RESEARCH ARTICLE

Performance of organic entire male pigs from two sire lines under two feeding strategies Part 1: Growth performance, carcass quality, and injury prevalence

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HIGHLIGHTS

- **Fattening of entire male pigs from Duroc and Piétrain sire lines under organic conditions led to satisfactory performance and carcass characteristics.**
- **Feeding potato starch resulted in slightly lower meat yield compared to the control feed.**
- **Aggressive behaviour was low under the studied management strategies.**

KEYWORDS **Duroc, Piétrain, raw potato starch, growth performance, carcass quality**

Abstract

Castration of young male pigs in organic husbandry systems without anaesthesia contradicts animal welfare principles and consumers' perception of organic animal husbandry practices. On the other hand, fattening of boars can result in undesirable performance, meat and carcass qualities, and aggressive behaviour resulting in injuries.

The objective of the present study in organic boar fattening was to test the effect of two terminal sire lines (Duroc vs Piétrain) and two feeding strategies (without vs with 10 % raw potato starch starting from the live weight of 95 kg prior to slaughter) on performance and carcass quality parameters as well as animal welfare.

Daily weight gain, feed conversion, dressing rate, carcass lean, and injury prevalence were measured in a total of 280 boars (65 Duroc Control, 73 Duroc Potato starch, 68 Piétrain Control, 74 Piétrain Potato starch). Testing was performed under organic housing and feeding conditions using German Landrace x German Large White sows which were artificially inseminated using Duroc or Pietrain sires, respectively. Statistics are based on ANOVA (proc glm) by SAS 9.4.

Concerning performance and carcass quality, the results confirmed the known differences between the terminal sire lines also in organic entire male pigs; Duroc was superior in daily weight gain, while Piétrain was superior in dressing percentage and lean meat content. Feed conversion ratio did not differ between sire lines and the offer of raw potato starch prior to slaughter remained without noteworthy effect on daily feed intake, feed conversion ratio, and carcass quality. Injury prevalence was generally low, thus indicating no concerns of animal welfare when fattening entire male pigs under organic conditions.

1 Introduction

Castration of male piglets is a standard practice in central European pork production to avoid the occurrence of boar taint in meat, which is an off-odour that can decrease consumer liking (Bonneau et al., 1992). Since animal integrity is an important factor in organic husbandry, the practice of castration conflicts the organic farming principles. The castration of young male pigs without anaesthesia contradicts consumer expectations of organic husbandry practices, which is that they are animal-friendly and as little pain as

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possible is involved in pig farming. According to EU regulations on organic pig husbandry, the use of analgesia and/or anaesthesia during castration is mandatory (EU 2018).

In Germany, the termination of pig castration without anaesthesia was planned by 2018 but was postponed until 2021 because the existing alternatives were deemed as non-applicable to the common practices in pork production. Fattening of entire male pigs could be one way to achieve animal integrity and meet the consumer expectations of organic animal husbandry systems. However, fattening of boars entails economic and animal welfare challenges. Regardless of the better feed conversion ratio of boars, classification and billing systems of slaughter companies sometimes discriminate boar carcasses. Furthermore, an increase in injuries might occur due to sexual and/or aggressive behaviour of boars (Rydhmer et al., 2006). Nevertheless, the occurrence of boar taint is the main problem in marketing the meat of entire male pigs. Boar taint, which is described as a sweaty, musky, faecal, or urine-like odour by consumers sensitive to the compound, is caused by the accumulation of skatole, androstenone, and, to a lesser extent, indole in the fat of entire male pigs. It has been shown that skatole and indole formation and accumulation in pigs can be reduced by feeding strategies that influence the amount of energy and tryptophan available to the gastrointestinal bacteria (Wesoly and Weiler, 2012). Amongst others, the inclusion of potato starch in the diet has such an effect (Chen et al., 2007; Øverland et al., 2011; Pauly et al., 2008; Zamaratskaia et al., 2005). Androstenone is a pheromone and can accumulate in the fat of pigs. Androstenone levels are mainly determined by genetic factors and age at puberty and differ between genotypes (Zamaratskaia and Squires, 2009). For instance, Duroc genotypes are associated with higher androstenone concentrations in fat than other genotypes. Both factors can be taken into account by different management choices that are made in conventional and organic pig fattening systems. Therefore, the aim of this study was to compare the effect of two terminal sire lines Duroc and Piétrain and the use of raw potato starch on growth performance, carcass quality and the occurrance of injuries while rearing of entire male pigs under organic conditions.

