Effects of three genotypes and two roughages in organic heavy pig production for dry fermented sausage manufacture

2. Meat quality, fatty acid pattern, and product quality

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Abstract

Castrated heavy pigs of > 160 kg body weight are used for dry fermented sausage manufacture due to the required fat quantity and quality. Today, most organic production systems use modern hybrids (Hy) with often insufficient fat features. The use of endangered breeds with high body fat synthesis capacity like Saddlebacks (Sa) could be an alternative with an additional benefit as to maintaining biodiversity.

This study with a total of 132 castrates analysed the effects of three genotypes (Sa, Piétrain*Sa (PiSa), Hy) and two roughage sources (grass-clover silage, straw) on performance, carcass-, meat-, fat-, product-quality, and economic aspects. The present paper deals with meat quality (MQ), fatty acid pattern (FAP), and product quality of dry fermented sausage (PQ). MQ and FAP are both influenced significantly by the genotype but not to a noteworthy extent by the roughage source. Regarding MQ, all genotypes were well suited. Concerning FAP, critical poly-unsaturated fatty acid content of back fat required for the production of dry fermented sausages was exceeded by Hy (15.9 %) whereas Sa was best suited with the lowest mean content (11.9 %) under the trial's particular feeding conditions. This suitability of the raw material for the production of dry fermented sausages can also be seen in PQ of the end-product: Sa sausages tend to have the best PQ whereas Hy tend to have the lowest PQ. PiSa always ranked in the middle for nearly all analysed criteria of MQ, FAP and PQ.

Considering the good results of performance, carcass quality and economics of PiSa (1st communication), crossbreeding of Sa with a modern sire line seems to be the best way to ensure the survival of an old endangered pig breed via value creation by producing a premium pork speciality like dry fermented sausage.

Keywords: *Heavy pigs, Saddleback, meat quality, fatty acid pattern, product quality, dry sausage*

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Zusammenfassung

Effekt unterschiedlicher Genotypen und Raufutter in der ökologischen Mast schwerer Schweine zur Rohwursther-stellung

2. Fleischqualität, Fettsäurenmuster und Wurstqualität

Zur Herstellung langgereifter Rohwurst werden kastrierte schwere Schweine wegen der benötigten Fettmenge und -qualität genutzt; vor allem moderne Hybride (Hy) mit oftmals unzureichenden Fettkriterien. Alte Rassen, z.B. Sattelschweine (Sa), mit ihrer hohen *de-novo* Fettsynthesekapazität könnten eine Alternative sein mit gleichzeitigem Beitrag zu deren Erhaltung.

Es wurden die Effekte dreier Genotypen (Sa, Piétrain*Sa (PiSa), Hy) und zweier Raufutter (Kleegrassilage, Stroh) auf Mastleistung (ML), Schlachtkörper(SQ)-, Fleisch(FQ)- und Wurstqualität (WQ), Fettsäurenmuster (FSM) sowie Wirtschaftlichkeit (W) überprüft. Dieser Artikel handelt von FQ, FSM und WQ. FQ und FSM wurden vom Genotyp signifikant beeinflusst, vom Raufutter in nicht nennenswertem Umfang. Bei der FQ schnitten sämtliche Genotypen gleichermaßen gut ab. Beim FSM im Rückenspeck hatte Hy den höchsten (15,9 %) und Sa den niedrigsten (11,9 %) Polyensäurengehalt. Sa zeigte tendenziell die beste WQ, Hy tendenziell die schlechteste. PiSa nahm bei fast sämtlichen Kriterien eine mittlere Stellung ein.

Zusammen mit den guten Ergebnissen von PiSa bei ML, SQ und W (erste Mitteilung) wird geschlussfolgert, dass die Einkreuzung eines modernen Endstufenebers am besten geeignet scheint, alte bedrohte Rassen mit Hilfe der Wertschöpfung im Premiumsegment (z.B. Rohwurst) zu erhalten.

Keywords: *Schwere Schweine, Sattelschwein, Fleischqualität, Fettsäurenmuster, Produktqualität, Langgereifte Rohwurst*

1 Introduction

In some regions of Europe heavy pigs slaughtered at about 160 kg live weight are used for the production of traditional pork products such as dry fermented sausages. Most heavy pig production systems – also in organic agriculture – currently use modern pig genotypes which are characterized by a high body protein synthesis capacity, since pig breeding programmes aimed for „lean meat" are desired by the fresh pork sector. Specific feeding regimes can increase fat levels in modern genotypes, but the amount and quality of fat of heavy pigs are often unsatisfactory with respect to the needs of processors of specific traditional pork products such as dry fermented sausages (Bellof and Burgstaller, 1992; Fischer et al., 2006a).

In this context the most important fat parameters are the consistency and the oxidative stability. Both parameters are mainly influenced by the fatty acid composition. In general a higher amount of unsaturated fatty acids leads to a softer fat with a higher susceptibility for oxidation (Bee, 2004). For optimal processing quality concerning consistency and oxidative stability recommendations have been formulated, limiting the poly-unsaturated fatty acid content (PUFA) of the back fat to a maximum of 12 to 15 % (Warnants et al., 1996; Scheeder et al., 2001; Bee, 2004; Fischer et al., 2006b). The PUFA content in back fat depends on slaughter weight, genotype, feeding and on environmental factors. But in brief: Regardless of the genetic type or life weight class, an increase in body own fat synthesis is associated with an increase in saturated and monounsaturated fatty acids and a remarkable reduction in polyunsaturated fatty acid content (Lo Fiego et al., 2005).

Traditional breeds (e.g. German Saddleback) are known to have lower protein synthesis capacity and higher carcass fat yields. This leads to a sufficient quantity and quality of fat with a high amount of saturated fatty acids due to intensive *de-novo* fat synthesis (Nürnberg et al., 1998) which is favourable for dry fermented sausage production. The German Saddleback pigs produce a very high fatty tissue percentage with a good meat quality. The high intramuscular fat content and its favourable fatty acid composition have advantages as to sensory evaluation and processing conditions (Nürnberg et al., 1997).

