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An Exemplary View on the Influence of Genotype and Feeding on Growth Performance, Carcass Quality, and Meat Quality in Organic Pig Fattening

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Abstract

In organic pig fattening the choice of a suitable genotype and an adequate diet depends on the marketing goal and influences product quality (carcass and meat quality) and the economic success of the farmer. Carcass quality-dominated, respectively meat quantity-oriented, organic marketing goals require modern genotypes with high body protein synthesis capacity, i.e., low Duroc gene proportions. Diets must be of high nutrient value, meaning high quality amino acid pattern, which result in a more or less high external nutrient input into the organic agricultural system. Meat quality-dominated marketing targets, which have to accept less lean meat-rich carcasses, tolerate genotypes with lower body protein synthesis capacity, i.e., high Duroc gene proportions, and demand more extensive diets with lower amino acid quality up to pure on-farm diets, resulting in a low external input system.

Key words

Organic pig fattening, Duroc, feeding, growth performance, carcass quality, meat quality, high external input system, low external input system

Introduction

In organic pig fattening the choice of a suitable genotype and an adequate diet depends on the marketing goal and strongly influences product quality, i.e., carcass and meat quality, and the economic success of the farmer.

Market-partners demand the consideration of Duroc genes in the fattener due to expected positive effects on meat quality [Laube et al. 2000, Mörlein et al. 2007] and in order to enhance market appearance, e.g., in the organic pork segment of tegut® [Euen 2008], one of the most important organic food retailers in Germany. In contrast, increasing Duroc gene proportions are associated with decreased body protein synthesis [Ellis et al. 1996], leading to inferior carcass quality and value creation. Against this background, it was the aim of the subsequent presented study to deduce the optimal Duroc gene percentage against the carcass-quality based, i.e. lean-meat quantity dominated marketing goal in organic pork marketing with fatteners of varying Duroc gene proportion; (Experiment 1 - Influence of Genotype: varying Duroc gene proportion). A synopsis of this trial is published by Brandt et al. [2009].

The diet also strongly influences product quality, including carcass quality or meat quality, growth performance and the economic success of organic pig fattening. Whereas in organic monogastric feeding the demand-covering energy supply is unproblematic, the demand-covering supply of the first two limiting amino acids, Lysine and Methionine, presents considerable difficulties for the following reasons [Zollitsch et al. 2004, Wlcek und Zollitsch 2004]: (i) insufficient amino acid pattern of the available cereals and grain legumes, (ii) missing availability of alternative feed supplements because of (a) unsolved planting risks (e.g. rape, rapecake), (b) problematic genuine origin (e.g. soy, soy products, incl. GMO-complex), (c) missing primary products of organic origin (e.g. potato protein) and (d) explicit ban on further options (e.g. extracted soy bean meal, crystalline amino acids). It is obvious that the future EU regulation, requiring solely the use of feed ingredients of 100% organic origin, exacerbates the problems instead of reducing them. The expected unbalanced diets are without relevance for the health of fattening pigs, but tend to result in economic losses due to impaired growth performance and carcass quality, i.e., lean meat percentage, whereas lipid-based meat quality traits could be influenced positively [Sundrum et al. 2000, Zollitsch 2007]. This study thus compares the influence of a pure on-farm finishing diet (as an example of Methionine deficiency in solely farm grown diets) with a mixed finishing diet (consisting of farm grown, regionally available, and imported feed ingredients) on growth performance, carcass quality, meat quality and economic traits; (Experiment 2 - Influence of feeding: mixed versus pure on-farm finishing diet). A short communication of the trial is published by Weißmann et al. [2004].

Material and methods

Experiment 1 – Influence of Genotype: varying Duroc gene proportion

The trial was performed at the testing station in Rohrsen of the Agricultural Chamber of Lower Saxony, Germany using two runs in 2008 and 2009, respectively. The paper deals with the results of the first run in 2008, including 96 fattening pigs with an increasing Duroc gene proportion. Due to the loss of three animals, 93 fatteners remained for analysis (Table 1). The GLW*GLR (GLW: German Large White, GLR: German Landrace) dam genotype of the fatteners without Duroc gene proportion was a commercial Dan-Hybrid® sow, the GLW*GLR dam genotype of the fatteners with 50% Duroc gene proportion was a commercial BHZP® sow (BHZP: Bundes-Hybrid-Zucht-Programm – a commercial German breeding programme), whereas the Du*GLR (Du: Duroc) dams of the fatteners with 25% and 75% Duroc gene proportion were crossbred sows of the same herd of the Institute of Animal Genetics, Friedrich Loeffler-Institut (FLI) in Mariensee, Germany. The terminal sire lines consisted of a various number of boars used in form of artificial insemination. All fatteners were individually identified by electronic ear tags on the occasion of initial weighing and grouping at the performance testing station.

