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

1. Performance, carcass quality, and economic aspects

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Abstract

Castrated heavy pigs of >160 kg live weight are used for traditional pork specialties (e.g. dry fermented sausages) 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, e.g. Saddleback (Sa), could be an alternative with the additional benefit of maintaining biodiversity.

This study with a total of 132 castrates analysed the effects of three different genotypes (Sa, Piétrain*Sa (PiSa), Hy) and two different roughage sources (grass-clover silage, straw) on performance, carcass-, meat-, fat-, product-quality (dry fermented sausage), and economic aspects. The present paper deals with performance (PF), carcass quality (CQ), and economic aspects (EA). It is found that PF and CQ are both influenced significantly by the genotype but not by the roughage source. Hy showed the best and Sa the poorest PF (e.g. 804 g vs. 634 g daily weight gain). Concerning CQ, Sa showed the fattest and Hy the leanest carcass (e.g. 1 : 1.36 vs. 1 : 0.49 lean to fat ratio). Concerning EA, Sa generated only about 60 % of the surplus of the revenues over feed and piglet costs compared to Hy. PiSa always ranked in the middle.

It can be concluded that under organic farming conditions Sa and PiSa seem to be suitable for heavy pig production to produce premium segment pork specialities in the form of dry fermented sausages due to performance and carcass quality traits. But as long as the payout price is not adapted to carcass quality or the suitability for processing, in particular the fattening of Sa will not be interesting from an economic point of view.

Keywords: *heavy pig, saddleback, performance, carcass quality, economics*

Zusammenfassung

Effekt unterschiedlicher Genotypen und Raufutter in der ökologischen Mast schwerer Schweine zur Rohwurstherstellung

1. Mastleistung, Schlachtkörperqualität und Wirtschaftlichkeit

Zur Herstellung langgereifter Rohwurst werden Kastraten >160 kg Lebendmasse wegen der benötigten Fettmenge und -qualität genutzt. Zur Mast kommen vor allem moderne Hybriden (Hy), bei denen beides oftmals unzureichend ausfällt. Alte gefährdete Rassen, z.B. Sattelschweine (Sa), mit einer hohen *de-novo* Fettsynthesekapazität könnten eine Alternative darstellen und damit zu deren Erhaltung beitragen.

Es wurden die Effekte von drei Genotypen (Sa, Piétrain*Sa(PiSa), Hy) und zwei Raufuttern (Kleegrassilage, Stroh) auf Mastleistung (ML), Schlachtkörper (SQ)-, Fleisch-, Fett- und Wurstqualität sowie Wirtschaftlichkeit (W) überprüft. Dieser Artikel präsentiert die Ergebnisse zu ML, SQ und W. Der Genotyp jedoch nicht das Raufutter beeinflussten ML und SQ signifikant. Hy zeigte gegenüber Sa die beste ML (804 g vs. 634 g tägl. Zunahme) und bei SQ die geringste Verfettung (1 : 1,36 vs. 1 : 0,49 Fleisch : Fett-Verhältnis). Bezüglich W erreichte Sa nur 60 % des Überschusses über die Ferkel-Futter-Kosten von Hy. Bei sämtlichen Kriterien lagen die Ergebnisse von PiSa zwischen Hy und Sa.

Hinsichtlich der Fettquantitäten scheinen Sa und PiSa für die Rohwurstherstellung am besten geeignet zu sein. Jedoch ist die Mast von Sa in Reinzucht ökonomisch uninteressant, solange der Auszahlungspreis nicht an deren geeignete Schlachtkörperqualität für die Weiterverarbeitung angepasst wird.

Schlüsselworte: *Schwere Schweine, Sattelschwein, Mastleistung, Schlachtkörperqualität, Wirtschaftlichkeit*

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1 Introduction

Heavy pigs (castrated males, 150 to 160 kg live weight) are used for the production of traditional, regional pork specialties (e.g. dry fermented sausages or ham) in several regions of Europe. In this high body weight class, the meat quality, the amount and the quality of fat (e.g. firm, oxidation resistant) are sufficient for the processing of traditional pork products to ensure improved product quality. First and foremost the quality of lean meat and the consistence of the fatty tissue have to be considered (Burgstaller et al., 1992; Bellof and Burgstaller, 1992; Girard et al., 1989; Haase, 2013).

Today, most of the heavy pig production systems use modern pig hybrids/genotypes which are characterized by a high body protein synthesis capacity (Bellof and Burgstaller, 1992), because breeding strategies have been aimed at increasing the lean meat to fat ratio in pigs during recent decades (Hadorn et al., 2008). For the production of traditional pork products such as dry fermented sausages, fat level and quality (Fischer et al., 2006) and meat quality (Bellof and Burgstaller, 1992) are often unsatisfactory.