Nevertheless old breeds have disadvantages concerning performance and carcass traits which might be improved by crossbreeding with an improved breed such as Piétrain (Legault et al., 1996). Crossbreeding of Saddlebacks is suggested for special marketing programs to improve performance and carcass traits and economic benefit (Pfeiffer, 2002; Golze et al., 2013; Leenhouwer and Merks, 2013; Weißmann, 2013). The use of traditional breeds (e.g. Saddleback) and/or the crossbreeds between traditional and modern genotypes could therefore be an alternative for the production of traditional, regional pork specialties and may provide an economically suitable strategy for the conservation of traditional breeds.

As already mentioned above, the feeding regimen influences meat, fat and consequently product quality of dry fermented sausages, beside the choice of the genotype. In this context the obligatory use of roughage in organic pig feeding (EC 834/2007) is of interest. In Germany, straw as roughage source is controversially discussed, whereas the positive image of grass-clover silage is of common consensus. But in the case of dry fermented sausage production the preferable use of grass-clover silage – contrary to straw – is not unproblematic. It could be shown that such a practice increases the levels of poly-unsaturated fatty acids and softens the texture of pork fat which contradicts dry fermented sausage production (Burgstaller et al., 1992; Warnants et al., 1996).

Against this background three genotypes (extensive = Saddleback (Sa), semi-intensive = Piétrain*Saddleback (PiSa), intensive = modern hybrid line (Hy)), always with grass-clover silage or straw as roughage source, were slaughtered at > 160 kg live weight. The aim was to analyze their suitability for the production of the regionally significant pork product dry fermented sausage. Under organic farming conditions the performance and carcass quality, the meat, fat and product (dry fermented sausages) quality and economic parameters were quantified. It refers to work package 3.3.1 (Effects of, and interactions between, pig genotype and dietary regimes on carcass, meat and processing quality characteristics – experimental approach) within the EU co-funded FP7 research project "Low Input Breeds" – LIB (www.lowinputbreeds.org).

The present paper deals with (i) meat quality, (ii) fatty acid pattern and (iii) product quality of dry fermented sausages produced of them.

A first communication (Schwalm et al., 2013) was concerned with performance, carcass quality and economics of heavy pig production. It could be shown that the old purebred Saddleback and its crossbreed with Piétrain are suitable for dry fermented sausage production as concerns performance and carcass quality (mainly in terms of fat amount), whereas heavy pig production with purebred Saddlebacks is too expensive due to the very high costs of the concentrate feeding mainly due to their poor conversion ratio of feed into body mass.

2 Material and methods

2.1 Animals, keeping and sausage production

Using two runs (2010/2011 and 2011/2012) a total of 132 barrows of three different genotypes with different classifications of the breeding intensity concerning body protein synthesis capacity (Saddleback (Sa): extensive; Piétrain*Sa (PiSa): semi-intensive; modern Hybrid – (Piétrain*Duroc)* (German Large White*German Landrace) (Hy): intensive) combined with two different roughage sources (grass-clover silage (gcs), straw (str)) was divided into six treatments ((i) Sa/gcs (n = 25), (ii) Sa/str (n = 21), (iii) PiSa/gcs (n = 21), (iv) PiSa/str (n = 21), (v) Hy/gcs (n = 22) and (vi) Hy/str (n = 22)) and used for evaluating meat quality, fatty acid pattern and product quality (of dry fermented sausage); for detailed information see Schwalm et al. (2013).

Animal housing was in accordance with organic farming regulations (EC 889/2008); for detailed information see Schwalm et al. (2013). A pen was always linked with genotypes and roughage source of only one treatment.

The concentrates were pelletized and consisted of feed ingredients of 100 % organic origin. The composition of the grower and of the finishing diet is shown in Table 1. Both concentrates were only optimized for energy and the first limiting amino acid Lysin by the diet formula. Neither the grower diet nor the finisher diet were analysed for fatty acid composition. Both diets were given *semi-ad libitum* following a live weight-dependent feeding curve with a feeding rest < 1 kg per pen and repast.

Table 1
Characterization of the concentrate diets (mean value (standard deviation))

		Grower period	Finisher period
Analysed probes	**n**	**6**	**6**
Winter barley	%	27.0	33.5
Triticale	%	25.5	22.0
Field peas	%	15.0	25.0
Field beans	%	15.0	13.0
Soya oilcake	%	9.0	- -
Sunflower oilcake	%	6.0	4.5
Mineral premix	%	2.5	2.0
Sum	%	100	100
Metabolizable energy, ME	MJ/kg	13.2 (0.24)	12.2 (0.20)
Crude protein	g/kg	180.0 (18.05)	151.0 (15.25)
Lysin	g/kg	10.9 (0.96)	8.2 (0.80)
Lysin-ME-ratio		0.83 (0.09)	0.67 (0.09)

Grass-clover silage and straw were offered in one separate rack per pen. The grass-clover silage is characterized by 31.7 % dry matter (DM) (CV 11.7 %), 15.9 % XP in DM (CV 6.6 %) and 22.8 % XF in DM (CV 13.9 %). It was offered daily with an average of 0.9 kg fresh matter per day and animal; a higher amount resulted in an even higher waste. Due to the impossibility of measuring real feed intake, the amounts of grass-clover silage mentioned are the amounts offered to but not consumed by the pigs. A special straw consumption was not observed. Straw was refilled when the racks were depleted; no further quantitative recordings and qualitative analyses were carried out. Both roughages were not analysed for fatty acid composition.

The fattening period started at an average initial live weight of 26.2 kg (CV 24 %) and the animals were slaughtered with a mean live weight of 164.1 kg (CV 3 %); for further information see Schwalm et al. (2013).