2 Materials and methods

2.1 Trial design and animals

The trial was performed at the eco-certified research farm of the Thünen Institute of Organic Farming (Trenthorst, Germany) from September 2012 until October 2015. Eight trial runs were conducted during this period. The 280 male growing-finishing pigs originated from the institute's sow herd consisting of 50 German Large White x German Landrace crossbred sows. For artificial insemination (AI), Duroc (Du) and Piétrain (Pi) boars were used. All pigs were marked with ear tags. At the beginning of the fattening phase, entire male pigs were randomly split into four treatment groups representing the combination of two different feeding strategies (use (+) vs non-use (-) of raw potato starch during late fattening) and two different terminal sire lines (Du vs Pi). The following allocation was obtained: Du+ (Du experimental group, 73 entire males), Du- (Du control group, 65 entire males), Pi+ (Pi experimental group, 74 entire males), and Pi- (Pi control group, 68 entire males). Due to the limited availability of organic potato starch and imbalances in the gender-distribution of some litters leading to a shortage of male progeny, the distribution of trial groups during the trial runs was uneven. *Table 1* shows the distribution of trial groups during the trial. The intended fattening period ranged from 27 kg to 115 kg bodyweight.

TABLE 1
Distribution of trial groups during the trial runs

Trial run	Du +	Du -	Pi +	Pi -	Total
1		18		20	38
2			30		30
3	30		9		39
4				39	39
5			27		27
6		36			36
7	34	2			36
8	9	9	8	9	35
Total	**73**	**65**	**74**	**68**	**280**

Du: Duroc; Pi: Piétrain; +: with potato starch; -: without potato starch

Across the four treatments (Du+, Du-, Pi+, Pi-), the trial started with a total average of 29.3 kg bodyweight (SD: 7.6 kg), the finishing period started with a total average of 56.5 kg bodyweight (SD: 8.4 kg), and the trial ended with a total average of 115.7 kg bodyweight (SD: 6.1 kg). Potato starch offer for the experimental groups (Du+, Pi+) started with a total average of 91.4 kg bodyweight (SD: 10.5 kg) and lasted for 27.9 days (SD: 10.8 d) until the end of the fattening period.

2.2 Housing, feeding, and slaughtering

The suckling period was divided into two parts: individual housing per sow and litter, which lasted 14 days, and group suckling with stable groups of 3 to 5 sows and their progeny for a period of 35 days. During the following rearing period animals were not regrouped. The experimental fattening unit comprised four pens for a maximum of ten animals per pen. Each pen consisted of an indoor area with 1.5 m^2 $animal^{-1}$ and an adjacent outdoor run with 1.1 m^2 $animal^{-1}$. Both compartments had a solid concrete floor with straw as litter material. Manure was removed twice a week with a subsequent straw replacement. In almost all cases, the indoor area was kept clean. Animal to feeding place ratio was 1:1 with a feeding trough on the left and the right indoor partition, each for five growing-finishing pigs. A watering place and a roughage rack were located on the longitudinal side of the outdoor run of each pen.

The feeding regime consisted of pelleted diets of 100 % organic origin with maximum use of farm-grown feed ingredients (cereals, grain legumes). With respect to the two fattening phases, diet types were a grower diet with

81 % farm-grown ingredients, a control finisher diet without raw potato starch with 91 % farm-grown ingredients, and an experimental finisher diet containing 10 % of raw potato starch kg^{-1} feed in proportional exchange to the amounts of cereals and grain legumes of the control finisher diet. This led to a 2.6 % lower content of protein in the experimental diet, while energy content did not differ between diets.