It is commonly recognized that local pig breeds represent a valuable genetic reserve for typical products or for recovering some properties of meat and fat, currently lost because of severe selective programs (Fortina et al., 2005). Traditional breeds are known to have lower protein synthesis capacity and higher carcass fat yields. This results in a sufficient quantity and quality of fat with a high amount of saturated fatty acids which is favourable for raw sausage production. Finally, this is due to intensive *de-novo* fat-synthesis (Nürnberg et al., 1998). Therefore, the use of traditional breeds (e.g. German or Angeln Saddleback) could be an alternative for the production of traditional, regional pork specialties. Additionally, the use of an old endangered breed might bring marketing advantages and may provide an economically suitable strategy for the conservation of endangered breeds.

The crossbreeding of unimproved breeds with Duroc or Piétrain is known to improve average daily weight gain, feed conversion ratio and lean meat content (Legault et al., 1996). In heavy pig production, this might be advantageous in order to improve performance and carcass traits compared to the purebred, resulting in effective fattening and an economic benefit.

It is well known that old breeds such as Saddlebacks have the potential to produce organoleptically preferable meat. But due to the serious disadvantages in growth and carcass quality, the use of this breed is limited to regional niche production (Paulke et al., 2011). German or Angeln Saddleback pigs produce a very high fatty tissue percentage with an improved meat quality. The fat quality measured by the fatty acid composition of the longissimus muscle in the Saddlebacks was favourable as to oxidative stability because of the high saturated fatty acid content. The high intramuscular fat content and the fatty acid composition resulted in advantages for sensory evaluation and processing conditions (Nürnberg et al., 1997).

The traditional breeds may be especially suitable for outdoor or extensive fattening. In these extensive systems, the use of green fodder as part of the feeding ration might be an option to minimize feeding costs. Additionally, in organic agriculture, the use of roughage, also for monogastric animals, is obligatory (EC 889/2008). Green fodder is known to increase PUFA content and leads to softer fat in the carcass. But for raw sausage production, firm fat with high oxidative stability is needed (Nürnberg et al., 1997).

Against this background, three genotypes (extensive = Saddleback (Sa), semi-intensive = Piétrain*Saddleback (PiSa), intensive = modern hybrid line (Hy)) were slaughtered at about 160 kg live weight. Each genotype was fed with grass-clover silage or straw as roughage source. 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 aspects were quantified. The study 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 performance traits, carcass quality, and economic aspects. A second paper (Schwalm et al., 2013) deals with aspects of meat, fat and product (dry fermented sausage) quality.

2 Material and methods

2.1 Animals & keeping

The study was performed at the certified organic experimental pig facility of the Thünen-Institute of Organic Farming in Trenthorst (Germany) using two runs in 2010/2011 (n = 69 animals) and 2011/2012 (n = 65 animals).

A total of 134 barrows of three different genotypes with different classifications of the breeding intensity concerning body protein synthesis capacity were used: Saddleback (Sa) – extensive; Piétrain*Sa (PiSa) – semi-intensive; modern Hybrid (Piétrain*Duroc)*(German Large White*German Landrace) (Hy) – intensive. Each group of genotypes originated from several litters (Sa = 12, PiSa = 10, Hy = 10). Terminal sires in PiSa (Pi) and hybrids (PiDu) were used via artificial insemination and Pi was of MHS-gen-sanitized nn-type.

Each of the three genotypes was fed two different roughage sources: grass-clover silage and straw.

The resulting six treatments were evaluated for selected traits of performance and of carcass quality.

Only barrows were used due to German Best Practice because female oestrus cycle is seen as contraindicated for dry fermented sausage production. This is due to specific hormonal metabolism conditions and the consequently non-free choice of the slaughtering date (Euen, 2013). This is in contrast to Calvo et al. (2010) who did not find significant differences in various meat quality traits.

Due to the loss of two animals, 132 heavy pigs remained for analysis. The distribution of genotypes, animal number and group number is shown in Table 1.

Table 1
Distribution of genotype, roughage source, animal and group numbers

Genotype	Hy [1]		PiSa [2]		Sa [3]	
Roughage source	gcs [4]	straw	gcs	straw	gcs	straw
Groups (n)	2	2	2	2	3	2
Animals (n)	22	22	21	21	27	21

[1] Modern Hybrid
[2] Piétrain * Saddleback
[3] Saddleback
[4] grass-clover silage

Animal housing was in accordance with organic farming regulations (EC 889/2008). The stocking rate was 10 to 11 animals per pen (group) with an animal : feeding place ratio of 1 : 1. Indoor area was 1.5 m^2 per animal, outdoor area (concrete solid floor) 1.2 m^2 per animal. Straw was used as litter in both compartments (indoor, outdoor). All fatteners were individually identified.