One day after slaughter a defined meat part (silverside including eye round, about 1,5 kg) and about 500 g back fat of every second pig per treatment were removed from the right carcass half and were stored at -20 °C for sausage production, until all animals of the respective run were slaughtered.

The sausages were made at MRI Kulmbach, Germany. Only back fat and meat of the experimental animals were used. All sausages were manufactured using the same technology, ingredients and formulation, which was

- 75 % lean meat (silverside including eye round)
- 25 % fat (back fat)
- 26 g/kg nitrite curing salt
- 5 g/kg spices (white pepper, coriander, cardamom, nutmeg, paprika, ginger)
- 2 g/kg sugar
- 0.5 g/kg starter culture
- 0.3 g/kg sodium ascorbat

The back fat, meat and ingredients mixture was packed into Naturin Därme 50/60 and left for five weeks in a ripening cabinet. The sausages were fermented according to the following ripening protocol:

time	temperature [°C]	relative humidity [%]	smoke
6 h	22	--	--
48 h	20	90	--
3 h	20	90	+
24 h	20	90	--
96 h	20	88	--
3 h	20	88	+
until five weeks	15	85	--

After ripening, the final product was vacuum-packed and stored at 12 °C for two month.

2.2 Data collection and analyses

Meat quality

Data collection and analyses concerning meat quality followed the guideline for on-station testing of growth performance, carcass quality and meat quality of the German Board for Performance Testing and Estimation of Breeding Value of the pig (ZDS, 2007). Always the left carcass half of all animals was used.

The physical meat quality traits pH-value, pH_{24}, (Knick pH-meter), electrical conductivity, EC_{24}, (Matthäus LF-star), meat color (Minolta CR-300, L*a*b*) were recorded 24 hours after slaughtering for loin and ham. Samples of drip loss were gained by a circular cutter (2.7 cm diameter, 2.9 cm depth) for loin (medial and lateral sample) and ham (one sample) 24 h after slaughtering and stored in a refrigerator at 8 °C for 24 h in special drip loss collectors (Fa. Sarstedt). Drip loss was recorded for the time span 24 h to 48 h post mortem (in case of loin as average of medial and lateral values). For detailed locations see Table 3.

Intramuscular fat content of the *Musculus longissimus dorsi* (13th rib) was determined by MRI Kulmbach, using Near-Infrared-Transmission Spectroscopy (FoodScan, Foss,

Rellingen, Germany). IMF-reference values used for the calibration ranged from 0.58 % to 8.74 % (thus, the analyzed samples were within the range of the calibration). To verify the estimation results of the FoodScan, 15 % of the samples were additionally analysed by a modified method according to § 64 in the German code of law for food and animal feed (LFGB, 2011). Fat was extracted with petroleum benzene in the Soxhlet-system 810 of BÜCHI Labortechnik GmbH (Essen, Germany) without prior HCl-digestion. Error and coefficient of determination for the 15 % re-analysed samples were SEP = 0.14 and R^2 = 0.98, respectively. 40 samples were analyzed by Soxhlet extraction only, because the amount per sample was too small to be measured with the FoodScan.

Fatty acid pattern

Fatty acids were determined by MRI Kulmbach for (i) subcutaneous back fat (outer layer without rind) adjacent to *Musculus longissimus dorsi* (13th rib), for (ii) ham fat (fat cover without rind above *Musculus semimembranosus*), and for (iii) intramuscular fat of the *Musculus longissimus dorsi* (13th rib) of the left carcass half of all animals. Fatty acids were analysed by gas chromatography (GC) using a Hewlett Packard 6890 series system with a J&W Scientific DB-23 capillary column (60 m x 0.25 mm, i.d. 0.25 µm; Agilent Technologies, Inc., US) and a flame ionisation detector. Sample preparation was performed as described by Schulte and Weber (1989). In brief, back fat samples were homogenized and melted with butylated hydroxytoluol. For transesterification from fatty acids to methyl esters, an aliquot of the liquid fat was mixed with toluol and trimethylsulfonium hydroxide (TMSH). Fat content of muscle tissue was extracted with a mixture of methanol and dichlormethane and then transesterified with TMSH. Then, the sample was injected into the GC system. GC conditions were as follows: injection temperature was 250 °C; carrier gas was Hydrogen, 1.3 ml/min, 1,710 split; column temperature program, 80 °C (5 min), up to 190 °C (rate 2 °C/min), up to 220 °C (1 °C/min), 220 °C (15 min); detector temperature 250 °C. For chromatogram evaluation the Chemsation Software (Agilent Technologies, Inc., US) was used. Calculation of fatty acids was based on the peak area of detected fatty acids (area percentage). Fatty acid concentrations < 0.5 % are not recorded.

Product quality of dry fermented sausage

During ripening (days of sampling: day 0 (subsequent to manufacturing), each week, end of ripening (week 5)) (i) pH and (ii) water activity (a_w) were analysed. The pH was determined electrometrically using a pH-meter 625 Climatic (Fa. Knick). Water activity was determined using an AWK-10 hygrometer (Fa. Nagy). For pH and a_w average values of three replicate measurements were used. The weight loss during ripening was calculated. One sausage per run, treatment and sampling time was used to measure the criteria. Data are presented only for the day subsequent to manufacturing and the end of ripening.

The color and the consistency were measured in ten not neighbouring slices at the end of ripening (five weeks subsequent to manufacturing). The color of the sausage was assessed with the L*a*b*-system using a Minolta Chroma-Meter CR-300 (Fa. Minolta). The consistency of the sausage was measured instrumentally two times per slice with the Instron 1140 (Fa. Instron). The samples used were 10 mm high, of 12.3 mm diameter, with a compression of 76 % at a temperature of 20 °C. One sausage per run, treatment and sampling time was used to measure the criteria.

The fat, protein, water, ash and connective tissue contents were determined according to the German standard of § 64 LFGB methods (LFGB, 2011) at the end of ripening. One sausage per run and treatment was used.

