1	65.1 – 65.5	1	1
61.1 – 62.0	2	7	65.6 – 66.0	3	-
62.1 – 62.5	2	1	66.1 – 67.0	-	1
62.6 – 63.0	3	3	> 67.0	-	2
63.1 – 63.5	1	-			

2.2. Slaughtering, preparation and processing of the meat products

Slaughtering of the pigs took place at the ALP-slaughter house in Posieux, Switzerland in the two independent lots at six weeks apart. Within one hour post mortem, a fat sample from each pig was collected from the outer layer of the backfat close to the hips according to the procedure of Proviande (2003). The FS was determined for each sample and thus for each individual pig on the same day at the UFAG laboratories (Sursee, Switzerland) using the method described by Scheeder *et al.* (1999). The following day, the carcasses were dissected according to Rebsamen, Schwörer, & Lorenz (1985) and prepared for the production of four different meat products grouped in compliance with the FS-classes given in Table 1. Salamis (SAL, a fermented sausage), raw-cured bacons (RCB, a raw-cured meat product), pork hamburgers (PHB, a pan-ready meat product) and Vienna sausages (VIS, a cooked sausage) were produced following traditional recipes and processing procedures (Table 2) at the Education Centre of the Swiss Meat Industry (ABZ), Spiez, Switzerland. With the exception of RCB (n = 47), which was produced from individual carcasses, the raw material was quantitatively pooled according to the above mentioned FS-classes. Processing of RCB (n = 47) and SAL (n = 20) was performed with cooled (below 3°C) raw materials according to Table 2 for each lot within 10 days post mortem. For PHB and VIS production (n = 14 each), the raw material was vacuum-packaged, frozen, thawed one day before processing, pooled by lots and then processed together in one step. At the beginning of processing of the four meat products, the quality of the raw material was visually assessed for fat consistency and the degree of drip loss and/or superficial water by specialists of the ABZ for each meat product separately.

2.3. Sample preparation and chemical analyses (nutrients, fatty acids)

Samples from all meat products and FS-classes were prepared by cutting, freezing in liquid nitrogen, grinding finely with a knife homogeniser (Vertec; Edmund Bühler GmbH, Hechingen, Germany) and freeze drying (Christ – Delta 1-24 LSC; Martin Christ, Gefriertrocknungsanlagen GmbH, Osterode am Harz, Germany) before further analyses.
Dry matter (105°C, 160 min) and crude ash content (550°C, until constant weight was reached) were measured gravimetrically (Leco TGA-601; Leco Corporation, MI-St Joseph, USA). The crude protein content was analysed after the procedure of Kjeldahl (factor: 6.25) and crude fat was determined by gravimetry after extraction with petroleum ether

(SLMB, 1999). After a hot extraction with 80% ethanol, sugar analysis was performed colorimetrically on an autoanalyser (II-Technicon, Bran + Luebbe, Norderstedt, Germany) with an orcine/sulphur acid-reagent. The fatty acid profile was determined according to Bee, Guex, & Herzog (2004). In order to refer the results of nutrient and fatty acid contents to fresh matter, the analysed values were corrected for the mass reduction of the corresponding sample during freeze drying.

Table 2
Recipes and processing procedures for the four meat products (ABZ, 2004)

	Recipe	Processing procedures
RCB (n = 47)	- 1 kg pig breast cuts - 25 g table salt - 6.5 g spices	- Salting: manually, storing for 14 days in a vat (6 – 7°C) - Washing - Drying/smoking: for 3 weeks (10 – 14°C, 75 – 80% relative humidity), periodically pressing
SAL (n = 20)	- 3.25 kg frozen pork meat (P1) - 0.75 kg frozen beef (B1) - 1 kg frozen pork backfat (P7) - 27 g table salt - 13 g spices and additives - 1 g cognac - 0.001 g starter culture	- Chopping of meat and backfat with a mincer (5 mm diameter of perforated disc) - Mixing in mixer and supplementation with spices, additives, starters and salt - Stuffing in horse casing - Treatment with surface culture - Drying: until weight loss of 30% is attained
PHB (n = 14)	- 4 kg slightly frozen pork meat (P3) - 16 g table salt - 2.3 g spices	- Chopping (2 mm diameter) - Kneading and formation of 100g spheres → turning in breadcrumbs and pressing to steaks
VIS (n = 14)	- 2 kg beef (B2) - 1.7 kg pork (P3) - 2.8 kg neck fat (P5) - 0.5 kg rind block - 2.3 kg water / ice - 19 g nitrite salt - 10 g spices and additives	- Chopping in cutter - Stuffing in sheep casings - Hot smoking - Cooking: 12 – 15 minutes at 74°C - Cooling