The pelletized concentrates consisted of feed ingredients of 100 % organic origin. The grower diet contained 52.5 % cereals, 30 % grain legumes, 15 % oilcake and 2.5 % mineral premix with 13.2 MJ Metabolizable Energy (ME)/kg (CV 1.8 %) and a Lysin-ME-ratio of 0.83 (CV 10.4 %). It was fed up to a live weight of around 70 kg. The following finisher diet consisted of 55.5 % cereals, 38 % grain legumes, 4.5 % oilcake and 2 % mineral premix with 12.2 MJ ME/kg (CV 1.6 %) and a Lysin-ME-ratio of 0.67 (CV 13.1 %). No further diet optimization was done with respect to essential amino acids for the grower and finisher diets (for more detailed information see Schwalm et al., 2013, second communication). Both diets were given *semi-ad libitum*. The daily allotted feed was based on a live weight-dependent feeding curve, with a daily feed rest < 1 kg per pen and repast. A mobile feeder with an integrated electronic scale (Vliebo, Netherlands) was used for concentrate offer.

The roughage (grass-clover silage, straw) was offered separately in one rack per pen. The grass-clover silage (dry matter (DM): 31.7 % (CV 11.7 %); XP: 15.9 % in DM (CV 6.6 %); XF: 22.8 % in DM (CV 13.9 %)) was given daily with an average of 0.9 kg fresh matter per day and animal. A higher offer was not considered due to considerably increasing waste. As it was not possible to measure the 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 wasted and racks were refilled when depleted; no further quantitative recordings and qualitative analyses were carried out.

2.2 Data collection & analyses

The fattening period started at an average initial live weight of 26.2 kg (CV 24 %) and animals were slaughtered with a mean live weight of 164.1 kg (CV 3 %). When animals reached a live weight > 159 kg, they were slaughtered the following week in a small family abattoir after a resting period of 45 min and electrical stunning.

Data collection of performance and carcass traits followed basically the federal standard of German testing stations (ZDS, 2007). Feed consumption (daily quantity of concentrate and roughage feed, without reweighing the feeding rest) and feed conversion ratio (only concentrates) were calculated as group average for the whole fattening, the grower and the finisher period. The data concerning live weight development and carcass traits were recorded individually.

The pigs were weighed at the beginning and the end of the trial with the last weighing on the day of slaughtering. Additionally, there were intermediate weighing every four weeks and weekly weighing prior to slaughter. The daily weight gain of each animal was calculated for the whole fattening, the grower, and the finisher period.

Dressing percentage was calculated from warm carcass weight and final live weight. One day after slaughter, muscle and fat area and five different fat thicknesses (for location details see Table 4) were measured, using the chilled carcass half according to the federal standard of German testing stations (ZDS, 2007). Fat thicknesses were measured using a manual calliper, muscle and fat areas were measured by standardised photography and subsequent electronically based planimetry (Matthäus® SCAN-STAR K). Lean meat content was calculated using the "Bonner Formula" (ZDS, 2007).

The carcass half was dissected into the main valuable cuts following the in-house-economic cut methodology of the abattoir (for details see Table 5). Cuts were weighed and are expressed as a percentage of cold carcass side (= (warm carcass weight – 2 % cooling loss)/2) (ZDS, 2007)).

Economic performance is expressed as surplus of the revenues over feed and piglet costs. The used prices are real prices within the trial period. The payout price of 3.27 Euro/kg carcass weight (Table 6) is used for all carcasses because in German heavy pig production the payout price is independent from carcass classification; it is based on Tegut® (Euen, 2013), one of the most important organic food retailers in Germany. The other prices are real prices paid by the Institute of Organic Farming (piglets, concentrates) or communicated by Löser (2013) (grass-clover silage, 30 % dry matter).

2.3 Statistics

Statistical data analyses was 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 feed consumption and feed conversion ratio during the whole fattening and the grower period, the average initial live weight (per group) was included in the model as a covariate. Likewise for feed consumption and feed conversion ratio in the fattening period, the average live weight at the beginning of the fattening period (per group) was used as a covariate. For the individually recorded performance traits, the initial live weight (expressed as the difference from the genotype average) was considered as covariate. For the carcass quality traits, the slaughter weight (expressed as the difference from the genotype average) was used as covariate. The parameters including the slaughter weight (e.g. dressing percentage and cuts as percentage of the slaughter weight) were calculated without covariates.

The LSQ-means were statistically compared using the Tukey-Kramer-Test (significance level $p < 0.05$).

3 Results

The parameters concerning performance and carcass quality were significantly influenced by the genotype, whereas the roughage source had no effect (except fat area, see Table 2). No interaction between genotype and roughage source could be found (except in the daily weight gain in the finisher period). Therefore, the selected results of performance and carcass quality are presented as shown in the output format of the following result Tables 3 to 5.