The fatty acid patterns of the sausages were only evaluated at the end of ripening for samples of the first run. In case of Hy, only the straw feeding based variant was available. The fatty acid determination followed the method mentioned above. One sausage per treatment was used.

The peroxide index and the acid value were evaluated according to the German standard of DGF-Einheitsmethoden – Abteilung C (DGF, 2011). TBARS (2-thiobarbituric acid reactive substance) measurements were done according to Botsoglou et al. (1994), and the TBARS values were expressed as milligrams of malonaldehyde per kg of sample. The three parameters of fat stability were evaluated at the end of ripening and after two months of storage. One sausage per run, treatment and sampling time was used to measure the criteria.

The whole product quality analyses were done by the MRI Kulmbach.

2.3 Statistics

Data analyses of meat quality criteria and fatty acid pattern were carried out with the General Linear Model (Proc GLM, SAS software package version 9.2), considering run, genotype, roughage source and the interaction genotype*roughage source as fixed effects. For the intramuscular fat content and the fatty acid composition the slaughter weight (expressed as the difference from the genotype average) was included in the model as a covariate. The remaining meat quality parameters were calculated without covariates. The LSQ-means were statistically compared using the Tukey-Kramer-Test (significance level $p < 0.05$).

For the criteria of product quality of dry fermented sausages only a descriptive statistic (including medium and standard deviation) was performed as the data structure was not sufficient for ANOVA (compare "M&M", "Product quality of dry fermented sausage").

3 Results

The significances of the effects of the statistical model on meat quality and fatty acid pattern are summarised in Table 2. Most meat quality parameters and all fatty acid patterns are influenced by the genotype, whereas the

roughage source has only a significant effect on pH_{24} and the fatty acid pattern of the back fat. The significant effect of the run on electrical conductivity, on intramuscular fat content and on fatty acid pattern mainly of the back fat cannot be explained. Due to the negligible genotype*roughage interaction the selected results of meat quality and fatty acid pattern are presented as shown in the output format of the following result tables 3 to 6.

Meat quality traits are shown in Table 3. The electrical conductivity 24 hours p.m. does not differ between genotypes or roughages. The pH_{24} in the *Musculus longissimus dorsi (M.l.d.)* as well as in the *Musculus semimembranosus (M.s.)* are slightly lower in the PiSa compared to the other two genotypes. Interestingly the pH_{24} of the grass-clover silage fed pigs is higher in both examined muscles *(M. l. d., M. s.)*. The *M. l. d.* of the PiSa seems to be redder (a*-value) and yellower (b*-value) compared to Sa and Hy, whereas the *M. s.* of the Hy is lighter (L*-value) and yellower (b*-value) compared to PiSa and Sa. The Sa have considerably lower drip losses of *M. l. d.* and *M. s.* The values reached only 72 % and 73 %, respectively, for M.l.d. of PiSa and Hy. Additionally, the intramuscular fat content of the *M. l. d.* of the Sa is nearly 20 % higher compared to PiSa, whereas differences in the IMF of Sa and Hy are not significant.

Fatty acid pattern of back fat is shown in Table 4. Saddlebacks have significantly the highest saturated fatty acid content and significantly the lowest poly-unsaturated fatty acid content whereas Hy behave in exactly the opposite way. PiSa takes an intermediate position. Roughage consumption (contrary to sole straw offer) results in significantly lower concentrations of mono-unsaturated (due to oleic acid) and significantly higher concentrations of poly-unsaturated fatty acids (due to linoleic acid and linolenic acid) in back fat. But the differences (-1.5 % for MUFA and +3.5 % for PUFA) are very small.

Fatty acid patterns of ham fat and intramuscular fat are shown in Table 5. Due to the minor relevance of ham fat and

Table 2
Significance levels of fixed effects on meat and fat quality traits

	r^2 (%)	Run (1^{st}, 2^{nd})	Genotype [1] (Hy, PiSa, Sa)	Roughage (gcs^2, straw)	G*R interaction
Electr. conductivity24 (loin)	20	***	ns	ns	ns
Electr. conductivity24 (ham)	33	***	ns	ns	ns
pH_{24} (loin)	22	ns	***	**	ns
pH_{24} (ham)	19	ns	***	**	ns
L* (loin)	4	ns	ns	ns	ns
a* (loin)	21	ns	***	ns	**
b* (loin)	14	ns	***	ns	ns
L* (ham)	7	ns	*	ns	ns
a* (ham)	2	ns	ns	ns	ns
b* (ham)	14	ns	**	ns	ns
Drip loss (loin)	19	ns	**	ns	ns
Drip loss (ham)	17	ns	**	ns	*
Intramuscular fat (loin)	19	*	*	ns	ns
Back fat					
– SFA[3]	29	***	***	ns	ns
– MUFA[4]	39	**	***	**	*
– PUFA[5]	66	***	***	**	ns
Ham fat					
– SFA[3]	47	***	***	ns	ns
– MUFA[4]	22	ns	***	ns	ns
– PUFA[5]	14	ns	**	ns	ns
Intramuscular fat					
– SFA[3]	8	ns	*	ns	ns
– MUFA[4]	9	ns	ns	ns	ns
– PUFA[5]	17	ns	***	ns	ns

[1] Hy: modern Hybrid; PiSa: Piétrain*Saddleback; Sa: Saddleback

[2] gcs: grass-clover silage

[3] Saturated Fatty Acids

[4] Mono-Unsaturated Fatty Acids

[5] Poly-Unsaturated Fatty Acids

Table 3
Meat quality traits by genotype and roughage source of heavy pigs (LSQM)