2.4 Determination of the volatile compounds

Homogenized samples of the four meat products (6.5 g SAL or RCB, respectively, and 6.0 g VIS or PHB, respectively) were weighed individually in a 20 mL headspace glass vial and preincubated for 10 min at 35°C. The headspace of the samples was extracted for 30 min at 35°C using a CTC Combi PAL auto sampler (CTC analytics, Zwingen, Switzerland) equipped with a 1 cm × 50/30 µm StableFlex Divinyl benzene / Carboxen / Polydimethylsiloxane (DVB/CAR/PDMS, Supelco) solid phase micro extraction (SPME)

fibre. The volatile compounds were desorbed by directly inserting the fibre for 10 min into the injection port of the GC (splitless mode for 3 min) maintained at 250°C. The same fibre unit was used for all the analyses.
A Trace 2000 DSQ gas chromatograph-mass spectrometry (GC-MS) system (Thermo, San José, California, USA) equipped with a flame ionisation detector (FID), a split/splitless injector and an Optima-5-MS capillary column (30 m × 0.25 mm ID × 0.25 µm film thickness, Macherey-Nagel, Oensingen, Switzerland) was used for the analysis. Chromatographic conditions were as follows: 4 min at 35°C, then up to 150°C at 5°C/min and further to 320°C at 10°C/min with 2 min hold. Helium was used as carrier gas at a constant flow of 1.0 mL/min. Mass spectra were obtained in the electron impact (EI) mode at 70 eV in full scan and a scan range from *m/z* 29-300. The GC-MS interface temperature was 290°C, the ion source operated at 250°C. The compounds were identified on the basis of the same linear retention indices and mass spectra tested with authentical reference compounds under the same analytical conditions as the samples.

2.5. Sensory analyses

The sensory profiles of the four meat products were determined by a panel of 10 trained panellists. Each product group was evaluated in a separate session. Half of the PHB were heated a second time after a one-day cooling period in order to detect off-flavours. Depending on the product, the intensity of five odour, six to nine flavour and two to three texture attributes was assessed on 10-point intensity scales. The samples were tested monadically in a partially randomised design and the tests were performed in separated booths with normal light illumination. Cold tap water and white bread were used to neutralize between samples.

2.6. Physical analyses

Texture parameters of sliceability for SAL and fat firmness for RCB were determined with the Warner-Bratzler-apparatus (WB) and by the needle penetration test (Standard needle, DIN 52010). The Warner-Bratzler device and the needle were attached to a Universal Testing Machine (Zwick Z2.5/TN1S, Zwick, Ulm, Germany). The crosshead speed was 100 mm/min and penetration depth was set to 15 mm. The results were expressed in N for the force (needle penetration, WB-shear force) and mJ for total WB-work (determined as force × deformation). Furthermore, the a_w-value at 25°C (AW-Sprint, Novasina, Pfäffikon, Switzerland) was determined for SAL.

2.7. Image analyses

Images of the RCB at the level of the 8th and the 11th rib cranial were taken with a digital Olympus DP 10 camera (Olympus, Zürich, Switzerland). The images were analysed using the AnalySIS 5.0 auto software (Soft Imaging System, Münster, Germany). The total and the meat cross-section areas (mm^2) were measured and the fat cross-section areas and meat:fat ratio were calculated.