The diets were optimised for metabolic energy (MJ ME) and the content of the first limiting amino acid lysine according to the recommendations for grower-finisher pigs reared under organic conditions of Zollitsch et al. (2002). The concentrate was offered twice daily according to a feeding curve based on live weight. Feed was offered semi ad libitum from 25 to 30 kg to 50 kg and restricted from 50 to 115 kg live weight resulting in a daily amount of 1.4 to 2.2 kg animal^{-1} and 2.4 to 2.9 kg animal^{-1}, respectively. As the offering of roughage is mandatory in organic pig feeding, all animals received grass-clover silage throughout the whole fattening period with a daily amount of 1 kg fresh matter animal^{-1}. Composition and analysed values of the trial diets are shown in *Table 2*.

All pigs received the same grower and control finisher diet until the first pig of the experimental group reached 95 kg body weight. The pigs were marked individually when they reached > 113 kg body weight, and only those pigs were slaughtered the next day. Animals were separated pen-wise and transported at 5:40 am to the nearby (13 km) small family abattoir, where they were unloaded pen-wise and immediately slaughtered by the use of the electrical stunning method.

TABLE 2
Composition and analysed contents of the experimental diets and grass-clover silage

Composition (%)	Grower		Standard finisher				Experimental finisher		Grass-clover silage	
Trial run	*1–7*	*8*	*1*	*2 + 3*	*4–7*	*8*	*2, 3, 5, 7*	*8*	*1–8*	*(1 kg day^{-1})*
Live weight range	*25–50 kg*		*51–115 kg*				*95–115 kg*		*25–115 kg*	
Wheat	0.0	27.0	0.0	0.0	0.0	26.0	0.0	23.0		
Barley	27.0	24.0	32.0	19.0	18.0	32.0	25.0	29.0		
Triticale	24.0	0.0	22.0	22.0	22.0	0.0	23.0	0.0		
Beans	15.0	15.0	13.0	26.0	26.0	18.0	17.0	16.0		
Peas	15.0	15.0	25.0	25.0	25.0	18.0	17.0	16.0		
Soycake	14.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0		
Rapeseed cake	0.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0		
Sunflower seed cake	2.0	0.0	3.0	3.0	3.0	0.0	3.0	0.0		
Citric acid	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0		
Mineral	2.5	2.5	2.0	2.0	3.0	3.0	2.0	3.0		
Potato starch	0.0	0.0	0.0	0.0	0.0	0.0	10.0	10.0		
Analysed contents (%)	$\bar{x}$	SD		$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD
Number of analyses	*9*		*10*				*9*		*5*	
Dry matter	91.2	0.63		91.4	0.53		90.7	0.66	26.3	6.58
Crude ash	5.8	0.30		5.3	0.38		5.0	0.57	10.8	0.57
Crude protein	18.9	1.07		17.7	1.33		15.1	0.46	17.9	1.88
Lysine	10.6	0.59		10.2	1.14		8.3	0.39	-	-
Methionine	2.5	0.21		2.0	0.13		1.9	0.08	-	-
Cysteine	3.2	0.28		2.8	0.14		2.5	0.12	-	-
Threonine	6.8	0.65		6.2	0.53		5.2	0.19	-	-
Tryptophan	1.9	0.15		1.6	0.10		1.4	0.04	-	-
Crude fat	2.4	0.85		2.0	0.51		1.7	0.53	2.6	0.69
Crude fibre	6.2	0.78		6.7	0.74		6.0	0.50	26.2	2.83
Sugar	3.9	1.04		3.7	0.26		3.0	0.40	-	-
Starch (OM)	42.9	1.47		45.8	1.47		50.0	0.82	-	-
Starch breakdown (OM)	17.0	3.57		15.0	2.14		17.2	2.62	-	-
Calculated energy content* (MJ ME/kg^{-1})	12.9	0.35		12.8	0.31		12.8	0.17	-	-

$\bar{x}$: mean; SD: standard deviation; OM: original matter; MJ ME: metabolisable energy in mega joule; *metabolisable energy calculated according to Society for Nutritional Physiology (GfE, 2008)