	Genotype [1]			Roughage	
	Hy	PiSa	Sa	gcs[2]	straw
EC_{24}[3], loin (*M. long. dorsi*, 13th/14th rib) [mS/cm]	2.22	2.20	2.05	2.27	2.04
EC_{24}[3], ham (*M. semimembranosus*) [mS/cm]	3.99	3.79	3.77	3.95	3.75
pH_{24}, loin (*M. long. dorsi*, 13th rib)	5.53^{a}	5.47^{b}	5.54^{a}	5.53^{x}	5.49^{y}
pH_{24}, ham (*M. semimembranosus*)	5.58^{a}	5.53^{b}	5.63^{a}	5.60^{x}	5.56^{y}
L*, loin (*M. long. dorsi*, 13th rib)	52.34	52.87	52.95	52.41	53.03
a*, loin (*M. long. dorsi*, 13th rib)	10.01^{b}	11.48^{a}	10.12^{b}	10.41	10.66
b*, loin (*M. long. dorsi*, 13th rib)	6.75^{b}	7.83^{a}	7.29^{ab}	7.18	7.40
L*, ham (*M. semimembranosus*)	41.13^{a}	38.67^{b}	38.40^{b}	39.88	38.93
a*, ham (*M. semimembranosus*)	11.91	12.14	12.09	12.19	11.90
b*, ham (*M. semimembranosus*)	6.40^{a}	5.02^{b}	4.95^{b}	5.78	5.13
Drip loss, loin (*M. long. dorsi*, 14th rib) [%]	6.24^{a}	6.30^{a}	4.56^{b}	5.46	5.93
Drip loss, ham (*M. semimembranosus*) [%]	2.31^{ab}	2.85^{a}	1.75^{b}	2.18	2.43
Intramuscular fat, loin (*M. long. dorsi*, 13th rib) [%]	2.64^{ab}	2.57^{b}	3.11^{a}	2.68	2.87

[1] Hy: modern Hybrid; PiSa: Piétrain*Saddleback; Sa: Saddleback

[2] gcs: grass-clover silage

[3] Electrical conductivity

[a, b] Different indices within row indicate significant differences for genotype (Tukey-Kramer-Test, $p < 0.05$)

[x, y] Different indices within row indicate significant differences for roughage (Tukey-Kramer-Test, $p < 0.05$)

Table 4
Fatty acid pattern (%) of subcutaneous back fat (outer layer, *M. long. dorsi*, 13th rib) by genotype and roughage source of heavy pigs (LSQM)

	Genotype [1]			Roughage	
	Hy	PiSa	Sa	gcs[2]	straw
C14:0	1.20^{b}	1.30^{a}	1.31^{a}	1.28	1.27
C16:0	21.66c	22.46^{b}	22.96^{a}	22.42	22.30
C18:0	12.00^{b}	12.04^{b}	12.55^{a}	12.32	12.07
C16:1 cis9	1.93	1.98	1.99	1.95	1.98
C18:1 cis9	42.13^{b}	43.24^{a}	43.46^{a}	42.63^{y}	43.25^{x}
C18:1 cis11	2.72^{b}	2.81^{ab}	2.85^{a}	2.76	2.83
C20:1	1.13^{b}	1.23^{a}	1.19^{ab}	1.17	1.19
C18:2n6	12.29^{a}	10.50^{b}	9.37^{c}	10.87^{x}	10.56^{y}
C18:3n3	1.30^{a}	1.11^{b}	1.02^{c}	1.21^{x}	1.08^{y}
C20:2	0.69^{a}	0.63^{b}	0.55^{c}	0.63	0.62
SFA[3]	35.84^{c}	36.72^{b}	37.79^{a}	36.95	36.62
MUFA[4]	48.63^{b}	49.87^{a}	50.18^{a}	49.18^{y}	49.94^{x}
PUFA[5]	15.38^{a}	13.26^{b}	11.89^{c}	13.74^{x}	13.28^{y}

[1] Hy: modern Hybrid; PiSa: Piétrain*Saddleback; Sa: Saddleback

[2] gcs: grass-clover silage

[3] Saturated Fatty Acids: C14:0, C16:0, C18:0

[4] Mono-Unsaturated Fatty Acids: C16:1 cis9, C18:1 cis9, C18:1 cis11, C20:1

[5] Poly-Unsaturated Fatty Acids: C18:2n6, C18:3n3, C20:2

[a, b, c] Different indices within row indicate significant differences for genotype (Tukey-Kramer-Test, $p < 0.05$)

[x, y] Different indices within row indicate significant differences for roughage (Tukey-Kramer-Test, $p < 0.05$)

Table 5
Fatty acid pattern (%) of ham fat and intramuscular fat by genotype and roughage source of heavy pigs (LSQM)

	Genotype [1]			Roughage	
	Hy	PiSa	Sa	gcs[2]	straw
Ham fat (above *M. semimembranosus*)					
– SFA[3]	38.65[a]	37.38[b]	37.62[b]	37.81	37.95
– MUFA[4]	44.95[b]	50.06[a]	52.65[a]	48.26	50.18
– PUFA[5]	11.96[a]	12.31[a]	10.78[b]	11.70	11.67
Intramuscular fat (*M. long. dorsi,* 13th rib)					
– SFA[3]	36.42[ab]	36.27[b]	37.07[a]	36.58	36.59
– MUFA[4]	53.87	53.60	54.20	53.73	54.05
– PUFA[5]	9.28[a]	9.64[a]	8.23[b]	9.24	8.86

[1] Hy: modern Hybrid; PiSa: Piétrain*Saddleback; Sa: Saddleback

[2] gcs: grass-clover silage

[3] Saturated Fatty Acids: C14:0, C16:0, C18:0

[4] Mono-Unsaturated Fatty Acids: C16:1 cis9, C18:1 cis9, C18:1 cis11, C20:1

[5] Poly-Unsaturated Fatty Acids: C18:2n6, C18:3n3, C20:2

[a, b] Different indices within row indicate significant differences (Tukey-Kramer-Test, $p < 0.05$)

intramuscular fat for dry fermented sausage manufacturing only the fatty acid groups are presented without the respective single fatty acids. In contrast to back fat, the Hy have significantly higher SFA contents of about 3% in ham fat compared to the mean SFA content in Sa and PiSa. And again, the Sa have the significantly lowest PUFA content. The mean MUFA content of the Sa and PiSa in ham fat is about 14% higher than the MUFA content of the Hy. Concerning intramuscular fat, the Sa have the highest SFA and the lowest PUFA content. In contrast to back fat, fatty acid patterns of ham fat and of intramuscular fat do not significantly respond to the different roughage sources.