Table 3 illustrates selected characteristics of the growth performance. As expected, Saddlebacks showed lower (-23 %) daily weight gains in the fattening period (in the grower period as well as in the finisher period) resulting in a longer fattening period (+22 % respectively +47.6 days) compared to the modern hybrid line. The daily feed amount given to the three genotypes showed no significant differences – according to the trial design. This leads to a worse feed conversion ratio in the fattening period (+21 %) for the Saddlebacks compared to the modern hybrid line with likewise significant differences in the grower period. In the finisher period, however, the feed conversion ratio was only different by trend. The results of the PiSa always ranked in the middle.

Concerning the carcass quality parameters shown in Table 4, the Saddlebacks had lower dressing percentages than the crossbreeds. Also, the Saddlebacks had obvious higher back fat thicknesses in all measured points. For example, the Fat thickness B of the Saddlebacks was about 2.3 times larger than that of the Hybrids, and about 1.6 times larger than that of the crossbreeds. A 33 % smaller muscle area of the Saddlebacks together with a nearly doubled fat area resulted in a wider lean to fat ratio by the factor 2.8 compared to the Hybrids. The lean to fat ratio clearly shows the lower lean meat amount of the Saddlebacks compared to the modern Hybrid. This is also demonstrated by the lean meat content, calculated by the Bonner Formula (even if the absolute values cannot be used in this high weight class because the formula is only valid till 105 kg carcass weight). The results of the PiSa always ranked in the middle.

The high fat synthesis of the Saddlebacks is also obvious in the cut weights (Table 5). For the Saddlebacks, the fatty joints such as neck, belly, and head with cheek had a higher impact on the carcass half weight compared to the Hybids.

The lean joints such as leg (ham) and shoulder were significantly smaller in Saddlebacks compared to the hybrid line. The cuts of the PiSa crossbreeds always ranked at medium level between the other two genotypes.

Table 2
Significance levels of fixed effects on growth performance and carcass quality traits

	r^2 (%)	Run (1^{st}, 2^{nd})	Genotype (Hy, PiSa, Sa[1])	Roughage (gcs[2], straw)	G*R interaction
Performance traits					
Daily feed intake[3] in the					
– grower period	75	ns	ns	ns	ns
– finisher period	53	ns	ns	ns	ns
– whole period	42	ns	ns	ns	ns
Feed conversion ratio[3] (only concentrate)					
– grower period	94	ns	**	ns	ns
– finisher period	77	ns	ns	ns	ns
– whole period	89	ns	*	ns	ns
Daily weight gain in the					
– grower period	41	ns	***	ns	ns
– finisher period	46	ns	***	ns	ns
– whole period	53	ns	***	ns	ns
Days on test	59	*	***	ns	ns
Carcass traits					
Carcass weight, warm	7	ns	ns	ns	ns
Dressing percentage	10	ns	*	ns	ns
Back fat thickness					
– hind	52	ns	***	ns	ns
– mid	63	**	***	ns	ns
– fore	80	ns	***	ns	ns
Lateral fat thickness	67	ns	***	ns	ns
Fat size B	83	ns	***	ns	ns
Muscle area	81	ns	***	ns	*
Fat area	81	ns	***	*	ns
Lean-fat-ratio	82	ns	***	ns	ns
Lean meat content	85	*	***	ns	ns
Cuts					
Neck	8	ns	*	ns	ns
Belly	19	ns	**	ns	*
Loin with back fat	17	ns	***	ns	ns
Shoulder	16	ns	*	ns	ns
Leg without foot	37	ns	***	ns	ns
Head with cheek	34	ns	***	ns	ns
Feet	14	ns	***	ns	ns

ns: not significant, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
[1] Hy = modern Hybrid, PiSa = Piétrain*Saddleback, Sa = Saddleback
[2] gcs = grass-clover silage
[3] feed intake and feed conversion ratio calculated for group (pen)

Table 3
Selected characteristics of growth performance by genotype and roughage source of heavy pigs (LSQM)

	Genotype[1]			Roughage	
	Hy	PiSa	Sa	gcs[2]	straw
Number of animals (pens) [n]	44 (4)	42 (4)	46 (5)	70 (7)	62 (6)
Days on test	173.6^{c}	199.9^{b}	221.3^{a}	195.7	200.9
Daily feed intake[3] [kg/animal] in the					
– grower period	2.30	2.30	2.05	2.31	2.12
– finisher period	3.06	3.11	3.30	3.21	3.11
– whole period	2.79	2.83	2.92	2.88	2.81
Feed conversion ratio[3] [kg feed (only concentrate) / kg live weight gain] in the					
– grower period	2.91^{b}	3.02^{b}	3.58^{a}	3.14	3.20
– finisher period	3.87	4.55	4.88	4.39	4.48
– whole period	3.64^{b}	4.01^{ab}	4.42^{a}	4.00	4.04
Daily weight gain [g/animal] in the					
– grower period	804^{a}	752^{a}	551^{b}	724	681
– finisher period	818^{a}	691^{b}	650^{b}	721	718
– whole period	804^{a}	707^{b}	634^{c}	719	711