2.3 Data collection

Feed samples were obtained every second week and combined into a mixed sample within diet type and production cycle, and analysed for its composition. Grass-clover silage composition was based on five samples (see *Table 2*). Feed and grass clover samples were analysed in the laboratory of the Thünen Institute of Organic Farming. Starch content and starch breakdown as indicators for the digestibility of the starch were analysed in a commercial laboratory. Performance and carcass quality data collection followed the federal standard of German pig testing stations (ZDS 2007). Bodyweight was individually measured every Monday with an electronic animal scale throughout the whole fattening period to calculate individual daily weight gain. Feed conversion ratio (only concentrate) was calculated for the growing, finishing, and total fattening phases as a group average according to the documented feed consumption per group (accumulated daily quantity of concentrate offered without weighing the feed refusals in relation to the weight gain per group). Dressing percentage was calculated from warm carcass weight and final body weight. Lean meat content was estimated 45 min p.m. using FOM pistol (Fat-O-Meat'er® S89k) between the second and third last rib of the left carcass half. The day after slaughter, the left half of the carcass was used to record carcass quality and meat quality traits. Electrical conductivity was measured between the 13th/14th rib using Matthäus® LF-star pistol. Minolta® CR-300 was used to record meat lightness (L*) of Musculus longissimus thoracis et lumborum (LTL) of the 13th rib. Muscle (MA) and fat area (FA) of the 13th rib were measured by distance standardised photography and subsequent digital planimetry (Matthäus® SCAN-STAR K).

To determine the consequences of fattening entire male pigs on animal welfare, the carcasses of all pigs were evaluated after scalding for scratches or injuries as signs of aggressive behaviour. An employee of the research station evaluated both sides of carcasses following the protocol of Ekesbo (1984). The evaluation was done for the whole body within a range of 0 (no scratches/injuries), 1 (slight scratches/injuries), and 2 (severe scratches/injuries).

2.4 Statistical analysis

Normal distribution of data residuals was confirmed graphically and statistically with the Shapiro-Wilk test. Data analysis was carried out using SAS 9.4 (Proc GLM) considering genotype, feeding, and genotype*feeding interaction as fixed effects, which always remained in the model. The included covariates were body weight at the trial start, weight at the start of the finishing phase, and weight at the beginning of potato starch feeding for the corresponding fattening performance phases. Slaughter weight was included as a covariate for the measurements of carcass and meat quality. These tested covariates remained in the model if significant. For the pairwise comparison of LSQ-means, the Tukey-Kramer test (significance level $p < 0.05$) was used.

The prevalence of injuries as described by the integument scoring was analysed using Fisher's exact test. Scores of 1 and 2 were combined due to their low frequency. Genotype and feeding regime were used as independent variables, while scoring value was the dependent variable (significance level $p < 0.05$).

3 Results and discussion

Table 3 shows the LSQ means for growth performance and carcass quality in relation to genotype and feeding regime.

The daily weight gain of Du sired pigs significantly exceeded the performance of Pi sired pigs. Feeding potato starch reduced the daily gain of Du pigs, while Pi pigs achieved higher daily gains. As Du pigs genetically have higher growth potential, they might be more sensitive to reduced nutrient density than Pi pigs (Edwards et al., 2006; Morales et al., 2013). Pauly et al. (2008) found no differences in daily gain of Swiss Large White entire male pigs when feeding 30 % potato starch seven days prior to slaughter under Swiss environment- and welfare-friendly conditions. In our study, the potato starch period prior to slaughter lasted 28 days on average, which might explain the differences in daily gain due to the longer exposition to feed reduced in nutrient density.

Feed conversion did not differ significantly between terminal sire lines or feeding strategies over all fattening periods, except for the first finishing period, which might be ascribed to a drop in the daily gain during one of the trial runs. The feed conversion ratio was in accordance with Grela et al. (2013), which was 3.16 kg feed kg^{-1} gain for organically fed pigs; this illustrates the inferior feed conversion ratio of organically fed pigs to conventionally fed pigs which was found to be between 2.38 and 2.69 kg feed kg^{-1} gain in the studies of Otten et al. (2013) and Pauly et al. (2008). Direct comparison of feed conversion ratio with other studies has to take into account that feed intake in this study was semi ad libitum, not measured individually, and feed residues were not weighed back. In general, the growth performance of the entire male pigs used in this study was at a satisfactory level for organically kept and fed pigs.