Product quality traits of dry fermented sausage are shown in Table 6. Due to the data structure the ANOVA procedure was impossible (compare M&M, Product quality of dry fermented sausage & Statistics). Hence, the following results are presented as mean value (mv) and standard deviation (sd) of the two runs for the respective quality traits.

The decline of the pH- and the aw-value during ripening can be seen in Table 5. The sausages of Sa tend to have a slightly higher pH value at the beginning and the end of the ripening compared to the other two genotypes. As expected, the aw-values decrease during ripening and there are no differences between the genotypes in both measured times. L*a*b*-values and weight loss during ripening do not differ noticeably between the genotypes. It seems that the Sa sausages have the firmest consistency compared to the sausages of PiSa and Hy. Roughage source obviously is without effect on the respective physically based product quality traits.

Concerning chemically based quality traits, the sausages of Sa have a considerably higher fat content (about 20% of Hy) in spite of the same recipe, whereas moisture and protein content are lower compared to Hy sausages. PiSa ranked in the middle. As a result, the fat-protein-ratio is about 40% higher in Sa than in Hy. But these differences could not be statistically proven due to the small number of batches (Table 6).

Fat stability is characterised by peroxide number, acid value and TBARS (Table 6). All fat stability parameters developed higher values during storage, indicating lower oxidative fat stability, except TBARS in PiSa. After two months of storage at 12 °C the Hy sausages show the highest values and Sa the lowest values in all parameters, the PiSa always rank in the middle. The better fat stability of Sa sausages can be confirmed by the fatty acid composition: Sa sausages have the lowest PUFA concentration (only 70% of Hy) and the highest SFA concentration (Table 6).

4 Discussion

For the utilisation of heavy pig carcasses for dry fermented sausage production, meat and fat quality is very important; not only regarding nutritive and organoleptic aspects but also from a technological point of view (Russo, 1989; Hadorn et al., 2008).

The PSE and DFD status of the raw meat is one of the most important processing characteristics of meat. The deviations from normal water holding capacity make a proper dry-curing process difficult (Gil et al., 1999). For the pork meat used for salami production the pH_{24} values (exclusion of DFD) should not exceed 6.0 to 6.2 (Bracher and Stoll, 2002) and EC_{24} values should not exceed 6.0 in loin or 9.5 in ham (topside) for exclusion of PSE conditions (Weißmann and Honikel, 1998). In our study (Table 3) the respective values are clearly below and they are in the range of literature data in case of exclusion of DFD (Virgili, Schivazappa, 2002) and of PSE conditions (Westphal, 2002).

Table 6
Mean value (mv) and standard deviation (sd) of selected product quality traits of dry fermented sausage by genotype and roughage source of heavy pigs

	Genotype [1]						Roughage			
	Hy		PiSa		Sa		gcs [2]		straw	
	mv	sd	mv	sd	mv	sd	mv	sd	mv	sd
Physical criteria										
– at the day of manufacturing										
pH	**5.53**	0.03	**5.52**	0.03	**5.60**	0.08	**5.54**	0.06	**5.56**	0.07
aw	**0.95**	0.00	**0.95**	0.00	**0.95**	0.01	**0.95**	0.00	**0.95**	0.01
– at the end of ripening …										
pH	**5.19**	0.11	**5.18**	0.04	**5.38**	0.16	**5.27**	0.14	**5.19**	0.12
aw	**0.89**	0.03	**0.88**	0.02	**0.88**	0.03	**0.88**	0.03	**0.88**	0.02
Weight loss [%]	**37.7**	3.4	**36.6**	1.4	**36.0**	2.6	**36.7**	2.6	**36.9**	2.1
L*	**54.15**	1.33	**53.93**	2.00	**53.25**	2.50	**53.55**	1.99	**54.15**	1.73
a*	**16.34**	2.95	**17.81**	2.41	**18.62**	1.68	**17.80**	2.29	**17.33**	2.70
b*	**10.85**	1.61	**11.08**	1.03	**11.39**	1.40	**11.17**	1.27	**10.99**	1.20
Consistency [N]	**31.0**	9.3	**27.6**	6.6	**42.2**	6.9	**33.2**	11.3	**32.8**	7.0
Chemical criteria										
– at the end of ripening										
Water [%]	**32.3**	2.1	**30.4**	1.9	**28.7**	2.5	**30.5**	2.8	**30.4**	2.0
Crude fat [%]	**35.0**	1.1	**39.1**	3.5	**41.6**	4.5	**38.4**	4.0	**38.9**	4.7
Crude protein [%]	**26.7**	2.7	**24.8**	1.6	**23.1**	3.2	**24.9**	2.6	**24.7**	3.0
Connective tissue [%]	**1.6**	0.2	**1.2**	0.1	**1.4**	0.1	**1.4**	0.3	**1.3**	0.1
Crude Ash [%]	**5.3**	0.6	**5.1**	0.3	**5.0**	0.2	**5.1**	0.3	**5.2**	0.5
SFA [3] [%]	**37.57**	-	**39.21**	0.16	**39.41**	1.07	**38.44**	0.79	**39.75**	0.59
MUFA [4] [%]	**47.61**	-	**49.19**	0.11	**49.63**	0.59	**48.92**	1.23	**49.24**	0.04
PUFA [5] [%]	**14.67**	-	**11.43**	0.28	**10.28**	0.00	**12.19**	2.25	**10.76**	0.67
Peroxide index [milli-equivalent oxygen/kg fat]	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0
Acid value [mg KOH/100g fat]	**13.47**	3.94	**12.02**	3.01	**12.13**	2.66	**11.93**	3.16	**13.32**	2.71
TBA [mg MDA/kg]	**0.127**	0.012	**0.122**	0.023	**0.089**	0.023	**0.109**	0.021	**0.120**	0.032
– at the end of storage (2 month, 12°C)										
Peroxide index [milli-equivalent oxygen/kg fat]	**2.80**	1.51	**1.62**	1.44	**1.09**	1.53	**1.78**	1.54	**1.87**	1.65
Acid value [mg KOH/100g fat]	**21.04**	1.51	**18.29**	1.81	**17.49**	0.82	**18.84**	2.32	**18.93**	1.81
TBA [mg MDA/kg]	**0.137**	0.031	**0.111**	0.032	**0.109**	0.058	**0.119**	0.037	**0.118**	0.046