2.8. Statistical analyses

The effect of the lot on the means of the measurands was tested by two-sample t-tests. As some differences were significant (but not of interest), the observed values of all measurands were corrected for possible differences of the means by centering on the total mean of both lots (by subtracting the mean of the respective lot and adding the total mean). This procedure eliminates the systematic difference between the lots while keeping the variability (the variance within each lot is invariant under this transformation). The significance of correlation and regression parameters between FS and the above mentioned (corrected) measurands, were determined at a level of significance of $P \leq 0.05$ (Systat, 2004). The linearity of relationships between FS and other variables was tested by the t-test of the slope in linear regression analysis. Inspection of the respective residuals did not indicate the need for quadratic terms.

3. Results

3.1. Fat-score variation and raw material evaluation

A good FS-variation (Table 1) resulted from the trial of Bee (2005). The raw materials for SAL- and RCB-production were characterized by the ABZ-specialists as wet and greasy when FS-values were ≥ 65 (Table 3). No FS-related differences in raw material quality were observed for VIS or PHB.

Table 3
Characterization of the raw materials during processing

RCB (n = 47)	during salting:	fat score ≥ 62: tendency to “wet” fat score ≥ 65: „extremely wet“
	during cutting:	no remarks
SAL (n = 20)		fat score ≤ 63: good stuffing fat score ≥ 65: greasy, sticky, wet stuffing
PHB (n = 14)		only small differences, no clear tendencies
VIS (n = 14)		no remarks

3.2. Raw nutrients and fatty acid composition

The raw nutrient contents of the four meat products (Table 4) were similar to the values given by Gerber, Scheeder, & Wenk (2006). The dry matter content was greater in RCB and SAL than in PHB and VIS which is to be expected from the processing procedures (cold-smoking and/or air-drying). Therefore ash, protein and fat contents in fresh matter were also higher in RCB and SAL than in PHB and VIS. No significant correlations were found between FS and dry matter, protein, fat or ash content for SAL, PHB and VIS (data not shown). For RCB, correlations with FS for dry matter, protein and fat content were -0.41 ($P = 0.01$), +0.34 ($P = 0.02$), and -0.36 ($P = 0.01$), respectively, whereas FS and ash content did not correlate ($P > 0.05$).

Table 4
Nutrient content and fatty acid profile over all fat-score classes (g per kg fresh matter, mean and standard deviation, % = in % of total fatty acids)

Parameter		Backfat[1] (n = 47)	RCB (n = 47)	SAL (n = 20)	PHB (n = 14)	VIS (n = 14)
Dry matter	g	958 ± 6	652 ± 30	696 ± 70	339 ± 43	375 ± 14
Crude ash	g	n.d.	44 ± 8	61 ± 6	24 ± 2	29 ± 1
Crude protein	g	n.d.	220 ± 23	291 ± 34	175 ± 16	136 ± 5
Crude fat	g	883 ± 70	378 ± 45	342 ± 34	144 ± 39	193 ± 18
Saturated fatty acids (SFA)	g	387 ± 21	163 ± 24	145 ± 14	63 ± 17	85 ± 8
	%	*41.3 ± 2.0*	*45.8 ± 2.2*	*46.7 ± 1.8*	*43.4 ± 1.7*	*43.8 ± 1.3*
Palmitic acid (C 16:0)	g	222 ± 10	96 ± 14	84 ± 8	37 ± 10	50 ± 5
	%	*23.8 ± 0.9*	*27.1 ± 1.1*	*27.0 ± 0.8*	*25.6 ± 0.8*	*25.9 ± 0.5*
Stearic acid (C 18:0)	g	146 ± 14	58 ± 10	53 ± 7	22 ± 6	29 ± 4
	%	*15.6 ± 1.5*	*16.2 ± 1.4*	*17.0 ± 1.2*	*15.2 ± 1.1*	*15.0 ± 1.0*
Monounsaturated fatty acids (MUFA)	g	413 ± 14	163 ± 25	142 ± 13	64 ± 17	91 ± 8
	%	*44.2 ± 1.7*	*46.0 ± 2.2*	*45.7 ± 1.8*	*44.0 ± 1.1*	*46.9 ± 1.3*
Oleic acid (C 18:1)	g	413 ± 14	150 ± 24	129 ± 12	58 ± 16	83 ± 7
	%	*15.6 ± 1.5*	*42.2 ± 2.3*	*41.7 ± 0.7*	*40.5 ± 1.0*	*42.7 ± 1.1*
Polyunsaturated fatty acids (PUFA)	g	135 ± 14	29 ± 9	24 ± 2	18 ± 5	18 ± 2
	%	*14.4 ± 1.5*	*8.1 ± 1.9*	*7.6 ± 0.7*	*12.6 ± 1.4*	*9.3 ± 0.4*
Linoleic acid (C 18:2)	g	116 ± 13	25 ± 7	20 ± 2	15 ± 4	15 ± 2
	%	*12.4 ± 1.3*	*7.0 ± 1.7*	*6.4 ± 0.5*	*10.7 ± 1.2*	*7.9 ± 0.3*