Table 1: Genotypes[1] and number of animals in the first run (experiment 1)

Terminal sire	Crossbred sow (sire * dam)	Notation	Duroc gene proportion	Number of animals		
				Castrates	Females	Total
Pi	DE * DL	Pi*(DE*DL)	0 %	13	11	24
DE	Du * DL	DE*(Du*DL)	25 %	14	14	28
Du	DE * DL	Du*(DE*DL)	50 %	12	12	24
Du	Du * DL	Du*(Du*DL)	75 %	12	5	17

[1] DE = Deutsches Edelschwein (German Large White), DL = Deutsche Landrasse (German Landrace), Du = Duroc, Pi = Piétrain

Animal keeping was in accordance with the EC Regulation 1804/99. The naturally ventilated external climate housing system consisted of 16 pens with straw bedding but without an extra outdoor area. The stocking rate was six animals per pen with an indoor area access of 2 m^2 per animal. Drinking water was offered by one nipple watering spot per pen. The pelletised diet was of 100% organic origin. It consisted of an initial diet (13.3 MJ ME, Lysine-ME-ratio: 0.87) up to about 45 kg live weight and a final diet (12.5 MJ ME, Lysine-ME-ratio: 0.64) both fed *ad libitum* in one self-feeder per pen, which was filled every day.

The fattening period ranged from about 28 kg live weight to about 118 kg live weight. Net feed consumption was recorded daily, weighing occurred weekly. When the animals reached > 112 kg live weight, they were slaughtered the subsequent week. Slaughtering took place after a standardised overnight resting period and CO_2 stunning in the abattoir of the FLI Institute of Animal Genetics in Mariensee, 36 km away from the testing station.

Feed conversion ratio was calculated as group average, the remaining criteria of growth performance, carcass quality and meat quality were individually recorded. The whole procedure of data collection followed the federal standard of the German testing stations [ZDS 2007]. In addition, the intramuscular fat content in the *Musculus longissimus dorsi* (*M.l.d.*) was estimated by Near-Infrared-Transmission spectroscopy (NIT). The according criteria of growth performance, carcass and meat quality can be seen in the following chapter "Results and discussion". Sensory meat quality will be presented after the analysis of the whole trial.

The data were analysed with the analysis of variance procedure. The general linear model consisted of the fixed effects genotype (0%, 25%, 50%, 75% Duroc gene proportion), sex (castrates, gilts) and their interaction (genotype*sex); additional covariates were live weight at start of fattening for fattening traits and live weight at slaughter for carcass and meat traits. Genotype*sex-interaction did not exist for all subsequently presented fattening, carcass, and meat traits.

Experiment 2 – Influence of feeding: mixed versus pure on-farm finishing diet

The trial was performed at the above-mentioned testing station in Rohrsen in the year 2004. A total of 64 animals of the genotype (Pi*Hampshire)*(Du*DL) were divided into a control group and an experimental group, each with 16 castrates and 16 females. Two animals were excluded from data analysis: one castrate due to clear failing the intended live weight at the end of fattening, and one carcass of a castrate due to loss at the commercial abattoir.

Housing conditions were the same as described above for Experiment 1, except for a stocking rate of four animals per pen with a resulting indoor area access of > 2 m^2 per animal. The fattening period ranged from about 20 kg live weight to about 118 kg live weight and was divided into an initial and finishing period. During the initial period of up to about 50 kg live weight, both groups received the same mixed diet consisting of on-farm grown, regionally available and imported feed (soy and soy products) ingredients. During the finishing period, one half of the animals got a mixed diet along the same line (control group), whereas the other animals got a solely on-farm based diet (experimental group), leading to the experimental design and the diet characteristics described in Table 2. The feed composition was analysed by a commercial laboratory.

The criteria of growth performance, carcass quality, and meat quality (only pH-value 45 min. *post mortem*) were recorded in the same way as described above for Experiment 1.