^{a,b,c} LSQM with different letters within a row differ significantly between the genotypes for $p < 0.05$ (Tukey-Kramer-Test)

[1] Hy = modern Hybrid, PiSa = Piétrain*Saddleback, Sa = Saddleback

[2] gcs = grass-clover-silage

[3] feed intake and feed conversion ratio calculated in groups (pen)

Table 4
Selected characteristics of carcass quality traits by genotype and roughage source of heavy pigs (LSQM)

	Genotype[1]			Roughage	
	Hy	PiSa	Sa	gcs[2]	straw
Carcass weight, warm [kg]	129.5	128.9	126.7	128.0	128.7
Dressing percentage [%]	78.2^{ab}	78.9^{a}	77.5^{b}	78.1	78.4
Back fat thickness [cm]					
– fore (thickest location at withers)	4.8^{c}	5.8^{b}	6.4^{a}	5.6	5.8
– mid (thinnest location above *M. long. dorsi*)	2.6^{c}	3.6^{b}	4.3^{a}	3.5	3.5
– hind (thinnest location above *M. glut. med.*)	2.1^{c}	3.2^{b}	4.6^{a}	3.3	3.3
Lateral fat thickness (ventral end of *M. lat. dorsi*, 13th rib) [cm]	4.2^{c}	4.9^{b}	6.1^{a}	5.1	5.1
Fat thickness B (thinnest location lateral *M. long. dorsi*, 13th rib) [cm]	1.9^{c}	2.8^{b}	4.3^{a}	3.0	3.1
Muscle area (*M. long. dorsi*, 13th rib) [cm^2]	58.19^{a}	52.57^{b}	39.22^{c}	50.41	49.58
Fat area (*M. long. dorsi*, 13th rib) [cm^2]	28.21^{c}	39.01^{b}	52.25^{a}	38.70^{y}	40.95^{x}
Lean to fat ratio [fat area / muscle area]	0.49^{c}	0.75^{b}	1.36^{a}	0.85	0.89
Lean meat content [%]	53.4a^{a}	42.2^{b}	33.3^{c}	44.5	43.4

^{a,b,c} LSQM with different letters within a row differ significantly between the genotypes for $p < 0.05$ (Tukey-Kramer-Test)

^{x,y} LSQM with different letters within a row differ significantly between the roughage sources for $p < 0.05$ (Tukey-Kramer-Test)

[1] Hy = modern Hybrid, PiSa = Piétrain*Saddleback, Sa = Saddleback

[2] gcs = grass-clover silage

Table 5
Amount of selected cuts of the cold carcass half by genotype and roughage source of heavy pigs (LSQM)

	Genotype[1]			Roughage	
	Hy	PiSa	Sa	gcs[2]	straw
Neck [%]	9.80[b]	10.04[b]	10.45[a]	10.09	10.11
Belly [%]	17.32[b]	17.30[b]	18.03[a]	17.52	17.58
Cutlet loin with tenderloin and back fat [%]	18.06[b]	18.18[b]	19.30[a]	18.55	18.48
Shoulder [%]	17.19[a]	16.88[ab]	16.50[b]	16.97	16.74
Leg without foot [%]	28.14[a]	27.57[b]	26.33[c]	27.37	27.32
Head with cheek [%]	8.16[b]	8.38[b]	9.06[a]	8.43	8.63
Feet [%]	2.48[a]	2.27[b]	2.43[a]	2.39	2.39

[a, b, c] LSQM with different letters within a row differ significantly between the genotypes for $p < 0.05$ (Tukey-Kramer-Test)

[1] Hy = modern Hybrid, PiSa = Piétrain*Saddleback, Sa = Saddleback

[2] gcs = grass-clover silage

Table 6
Economic performance (without value added taxes)