[1] Hy: modern Hybrid; PiSa: Piétrain*Saddleback; Sa: Saddleback

[2] gcs: grass-clover silage

[3] Saturated Fatty Acids: C14:0, C16:0, C18:0

[4] Mono-Unsaturated Fatty Acids: C16:1 cis9, C18:1 cis9, C18:1 cis11, C20:1

[5] Poly-Unsaturated Fatty Acids: C18:2n6, C18:3n3, C20:2

Meat lightness (L*) of the loin remained unaffected by genotype and roughage source (Table 2, Table 3). This confirms the findings of Nürnberg et al. (1997) who could not find differences in meat color (*M. l. d.*) between German Saddlebacks and German Landrace in contrast to Steinberg et al. (1998). This study reported relatively high L* values in Saddlebacks and explained the greater lightness as the effect of a higher IMF content.

In our study, the Sa clearly showed lower drip losses compared to the other two genotypes (Table 3). This is in accordance with Steinberg et al. (1998) and Brandt et al. (2011) but contradicts Nürnberg et al. (1997). However, drip losses of *M. l. d.* are strikingly high in our study. In literature drip losses in heavy pigs are within a wide range from 7.19 % to 8.29 % (Virgili et al., 2003; Lukić et al., 2010) to 1.2 % to 2.3 % (Fischer et al., 2006b; Peinado et al., 2012). These large differences

cannot be explained completely. A possible explanation may be the entire procedure of drip loss evaluation, also due to the significant influence of the location (Fischer, 2007). In our study, the overall mean value for medial and lateral drip loss in *M. l. d*. (13th rib) is 4.0 % and 7.4 %, respectively (data not presented). Therefore it is essential, inter alia, on which part of the *M. l. d.* the drip loss is evaluated.

Intramuscular fat content seems to be the best way to separate native pigs from improved ones (Pugliese and Sirtori, 2012). Interestingly the IMF content of Sa and Hy did not differ significantly (Table 3), but in this high weight class both genetics have higher IMF compared to PiSa.

In summary, it can be said that the roughage source was without any noticeable effect on physical and chemical meat quality traits in contrast to the genetic origin. The Sa showed the best meat quality characteristics for use in dried meat products. In literature the crossbreeding of Piétrain with German Saddleback is especially recommended, leading to higher lean meat content without diminishing meat quality (Ehlich, 2005). This could be confirmed by our own meat quality (Table 3) and carcass quality results presented in the first communication (Schwalm et al., 2013). To avoid PSE conditions, MHS-gene-sanitized lines (malignant hyperthermia syndrome) have to be used (Glodek, 1996).

In terms of meat and technological meat quality, fatty acid composition has an outstanding effect on the softness and oxidative stability of fat and meat, as high PUFA levels result in softer fat due to a lower melting point (Wood et al., 2003; Bee, 2004). The ability of unsaturated fatty acids, especially those with two or more double bounds, to rapid oxidation is important to rancidity and to color deterioration (Wood et al., 2003). Higher PUFA and lower pH_{24} are to be regarded as potentially harmful for pork undergoing a long aging because of increased fat susceptibility to rancidity and oiliness and enhanced muscle proteolysis (Virgili and Schivazappa, 2002).

For optimal processing quality concerning consistency and oxidative stability, recommendations have been formulated, limiting the PUFA content of the back fat to a maximum of 12 to 15 % (Kuhn et al., 1995; Warnants et al., 1996; Bee, 2004; Fischer et al., 2006b). In our study, only the Saddlebacks were below 12 % PUFA content in the back fat (mainly used for sausage production) with the Hy showing the highest amount (15.4 %) and PiSa having an intermediate position (Table 4).

Also in the ham fat and in the intramuscular fat, the Saddlebacks have the lowest PUFA concentrations (Table 5). This is in accordance with the studies of Glodek et al. (2004) and Volk et al. (2004). An increase in fat synthesis (due to breed or age) leads to a dilution of PUFA ingested (mainly C18 : 2 and C18:3) by the *de-novo* produced fatty acids (mainly C18 : 1) (Virgili et al., 2003; LoFiego et al., 2005; Fischer et al., 2006b).

Pasture contains relatively high amounts of PUFA which are by a majority from the omega-3 family. Especially linolenic acid content is higher in outdoor reared animals (Andrés et al., 2001). This can lead to technologically undesired carcass fat. This is why feeding of green fodder and/or silage in heavy pigs intended for dry fermented sausage production has to be seen critically (Burgstaller et al., 1992; Johansson et al., 2002). In our study, a slightly lower MUFA and a slightly higher PUFA content in the back fat of the silage fed group could be observed (Table 4), but the values are far below the differences between the genotypes and may not affect the quality of the produced sausages. This seems to be the effect of the small amount of silage offered to the pigs with an average of 0.9 kg grass-silage per animal and day (Schwalm et al., 2013). Concerning the other two fat origins (IMF, ham fat), no significant differences occurred as to the roughage source (Table 5). This is in agreement with the results of Miller et al. (1990) and Warnants et al. (1996), finding a lower dietary PUFA incorporation in IMF compared to back fat.