The two feeding groups were statistically compared using the t-test procedure at 5% significance level.

Results and discussion

Experiment 1 – Influence of Genotype: varying Duroc gene proportion

Table 3 depicts aspects of growth performance, carcass quality, and meat quality of fatteners with increasing Duroc gene proportion. The daily weight gain is on a very high level, but not affected by the varying Duroc gene proportion. Feed conversion ratio with 2.7 and 2.8 for the three genotypes from zero up to 50% Duroc gene portion ranges on a very good level compared to organic feeding conditions [Millet et al. 2004] whereas feed conversion ratio of the 75% Duroc gene proportion group significantly worsens to 3.1, which is in fact still good compared to organic field data worse than 4 [Löser & Deerberg 2004]. The results of daily weight gain and feed conversion ratio (Table 3) do not support the assumption of Blasco et al. [1994] that Duroc gene proportion improves growth performance of the fattener, but is in accordance with the findings of Jüngst & Tholen [2007] that Duroc as sire line impairs feed conversion ratio compared to Piétrain as sire line. The impaired feed conversion ratio of the animals with 75% Duroc gene proportion seems to be the result of the pigs' decreased feed energy mobilisation due to their increased body fat synthesis [Kapelanski et al. 2001], characterised by the lowest lean meat content, the smallest meat area, and the highest leaf fat weight of the animals in that group (Table 3). At the same time it is conspicuous that the development of the carcass traits in Table 3 is not synchronous to the increasing Duroc gene portion, as could be expected. This seems to be the effect of the mother's genotype. The sows in the 50% Duroc gene proportion group are commercial hybrids highly selected for carcass quality. In contrast the Du*DL sows of the remaining two groups are less intensively selected cross breeds, especially produced for the present experiment by the research farm. However, the decreasing carcass quality with increasing Duroc gene portion could be expected and is in accordance with other findings [Ellis et al. 1996, Jüngst & Tholen 2007]. Concerning meat quality, Table 3 reflects the positive effect of Duroc gene proportion in the fattener described in literature [Fischer et al. 2000, Jüngst & Tholen 2007, Mörlein et al. 2007]. For electrical conductivity (24 h *p.m.*) and for intramuscular fat content, however, the expected synchronism to the Duroc gene proportion is largely evident. The pH value 45 min *p.m.* remains unaffected on a high level, indicating no PSE susceptibility for all genotypes; this is the result of the widespread stress sanitation in Piétrain and German Landrace genotypes, the missing susceptibility for PSE within Duroc and German Large White, and not least, the gentle handling of the animals at the institute’s abattoir. Concerning water binding capacity, it can be seen that already 25% Duroc gene proportion significantly diminishes drip losses.

Table 2: Experimental design and diet characteristics (experiment 2)

		Initial period	Finishing period	
		Control + experimental group Mixed diet	Control group Mixed diet	Experimental group On-farm diet
Castrates / Females	n	30 / 32	15 / 16	15 / 16
Feed ingredients				
Winter barley (on-farm)	%	21	10	- -
Winter wheat (on-farm)	%	22	21	35
Winter rye (on-farm)	%	- -	10	5
Triticale (on-farm)	%	- -	18	6
Field beans (on-farm)	%	6	12	19
Field peas (on-farm)	%	12	- -	19
Lupines (on-farm)	%	- -	- -	14
Wheat bran (regional)	%	19	7	- -
Sunflower cake (regional)	%	- -	5	- -
Soybeans, toasted (import)	%	5	2	- -
Soycake (import)	%	13	13	- -
Minerals	%	2	2	2
Feed composition (referring to original substance with 89% dry matter)				
Metabolisable Energy, ME	MJ/kg	13,1	13,0	12,7
Crude protein	g/kg	176	175	180
Lysine	g/kg	9,3	8,1	9,1
Methionine	g/kg	2,3	2,4	1,8
Methionine + Cystine	g/kg	5,4	5,4	4,7
Ca	g/kg	7,9	7,1	7,4
P	g/kg	5,7	5,4	5,4

It can be reasoned that increasing Duroc gene portions result in an impaired feed conversion ratio, decreasing lean meat content, and increasing intramuscular fat content. It is concluded that in carcass-quality dominated marketing systems, the Duroc gene percentage should not exceed 50%; whereas 25 % Duroc gene portion already significantly promotes meat quality. Only for marketing systems very strictly based on and paying for meat quality should the Duroc gene portion exceed 50%, due to a significant promotion of intramuscular fat content but also significant decrease in carcasses’ lean meat content.