Dressing rate of Pi sire lines was 2.2 % higher than in Du sire lines, while Pi origins significantly exceed Du origins in lean meat content by about 1.2 %. Pi pigs are commonly known to have higher muscularity and lean meat percentages; however, the achieved dressing percentages (77 to 78 %) are low compared to conventionally kept Pi sire line pigs (e.g. 83 % , Gispert et al., 2007). The low overall dressing rates could be due to the mandatory use of roughage in organic pig feeding. Roughage increases the weight of the gastrointestinal tract and reduces the calculated dressing rate (Holinger et al., 2018). In this trial, the pigs received an average of 1 kg grass-clover silage per animal day^{-1}. The use of raw potato starch resulted in a significant reduction of dressing rate by 1.1 % points, while lean meat percentage did not differ between feeding strategies. The effect of feeding raw potato starch on pig intestines has been described by Fang et al. (2014) and Nofrarías et al. (2007), who found that the long-term intake of raw potato starch increased the weight of the large intestines and resulted in positive changes in the colonic microbiome. Genotype influenced the meat

TABLE 3
Effect of sire line (Duroc, Du vs Piétrain, Pi) and feeding strategy (with (+) vs without (-) raw potato starch on growth performance and carcass quality of entire male growing-finishing pigs (LSQ means and significance levels)

										P-Values		
	Du	Pi	+	-	Du +	Du -	Pi +	Pi -	SEM	Sire line	Feeding	Sire line x Feeding
Growth performance *(n animals)*	*138*	*142*	*147*	*133*	*73*	*65*	*74*	*68*				
Daily weight gain [g]												
Total trial period	**883**	**805**	**832**	**856**	**852**^{b}	**914**^{a}	**812**^{c}	**798**^{c}	7.4–11.2	**<0.001**	**0.026**	**<0.001**
Potato starch finishing	**958**	**854**	**886**	**926**	**904**^{b}	**1013**^{a}	**868**^{bc}	**840**^{c}	11.7–18.1	**<0.001**	**0.021**	**<0.001**
First finishing period	**936**	**856**	**894**	**897**	**905**^{b}	**967**^{a}	**884**^{b}	**827**^{c}	10.7–16.3	**<0.001**	0.851	**<0.001**
Early fattening period	**784**	**722**	765	742	774	794	709	735	9.3–14.0	**<0.001**	0.085	0.832
(n pens)	*15*	*15*	*16*	*14*	*8*	*7*	*8*	*7*				
Daily feed intake [kg feed]												
Total trial period	2.36	2.32	**2.29**	**2.38**	2.32	2.39	2.26	2.37	0.02–0.03	0.254	**0.006**	0.629
Potato starch period	**2.81**	**2.70**	2.77	2.74	2.85	2.78	2.69	2.71	0.03–0.04	**0.006**	0.511	0.301
First finishing period	**2.54**	**2.42**	2.42	2.54	2.51	2.57	2.33	2.50	0.04–0.05	**0.041**	0.051	0.318
Early fattening	1.78	1.74	1.70	1.81	1.74	1.82	1.67	1.80	0.04–0.07	0.535	0.119	0.660
(n pens)	*15*	*15*	*16*	*14*	*8*	*7*	*8*	*7*				
Feed conversion ratio [kg feed^{-1} kg weight gain]												
Total trial period	3.09	3.11	3.01	3.19	3.05	3.13	3.00	3.25	0.07–0.10	0.868	0.072	0.325
Potato starch period	4.27	4.14	4.21	4.20	4.43	4.11	3.99	4.30	0.17–0.28	0.602	0.984	0.239
First finishing period	2.77	2.82	2.72	2.87	**2.84**^{b}	**2.69**^{b}	**2.60**^{b}	**3.04**^{a}	0.06–0.09	0.552	0.105	**0.002**
Early fattening	**2.24**	**2.45**	2.33	2.36	2.23	2.24	2.43	2.48	0.06–0.10	**0.034**	0.762	0.864
Carcass quality *(n animals)*	138	142	147	133	73	65	74	68				
Dressing rate [%]	**75.5**	**77.7**	**76.1**	**77.2**	75.2	76.1	77.0	78.3	0.14–0.21	**<0.001**	**<0.001**	0.261
Lean meat content [%]	**54.2**	**55.4**	54.8	54.8	54.2	54.2	55.3	55.4	0.22–0.35	**0.006**	0.875	0.841
Meat area, LTL [cm^{2}]	**40.5**	**42.2**	**41.0**	**41.8**	40.1	40.9	41.8	42.6	0.27–0.44	**<0.001**	**0.047**	0.989
Fat area, LTL [cm^{2}]	13.6	13.1	13.5	13.2	13.9	13.3	13.0	13.1	0.21–0.35	0.094	0.507	0.264