	Hy[1]	PiSa[1]	Sa[1]
Final live weight [kg/animal]	165.0	165.0	165.0
Dressing percentage [%]	78.5	78.5	77.8
Carcass weight [kg/animal]	129.5	129.5	128.4
Payout price[2] [€/kg carcass weight]	3.27	3.27	3.27
Revenues [€/animal]	**423.47**	**423.47**	**419.87**
Piglet costs[2] (organic) [€/animal]	**110.00**	**110.00**	**110.00**
Live weight gain, standardised [kg/animal]	140	140	140
Feed-conversion-ratio, 1:	3.6	4.0	4.4
Amount of concentrates [kg/animal]	504	560	616
Concentrate price[2] (100% organic origin) [€/100kg]	39.00	39.00	39.00
Feed costs I (concentrates) [€/animal]	**196.56**	**218.40**	**240.24**
Surplus I [€/animal]	**116.91**	**95.07**	**69.63**
Grass-clover silage, fresh (31.7% dry matter) [kg/animal]	156	180	199
Grass-clover silage price[2] (30% dry matter, 100% organic origin) [€/100kg]	3.15	3.15	3.15
Feed costs II (grass-clover silage) [€/animal]	**4.91**	**5.67**	**6.27**
Surplus II [€/animal]	**112.00**	**89.40**	**63.36**

[1] Hy = modern Hybrid, PiSa = Piétrain*Saddleback, Sa = Saddleback

[2] Real prices during the trial period

Economic performance is shown in Table 6 as surplus of the revenues over the feed and piglet costs of the three genotypes. It is calculated for a standardised animal with a live weight of 165 kg using the trial data and the mean values of the respective prices during the trial period. It can be seen that Saddlebacks will generate surpluses of only about 60 % of the Hybrids. Again, PiSa crossbreeds have an intermediate position. The costs of an additional feeding of grass-clover silage were minimal. The amount of silage was 0.9 kg per day and animal. Due to the longest fattening period (Table 3), the Saddlebacks had the highest silage costs.

4 Discussion

There were no differences in performance and carcass quality parameters between pigs offered concentrate and straw or concentrate and additional grass-clover silage, except for the fat area (Table 2). This is in agreement with many studies which found that the intake of grass/clover silage (i) was very low and (ii) contributed to the energy supply of the pigs only to a small degree (Bellof et al., 1998; Kelly et al., 2007; Hagmüller et al., 2008). Especially, when cereal-based concentrates were available *ad libitum*, the voluntary intake of grass-glover silage was minimal (Bellof et al., 1998; Kelly et al., 2007). If concentrates are restricted, higher intakes of silage can be reached (Bellof et al., 1998). In our study, the amount of grass-clover silage given was recorded per pen, but the intake of the silage was not evaluated. But despite a restrictive offer, it was obvious that the consumption was low due to significant waste of grass-clover silage in the pen (results not presented). It is likely that the low intake was due to the nearly *ad libitum* concentrate offer during the trial. Therefore, the performance and carcass quality parameters were not noteworthy influenced by the roughage source. According to Kelly et al. (2007), there was no evidence of greater intake or utilisation of forages by the traditional breeds in our study.

The daily weight gain of the used breeds was fairly high (Table 3). In particular, the Hybrids showed very high daily weight gains and an improved feed conversion ratio with a narrow lean to fat ratio. This confirms the high body protein synthesis capacity in live weights above 120 kg, especially for the modern hybrid line. This is in accordance with Fischer et al. (2006). In their study, daily weight gains of heavy pigs were only 30 g lower compared to pigs slaughtered at 110 kg. Bellof and Burgstaller (1992) could even observe a further increase of the daily weight gains above 100 kg live weight for some crossbreeds (Du*DL, Pi*(Du*DL)).

In this trial under organic farming conditions, the daily weight gains were slightly below the daily weight gains of heavy pigs in conventional farming systems (729 to 894 g), reported in literature (Kuhn et al., 1994; Burgstaller and Jatsch, 1994; Fischer et al., 2006). But the performance traits must be seen in the context of the used breeds or crossbreeds (Bellof, Burgstaller, 1992; Fortina et al., 2005; Franci et al., 2003). Thus, the comparison of the exact values is difficult. Löser (2006) considers a daily weight gain of 650 g achievable for the production of heavy pigs under organic management conditions.

Due to the higher fat synthesis in heavy pigs, the feed conversion ratio gets worse, so that barrows need 3.1 kg feed per kg live weight gain (Fischer et al., 2006). According to Burgstaller et al. (1992), an *ad libitum* concentrate feeding leads to a feed conversion index of 3.65. This is in accordance with Kuhn et al. (1994). The authors could show that 1 kg body weight gain was reached by 3.35 to 3.99 kg feed, depending on the feeding regime. This shows that the feed conversion ratio of the Hybrids and PiSa crossbreeds was within the range reported in literature (Table 3).

In the fattening for conventional slaughter weights, German or Angeln Saddleback pigs have a worse feed conversion ratio (3.8) compared to improved breeds such as Piétrain (2.7) (Steinberg et al.,1998). This is also obvious in heavy pig production with a body weight of 160 kg. As expected, the daily weight gain of Saddlebacks was lower compared to Hybrids and PiSa crossbreeds, and the feed conversion ratio was worse (Table 3). The lower growth rate of unimproved breeds confirms the results found in other European pig breeds used for heavy pig production (Franci et al., 2003; Serra et al., 1998; Legault et al., 1996).