Table 3: Aspects of growth performance, carcass and meat quality of fatteners with varying Duroc gene proportion (LSM, experiment 1)

	Duroc gene proportion				Significance^{1}
	0 %	25 %	50 %	75 %	
Number of animals	24	28	24	17	
<u>Growth performance</u>					
Fattening period, d	99	96	98	101	ns
Daily weight gain, g/d	951	975	964	944	ns
Feed conversion ratio, kg feed / kg weight gain (number of recorded groups)	2,7^{b} (4)	2,8^{b} (5)	2,7^{b} (4)	3,1^{a} (3)	* * *
<u>Carcass quality</u>					
Dressing rate, %	81,5^{a}	80,7^{b}	80,5^{b}	80,6^{b}	* * *
Lean meat percentage, %	57,5^{a}	54,4^{c}	56,0^{b}	52,1^{d}	* * *
Lean meat area (*M.l.d.*, 13th rib), cm^2	54,3^{a}	46,2^{b}	47,0^{b}	42,0^{c}	* * *
Leaf fat, g	1.253^{d}	1.517^{b}	1.435^{c}	1.919^{a}	* * *
<u>Meat quality</u>					
pH_1 (*M.l.d.*, 13th /14th rib, 45 min *p. m.*)	6,33	6,39	6,44	6,22	ns
EC_24 (electrical conductivity, *M.l.d.*, 13th/14th rib, 24 h *p. m.*), mS/cm	5,89^{a}	4,79^{b}	4,59^{b}	3,79^{c}	* *
Drip loss – DL (*M.l.d.*, 13th rib)					
- DL_24 (24 h *p. m.*), %	2,9^{a}	1,6^{b}	1,3^{b}	1,9^{b}	* * *
- DL_48 (48 h *p. m.*), %	5,0^{a}	3,4^{b}	2,9^{b}	3,5^{b}	* * *
Intramuscular fat content – (*M.l.d.*, 13th rib), %	1,5^{c}	2,2^{b}	2,4$^{a, b}$	2,7^{a}	* * *

[1] F-Test from analysis of variance; ns: non significant, *** significant for P < 0.001, ** significant for P < 0.01

[a, b, c, d] LSM with different letters within a row differ significantly (Tukey-Kramer-Test)

Experiment 2 – Influence of feeding: mixed versus pure on-farm finishing diet

Both finishing diets should cover the energy and Lysine demand of fattening pigs with an average daily weight gain of about 800 g leading to 12.5 MJ ME and 8.6 g Lysine per kg feed [DLG 2002]. Furthermore the mixed finishing diet of the control group with 5.4 g Methionine + Cystine / kg feed should cover the demand for sulphur-containing amino acids, whereas due to the pure on-farm finishing diet of the experimental group, a non demand-covering Methionine + Cystine supply of about 4.5 g / kg feed was accepted. These intended feed compositions were only partially achieved (Table 2). The intended demand-covering Lysine-energy-quotient in the finishing diet of 0.69 [DLG 2002] was undercut in the control group (0.62), but slightly exceeded in the experimental group with 0.72 (comp. Table 2). The recommended amount of Methionine + Cystine to Lysine content of > 60% [DLG 2002] was fulfilled by the control group (67%) but failed by the experimental group (52%), as expected (comp. Table 2). The recommended amount of Methionine to sulphur-containing amino acids of > 50% [DLG 2002] was not achieved in both groups. Whereas the control group still reached 44%, the experimental group failed strongly with only 38% (comp. Table 2). In consequence, the pure on-farm finishing diet of the experimental group is characterised by the expected (and desired) deficit of the sulphur-containing amino acids Methionine and Cystine, but simultaneously disposes over an advantage in Lysine supply compared to the control group. But all diet characteristics considered the mixed finishing diet possesses a more well-balanced amino acid pattern compared to the pure on-farm finishing diet.

Table 4 points out aspects of growth performance, carcass quality, meat quality and economic success depending on the different feeding strategies in the final fattening period.