[1] from Bee (2005); n.d. = not determined

Within the four meat products the contents of saturated fatty acids (SFA) were similar to those of MUFA. Their PUFA contents varied between 7 and 13% of total fatty acids (TFA). The SFA consisted mainly of palmitic (58 – 60%) and stearic acid (34 – 37%), whereas the MUFA was mostly composed of oleic acid (90 – 92%) and PUFA of linoleic acid (83 – 86%). In comparison to the backfat composition, lower PUFA (Δ = 1.8 – 6.8%) and increased SFA percentages (Δ = 2.1 – 5.4%) were determined in the fat of the different meat products. In spite of the different fat origins [FS: sampled from the outer layer of the backfat close to the hips – meat products: processed with different kinds of fat (Table 2)], FS only correlated with the SFA content in fresh matter of RCB (r = -0.55, *P* = 0.00), SAL (r = -0.68, *P* = 0.00) and VIS (r = -0.70, *P* = 0.01), but not with PHB nor was there a significant correlation with MUFA- or PUFA-contents in the fresh matter of the four meat products. As regards the TFA content, FS correlated significantly with the SFA and PUFA percentages in RCB, SAL and PHB and with the MUFA levels in SAL (Table 5). With regard to the content of crude fat, significant correlations with FS were found for the SFA percentages in RCB, SAL and PHB and PUFA percentages in RCB and PHB. No corresponding correlations were found for VIS.

Table 5
Correlations between fat score and fatty acid groups

Parameter	RCB (n = 47)	SAL (n = 20)	PHB (n = 14)	VIS (n = 14)
% in crude fat				
Saturated fatty acids	- 0.54***	- 0.61**	- 0.79***	n.s.
Monounsaturated fatty acids	n.s.	n.s.	n.s.	n.s.
Polyunsaturated fatty acids	0.36*	n.s.	0.67**	n.s.
% in total fatty acids				
Saturated fatty acids	- 0.49***	- 0.62**	- 0.62*	n.s.
Monounsaturated fatty acids	n.s.	0.49*	n.s.	n.s.
Polyunsaturated fatty acids	0.53***	0.73***	0.79***	n.s.

** P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001, n.s. = not significant*

3.3. Sensory quality and fat oxidation

Only a few sensory characteristics [spicy (r = 0.40, *P* = 0.01), smoky (r = 0.33, *P* = 0.02) and fibrous (r = 0.41, *P* = 0.00)] of RCB were correlated with the FS, whereas no significant relationships were observed for all of the other attributes of RCB or the other meat products in general (*P* > 0.05). Regardless of the FS, reheating of cooled PHB was followed by significant negative effects on the attributes rancidity (*P* = 0.00), juiciness (*P* = 0.00), tenderness (*P* = 0.03) and animal-like aroma (*P* = 0.00).
Only the 1-octen-3-ol signal in RCB (r = 0.51, *P* = 0.00) and in SAL (r = 0.46, *P* = 0.05), but not in the other meat products *(P* > 0.05), correlated with the FS. Reheating of PHB was followed by significantly increased signals for pentanal (*P* = 0.00), 1-pentanol (*P* = 0.00) and 1-octen-3-ol (*P* = 0.00).