Du: Duroc; Pi: Piétrain; +: with potato starch; -: without potato starch; LTL: Musculus longissimus thoracis et lumborum
Significant differences within sire line or feeding ($p < 0.05$ Tukey-Kramer test), different indices (a,b,c,d) within row indicate significant differences between sire line x feeding groups

area of the LTL in Pi origins, yielding larger meat areas of the LTL. Pi sired pigs are known to have high protein accretion rates (Gispert et al., 2007), which they seem to achieve under organic conditions as well. The meat area of the LTL of the trial group pigs was lower by 1.8 % compared to the control group pigs. The reducing effect of the potato starch diet on the meat area of the LTL in this trial cannot be ascribed to the potato starch itself but could be a result of the different protein content and lysine/energy ratio, which were lower during the potato starch feeding period. Reduced loin meat areas when feeding diets were lower in protein or lysine/energy ratios also have been described by Castell et al. (1994), Kerr et al. (2003) and Zhang et al. (2008).

The prevalence of scratches as a sign of aggressive behaviour was low in general and was significantly ($p < 0.01$) higher for Pi pigs (*Figure 1*). Although intact male pigs tend to show more aggressive behaviour, Rydhmer et al. (2006), Vanheukelom et al. (2012), and Holinger et al. (2015) found only small differences in injuries between females, castrates, and entire male pigs. In the current study there was no effect of feeding potato starch on the prevalence of scratches. This low prevalence of injuries in this study might be due to avoiding the regrouping of the animals throughout the complete fattening phase as well as the group suckling of piglets, during which the animals are already acquainted with each other. Furthermore, enriched housing conditions (as

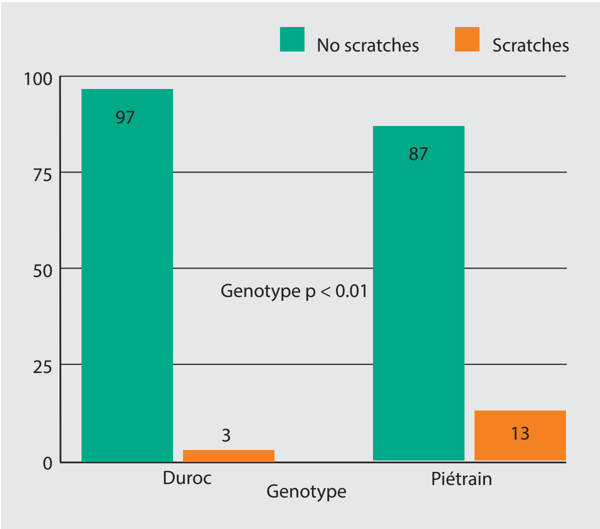

FIGURE 1
Prevalence of scratches (%) in relation to genotype

they are likely to be found in organic pig keeping) are known to reduce the occurrence of injuries and/or aggressive behaviour in pigs (Lindgren et al., 2014; Prunier et al., 2013; Scott et al., 2006).

4 Conclusion

Fattening of entire male pigs under organic conditions led to satisfactory performance and carcass qualities. The results of performance and carcass quality revealed differences between Duroc and Piétrain sire lined pigs. Apart from slightly lower dressing percentage, feeding raw potato starch during the end of the fattening phase had no noteworthy effect on performance and carcass characteristics. Concerning the influence of sire line and raw potato starch on boar taint, we refer to the companion paper "Organic fattening of entire male pigs from two sire lines under two feeding strategies Part 2: Meat quality and boar taint" (Werner et al., 2020).

The low prevalence of injuries found in this study indicates that fattening of boars under certain management strategies (stability of animal groups since the rearing phase, space and occupational material, feeding of roughage) is possible without negative influences on animal health and welfare.

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