The pH and aw-values of dry fermented sausages at the beginning and at the end of the ripening period are within normal ranges and show the expected decline during ripening (Table 6). The Sa tend to have slightly higher pH values. This is in accordance with higher pH values at the end of the ripening in dry fermented sausages with higher fat content (Rödel, 1985). The results of Hadorn et al. (2008) indicate that the a_w-value in salami increases with increasing PUFA content. This could not be observed in our study (Table 6) despite the highest PUFA contents in the back fat of the Hy (Table 5), but maybe the differences are too small to cause a change of the a_w-value in the sausage.

Concerning sausage color, there are no clear tendencies between the genotypes or the roughage sources (Table 6). Miller et al. (1993) and Warnants et al. (1998) report that the b*-value (of the L*a*b*-system) is higher for salamis with a higher PUFA level, although the carcass fat showed no yellow discolouration. The results of our study do not confirm this combination (Table 6). In accordance with Caprino et al. (2007), dry fermented sausages of old breeds tend to be redder, represented by the highest a*-value of the Sa.

The higher firmness of the Sa sausages (Table 6) can probably be attributed to the lower PUFA content of the back fat used (Table 4) and of the sausage (Table 6). In the manufacturing of salami/cervelat sausage, an increased number of double bindings results in a soft and greasy consistency of the end product (Houben and Krol, 1980; Warnants et al., 1998; Hadorn et al., 2008).

Concerning the tendencies in the nutrient composition of the sausage (Table 6), the lowest water content is associated with the highest fat content and therefore lowest protein content in the Sa, and vice versa for the Hy; PiSa ranks in the middle. Together with the fat level of the basic material (Schwalm et al., 2013), the presented results make for a conclusive overall picture.

Lipid oxidation is a major quality deteriorative process in muscle foods resulting in a variety of breakdown products which produce off-flavours (Valencia et al., 2008). Especially PUFA are highly sensitive to oxidation (Wood et al., 2003). After 2 months of storage at 12 °C the Sa sausages tend to have the best values in all parameters concerning the oxidative fat stability (peroxide index, acid value, TBARS) (Table 6). The better fat stability of Sa sausages can be confirmed by the fatty acid composition: Sa sausages have the lowest PUFA concentration (only 70 % of Hy) and the

highest SFA concentration (Table 6). The lower PUFA content (and therefore better fat stability) of fermented sausages of primitive breeds (Mangaliza, Moravaka) has been shown by Stajić et al. (2011).

TBARS values above 0.5 MDA/kg are considered as critical since they indicate a level of lipid oxidation products resulting in rancid odour and taste (Sheard et al., 2000; Wood et al., 2008). In our dry fermented sausages, TBARS values did not exceed the critical 0.5 MDA-value (Table 6), but rancidity and beginning fat oxidation could be sensorially detected in all sausages after the storage time (comments of the taste panel; data not presented). This is confirmed by the acid values and peroxide indexes, especially at the end of storage.

As a final synopsis, it can be summarised that the results of meat quality and of fatty acid pattern are reflected in the tendencies of the product quality of the dry fermented sausages. Compared to modern hybrids (Hy) and the crossbreed between modern Piétrain and old Saddleback (PiSa) purebred Saddlebacks (Sa) have characteristics of meat quality and chiefly of fatty acid pattern which are more or less optimally suitable for dry fermented sausage production. Meat and fat quality characteristics predestine the Saddlebacks for dry fermented sausage manufacturing. Whereas the genetic origin plays a significant role in dry fermented sausage production, the roughages offered are without practical relevance. But this is only proven for the conditions of our study with an average daily grass-clover supply per pig not exceeding 1 kg.

5 Overall conclusions

It could be shown in the present paper that – from the viewpoint of meat and especially of fat quality – modern hybrids have sub-optimal preconditions for dry fermented sausage production in the range of about 150 to 170 kg live weight at slaughter (under the particular diet composition of our trial), whereas old purebred Saddlebacks are well suited. This is also true for carcass quality: whereas the Saddlebacks have sufficient fat quantities, the modern hybrids represent the lower limit (Schwalm et al., 2013). Performance characteristics are inconsistent. Modern hybrids have the best level of daily weight gain and of feed conversion ratio. On the other hand old Saddlebacks still have a remarkable level of daily weight gain but an inacceptable poor level of feed conversion resulting in very high production costs with a surplus of the revenues over the feed and piglet costs of only 57 % compared to the modern hybrids (Schwalm et al., 2013). Although product quality of dry fermented sausages of Saddleback origin tends to be a little bit higher compared to the modern hybrids, it seems completely unrealistic to achieve selling prices (and sales volumes) which could compensate the strikingly higher production costs of the Saddlebacks; even if the selling arguments of a local breed and a local origin of production could be used. Therefore, it cannot be maintained that the production and merchandising of a pork speciality like dry fermented sausage only based on purebred Saddlebacks is a goal to ensure the survival of endangered purebred old breeds via economically based value creation.

But the use of crossbreeds between old Saddlebacks and a modern terminal sire line like Piétrain is an auspicious alternative (under the strict obedience to use MHS-gene-sanitized lines). The PiSa crossbreeds of our study are characterised by positive manifestations of (i) meat quality, (ii) fatty acid pattern and (iii) product quality as well as (iv) performance, (v) carcass quality and (vi) economics (Schwalm et al., 2013) providing the potential for a sustainable dry fermented sausage production. The necessity of a purebred old pig breed like Saddlebacks as mating partner within this concept opens a promising goal to ensure the survival of purebred Saddlebacks as a typical representative of an old endangered breed.

This consideration need not necessarily remain a pious hope as over the last few years, meat products made of native pigs reared extensively or organically have been met with an ever increasing and renewed interest from customers (Madonia et al., 2007; Maiorano, 2009).

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7 Disclaimer

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