Table 6
Physical characteristics of raw-cured bacon and salami in relation to the fat score

Product	Parameter	Regression equation	r^A
RCB	Total cross-section area[B], *mm²*	= 9'517 - 79.0 × fat score	- 0.43
	Fat area[B], *mm²*	= 6'773 - 71.2 × fat score	- 0.46
	Meat:fat-ratio[B], *%*	= -86.2 + 3.0 × fat score	+ 0.39
	Needle penetration force, *N*	= 4.27 - 0.041 × fat score	- 0.31
SAL	Warner-Bratzler total work, *mJ*	= 14.30 - 0.17 × fat score	- 0.66
	Warner-Bratzler maximal force, *N*	= 565 - 7.0 × fat score	- 0.60
	a_w	= 0.751 + 0.0022 × fat score	+ 0.63

[A] Correlation coefficient (P ≤ 0.05)
[B] Determined from the cross-section area at the 8. and 11. rip cranial (average)

3.4. Texture, a_w-value and meat:fat-ratio

The texture properties of SAL and the firmness of the RCB-fat were negatively correlated with FS (Table 6); no significant relationships between FS and texture were observed for VIS and PHB (data not shown). The FS-related differences in texture of SAL and RCB were similar to those seen between the two slaughter lots. The a_w-values of SAL were positively correlated with FS. Also, a low, but significant positive correlation between FS and the meat:fat-ratio was found in RCB which averaged a 3% increase per FS-unit. This was mainly due to changes in the fat cross-section area since no significant correlation was found between FS and the meat cross-section area in RCB.

4. Discussion

As expected, various significant correlations between FS and SFA as well as between FS and PUFA (exception: SAL, $P > 0.05$), but not with MUFA alone, could be shown for SAL, RCB and PHB. The relationships between FS and SFA can be explained by the fact that SFA is inversely linked to the content of total unsaturated fatty acids (TUFA = MUFA + PUFA). This is due to the close relationship between FS and the degree of unsaturation, which is a result of the total number of double bonds originating from MUFA as well as from PUFA (Stoll & Bee, 2002). The correlations between FS and PUFA may be due to the fact, that dietary PUFA are mainly incorporated directly into body fat (Wenk et al., 1990), whereas MUFA are also built up from SFA and the enzyme Δ9-desaturase in the body itself (Bee, 2004). Another reason could be the differences in PUFA-content between the two experimental finisher diets, whereas MUFA contents were almost the same. However, it remained unclear from our data why no corresponding correlations could be found for VIS.

Depending on the meat product, the differences in relative fatty acid composition between the backfat and the different meat products may be due to the differences in fat sources (PHB, VIS) and/or due to the occurrence of fat oxidation (SAL, RCB). Although a PUFA reduction caused by oxidation could not be seen directly from our data, fat oxidation was observed by the determination of volatile compounds. The large variations in fat and fatty acid content in PHB are probably due to the fact that only frozen pork meat (P3) was used, which had been standardized visually by its content of fat and connective tissue, as it is common in practice. However, it has to be stated that this variation would not fit to industrial standards, where cuts from a much larger number of animals are usually taken allowing a better adjustment of the nutrient content of hamburgers.

Only the raw-cured meat products (RCB, SAL) ripened over a longer period, and not the cooked or pan-ready meat products such as VIS and PHB, respectively, showed a tendency to poorer processing quality (judging of raw material, physical parameters) with increasing FS, which is of importance for the meat industry. For technological ($\rightarrow$ fat quality) as well as hygienic reasons ($\rightarrow$ increase in free water), raw material from carcasses with a FS $\geq$ 65 is less appropriate for meat processing. In the meat industry, the occurrence of carcasses with higher water losses and/or elevated amounts of superficial water is occasionally observed in connection with low fat percentages, which suggests a partial replacement of fat with water within the fat cells (Häuser, 2005; Wenk *et al.,* 1990). However, the lean meat percentage was not affected by the feeding regimen in the experiment of Bee (2005) and thus in our study. As already mentioned this is due to the equalised energy and protein content of the two finisher diets and also in accordance with the results of Bee & Wenk (1994) and Warnants *et al.* (1999). It may therefore be hypothesized, that the occurrence of carcasses with higher water losses and/or elevated