The conversion of feed into lean tissue growth is markedly more efficient than into adipose tissue. As a consequence, the fatter animals of unimproved breeds such as Saddlebacks result in a worse feed conversion ratio. But both parameters for Saddlebacks were within the range or even better when compared to other extensive breeds used for heavy pig production; for example Limousin pigs and Gascon in France (Legault et al., 1996) or Casertana and Mora Romagnola in Italy (Fortina et al., 2005). The feed conversion indexes for the two Italian breeds fed with a commercial concentrate diet (ca. 50 to 160 kg live weight) were 4.2 and 4.3 and the daily weight gains (up to a live weight of 160 kg) were 524 g and 451 g, respectively (Fortina et al., 2005).

The crossbreed between Piétrain and Saddleback (PiSa) showed significantly improved performance traits compared to the purebred Saddlebacks (Table 3). This confirms the results of Legault et al. (1996) that crossbreeding unimproved breeds with Duroc or Piétrain results in a significant improvement of average daily weight gain and of feed conversion ratio.

In face of the high slaughter weight, the modern hybrid line showed only a moderate fat synthesis. Mean fat size B (thinnest location 13th rib) was only 1.9 cm (Table 4). This is in accordance with Fischer et al. (2006). In this study, Pi*DL crossbreeds with a final live weight of 160 kg only reached a fat size B of about 2 cm. The authors assumed that such fat sizes indicate fat quantities which are not sufficient for the production of dry fermented sausages. In our study, the PiSa crossbreeds and Saddlebacks reached considerable higher fat sizes in all measured points, indicating higher fat yields (Table 4). This leads to the conclusion that these breeds are more suitable for the production of dry fermented sausages with respect to the quantity of fat. The higher fatness of Saddleback pigs confirms again the strong adipogenetic ability of the unimproved breeds (Labroue et al., 2000; Franci et al., 2003). Crossbreeds between improved and unimproved breeds show intermediate values concerning the back fat with respect to parental breeds (Franci et al., 2003). This becomes evident in the fat sizes of our PiSa crossbreeds which always ranked in the middle between Saddlebacks and Hybrids (Table 4).

The important impact of the genotype is confirmed by Bellof and Burgstaller (1992). The authors observed lean to fat ratios between 1 : 0.48 and 1 : 0.63 in heavy barrows (160 kg live weight) of a large variety of genotypes. This is in accordance with Fischer et al. (2006) and with the modern hybrid line in the present paper. In our trial – as expected, the Saddlebacks had excessive higher lean to fat ratios due to the high body fat synthesis of this unimproved breed. PiSa ranked between Saddlebacks and Hybrids (Table 4). This confirms the results of Legault et al. (1996) that crossbreeding unimproved breeds with Duroc or Piétrain results in a significant improvement of lean meat content.

A number of studies have found little effect of slaughter weight on primal cut distribution (Cisneros et al., 1996; Martin et al., 1980; Fischer et al., 2006). When data are expressed as a percentage of side weight, loin and belly increase while shoulder and ham decrease with increasing slaughter weight, but only within small ranges (Martin et al., 1980). Fischer et al. (2006) could not observe serious changes in cut proportions when live weight at slaughter was increased up to 160 kg, except for the back fat. But the authors emphasized that this result has been only proven for the used breed (Pi*German Landrace).

The comparison of the exact values of the cuts (Table 5) with data of literature is difficult due to the different cut procedures used. But the high fat synthesis of the Saddlebacks is also obvious in the cut weights expressed as percent of the carcass half. In the Saddlebacks, the fatty joints such as neck, belly and head with cheek had a higher impact on the carcass half weight compared to the Hybrids.

The amount of cuts significantly differed between the breeds, but the absolute differences are relatively small (Table 5). There was no opportunity to dissect the cuts into fat and lean tissue. Hence, only the gross weight was evaluated. But it can be assumed that the Saddlebacks have a higher fat content in the cuts compared to PiSa crossbreeds and Hybrids.

For the production of traditional regional pork specialties like dry fermented sausages (e.g. Ahle Wurscht®), the whole carcass (exclusive tenderloin) of heavy pigs is used (Haase, 2013). The back fat and the fat of the shoulder are preferred for the production of dried products because these fatty parts have the best characteristics for processing (Euen, 2013). Especially the amount and the quality of the back fat are essential for the production. In modern hybrid lines, the back fat is often not sufficient in quantity and quality (Fischer et al., 2006; Euen, 2013). It can be assumed that the use of Saddlebacks or of crossbreds with Pi for heavy pig production could lead to a sufficient quantity of fat needed for traditional dry products.