amounts of superficial water is related to the fat composition itself, although the reasons for this cannot be derived from our results. The poorer applicability of raw material from carcasses with a FS $\geq$ 65 can also be seen for the corresponding SAL, where a higher incidence of greasy, sticky and wet stuffings were observed. This was shown for the final product too, where the WB-force was decreased by 7 N per increasing FS-unit when cutting the SAL. Also a_w-values were increased with higher FS, even though they were changed only for 0.011 units when differences in FS reached 5 FS-units. Although it could not be observed in our products and differences in a_w-value were low, it can be hypothesized that a coating effect by the softer fat during the drying process of the SAL may have contributed to the positive relationship between FS and a_w-value. The softer and greasier consistency in the high-FS SAL is in accordance with results reported by Warnants, Van Oeckel, & Boucqué (1998), who observed a softer consistency in their salamis with more than 14% PUFA. The regression analysis of Gläser, Wenk, & Scheeder (2004) revealed that all of the tested consistency traits in lard were mainly dependent on SFA content, particularly stearic acid. Also Scheeder, Gläser, Schwörer, & Wenk (1998) stated that texture properties of salami are closely related to their fat composition. However, it must be considered, that the differences in texture between the two lots in our trial were sometimes even larger than those related to the FS.

According to the recent discussions concerning price reductions for bellies with high fat proportions in Switzerland, it may be of interest that by an increase in FS by one unit the meat:fat-ratio of RCB was inflated by 3%, even if their correlation was rather low. This was mainly due to lower fat areas in the RCB-cross-section, whereas meat areas remained independent of the FS.

Significant correlations between FS and fat oxidation markers could only be shown for a single substance (1-octen-3-ol: mushroom-like) in RCB and SAL. It can be seen from the reheating data of PHB, that besides FS, other factors such as temperature treatment may also have detrimental effects on the occurrence of fat oxidation. Scheeder *et al.* (1998) also concluded from their studies on salami that the fatty acid profile is only one of several factors which have an influence on fat oxidation. Bryhni, Kjos, Ofstad, & Hunt (2002) have reported that high PUFA levels (50 vs. 31%) in fish-oil enriched pig diets are followed by an increase in fat oxidation and the occurrence of rancid odour in sausages, independent of the level of fish oil.

Sensory-related correlations with FS were only seen for three out of 14 different attributes in RCB and none at all in the other meat products. On the whole, FS-related changes in the perceived intensity of sensory attributes were generally small and are therefore of minor importance. This is in accordance with Pastorelli *et al.* (2003), who concluded from their trial with dry-cured Parma ham from pigs fed different fat sources (tallow, corn oil, rapeseed oil) that changes in the fatty acid composition do not greatly influence the sensory characteristics. In salami produced with 15% total fat with different amounts of virgin olive oil replacing pork backfat, Severini, De Pilli, & Baiano (2003) also found that chemical, physical and sensory product characteristics were not substantially affected by the fat source, except for firmness and a_w-value. Warnants *et al.* (1998) observed that up to 15% PUFA in salami resulted in an acceptable taste when linoleic acid was the predominant fatty acid; salamis with higher PUFA-percentages were rejected by the taste panel. According to Stiebing, Kühne, & Rödel (1993), the PUFA percentage should not exceed 14% for moderate-time storage and 12% for long-time storage of dry sausages to avoid adverse effects on firmness and fat oxidation. In our trial, the PUFA percentage was below 9% in all salami samples produced with a recipe similar to those used in practice. This may explain the rather small effects on sensory attributes.

Conclusions

Depending on the kind of meat product, some significant correlations of different parameters with FS could be observed. They were mainly concentrated on the raw-cured meat products, RCB and SAL, as no significant correlations between FS and technological as well as sensorial parameters were seen for VIS and PHB. There were also significant effects between the two slaughter lots, which were sometimes similar to those corresponding to the FS.
Due to the relevance of the FS to the profitability of Swiss pig production, the actual FS-threshold of 62 is periodically questioned by pig producers and feed manufacturers. However, it is not possible to redefine the actual FS-limit based only on the present data. This is due to the fact that all of the observed relationships with FS were linear and differed between the four meat products and variations in other factors, as shown for the lot effects, contributed to not being able to redefine a FS-threshold which could be utilised in practise.

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