The surplus of the revenues over the feed and piglet costs is used to characterize economic performance (Table 6). It is a simple but meaningful figure because more than 90 % of the allocable variable costs in pig fattening are due to feed and piglet costs (Rasmussen, 2004). In the present study, the remaining variable costs (e.g. veterinarian, electricity …) can be considered as equal between the treatments and therefore as negligible. The prices used for calculation necessarily have snapshot character. But the difference between the treatments is of interest but not the absolute level.

The poor ranking of the Saddlebacks is mainly (i) due to impaired feed conversion (Table 3) with higher feed consumption (Table 6) and (ii) due to lower dressing rate with lower carcass weight (Table 4). A further aggravating fact is the longer fattening period of the Saddlebacks, resulting in fewer fattening runs per year and reducing the benefit per fattening place. Roughage costs per animal are minimal (Table 6). In Germany, straw is little accepted as roughage source. The feeding of grass-clover silage had no benefits concerning performance and carcass quality traits in heavy pig production under nearly *ad libitum* concentrate feeding but increased production costs (Table 6). If concentrates are more restricted, than the use of grass-clover silage might have a higher potential (Bellof et al., 1998).

The calculation of Löser (2006) uses key data of the branch evaluation of 2003/2004 for the fattening of heavy pigs in organic farming. In this study, only a payout price of 2.50 Euro/kg carcass weight was reached but with lower feed and piglet costs as compared to 2013. In our study, the revenues minus feed and piglet costs were 69.63 to 116.97 Euro (Table 6) according to the breeds used. This is considerably lower compared to Löser (2006) with 161.00 Euro. This is mainly due to the clearly lower costs for concentrates (22 Euro/100 kg). As a conclusion, the piglet and feed costs are essential for the economic performance also in the production of heavy pigs. This is already proven for the usual organic pork market with final live weights of about 115 to 120 kg (Wucherpfennig, 2010). In heavy pig production today, the payout price is not influenced by fat quantity and quality or other carcass quality criteria which guarantee the suitability for the respective pork products. Hence, the worse feed conversion ratio of the Saddlebacks could not be compensated and the economic benefit is lower compared to PiSa crossbreeds and Hybrids.

The economic benefit of endangered pig breeds may be considerably improved if crossbreeding schemes are used (Chainetr et al., 2002; Legault et al., 1996; Franci et al., 2003). Crossbreeding of the German or Angeln Saddlebacks is suggested for special marketing programs. This is due to the expected improvement of performance and carcass traits and the corresponding economic benefit (Golze et al., 2013; Pfeiffer 2002; Leenhouwer and Merks, 2013; Weißmann, 2013). These crossbreeding schemes could be adapted to ecological production niches or designed for specific quality products (Chainetr et al., 2002). In our study, the higher economic benefit of the crossbreed PiSa confirms these proposals due to the lower feeding costs (Table 6). An alternative would be that the payout price for the Saddleback and its crossbreeds is adapted to honour the higher quantity of fat, the possibly better meat and fat quality and the possibly better suitability for processing concerning the production of traditional pork specialities. But so far this approach seems to be unrealistic.

5 Conclusions

Under organic farming conditions, Saddlebacks and PiSa crossbreeds seem to be suitable for heavy pig production to produce premium segment pork specialities in the form of dry fermented sausages concerning performance and carcass quality. The low protein level coupled with a high *de-novo* fat synthesis can provide sufficient fat quantities at a final live weight of about 160 kg.

But as long as the payout price is not adapted to carcass quality or the suitability for processing, the fattening of Saddlebacks is not interesting from an economic point of view. Against the background of a sufficient fat quantity when exceeding 2 cm of fat measurement B, Saddlebacks would be more economically competitive if they are slaughtered significantly below 160 kg live weight. But for this strategy more information concerning fatty tissue development is needed to identify the optimal final live weight.

The crossbreeding of Saddlebacks with Piétrain results in improved performance, carcass quality, and economics. This might be a practicable way for the surviving of old, endangered breeds.

Even though the market of heavy pig production is a niche market, under the condition that the animals are used economically, a valuable contribution to the maintenance of old threatened pig breeds could be achieved under the motto "Protect them by eating them".

6 Acknowledgement

The authors gratefully acknowledge funding from the European Community financial participation under the Seventh Framework Programme for Research, Technological Development and Demonstration Activities, for the Integrated Project LOWINPUTBREEDS FP7-CP-IP 222623.

The authors would like to thank Horst Brandt, Institute of Animal Breeding and Genetics, University of Giessen, Germany, for statistical advice.

7 Disclaimer

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