Table 4: Aspects of growth performance, carcass, meat quality and economy under varying finishing diet conditions of 100% organic origin (means, experiment 2)

	Control group Mixed finishing diet	Experimental group On-farm finishing diet
Number of castrates / females	15 / 16	15 / 16
Growth traits		
Initial live weight, kg	22.1	22.1
Final live weight, kg	117.2	117.4
Weight gain during fattening period, g/d	831	835
Feed conversion ratio, kg feed / kg weight gain (number of recorded groups)	2.8 (8)	2.9 (8)
Carcass traits		
Carcass weight, kg	90.2	89.6
Lean to fat ratio (*M.l.d.*, 13th rib), 1 :	0.36 ^{b}	0.40 ^{a}
Lean meat percentage, %	56.4 ^{a}	55.2 ^{b}
pH_1 (*M.l.d.*, 13th/14th rib, 45 min *p. m.*)	6.5	6.5
Economic traits		
Revenues (without taxes), €/animal	204.07	202.28
Feed costs (without taxes), €/animal	100.86	100.35
Piglet costs (without taxes), €/animal	72.35	72.35
Surplus, €/animal	30.86	29.58

$^{a, b}$ Means with different letters within a row belonging to growth traits and carcass traits differ significantly for $p < 0.05$ (t-test)

It can be seen that growth performance moves on a high level (comp. also Table 3) and remains unaffected by the different finishing diets, which is mainly the effect of a sufficient energy supply [Moehn et al. 2000]. The clear Methionine deficit was without negative consequences. In contrast, carcass quality was negatively influenced by the poor amino acid quality in the on-farm finishing diet and led to a lowered body protein synthesis but enhanced body fat synthesis (Table 4). This is in accordance with findings of various other studies [Kelly et al. 2007, Millet et al. 2006, Millet et al. 2005, Wood et al. 2004]. But it seems that the amino acid deficiency, respectively imbalance, only had a marginal effect because the decrease of the animals' body protein synthesis was so small that the simultaneously enhanced body fat synthesis did not negatively affect growth performance (Table 4). Meat quality was only considered in terms of PSE exclusion. The corresponding mean pH-values for both groups of 6.5 ± 0.2 in the *Musculus longissimus dorsi* (13th/14th rib), measured 45 min *p. m.,* indicate a good level without any PSE conditions (Table 4). But this effect is based on the genetic origin and the pre-slaughter conditions but not on the diet fed [Fischer 2001]. The surplus of the revenues after feed and piglet costs is used to describe economic success (Table 4). This simple figure is very meaningful because feed and piglet costs amount to more than 90% to the allocable variable costs of the production process “pig fattening” [Rasmussen 2004]. The key data are (basis May 2004, without taxes): payouts per kg carcass weight (Ökoland – commercial organic trade cooperative): 2.27 € (control group, 56.4% lean meat, comp. Table 4), 2.25 € (experimental group, 55.2% lean meat, comp. Table 4); mean carcass weight: 89.9 kg / animal for both groups (comp. Table 4: carcass traits); mean live weight gain: 95.2 kg / animal for both groups (comp. Table 4: growth traits); feed amounts (data not presented): 50 kg initial feed (control and experimental group, respectively), 218 kg mixed finishing feed (control group), 229 kg on-farm finishing feed (experimental group); feed costs per 100 kg feed (Reudink – commercial feed mill): 40.40 € (initial feed), 37.00 € (mixed finishing feed), 35.00 € (on-farm finishing feed). The revenues, total feed costs, piglet costs and the corresponding surpluses of the revenues can be seen in Table 4. The resulting increment of 1.28 € per animal in favour of the control group shows that the minor feed costs of the pure on-farm finishing diet could not compensate the decrease in lean meat percentage of the animals of the experimental group. But the difference is small, so that a recommendation strongly depends on the actual price-cost relationship. But in addition it has to be considered that the difference between both groups may be higher in practice because the slight deficiency of the first limiting amino acid Lysine in the mixed finishing diet of the control group (see above) is not system inherent but seems to be the result of a failed recipe or feed mixture.

It can be reasoned that a pure on-farm finishing diet consisting of cereals and grain legumes is characterised by a deficit of sulphur-containing amino acids, in particular Methionine. Whereas growth performance remains unaffected on a high level, the body protein synthesis and therefore the economic important lean meat percentage are significantly diminished, leading to a lowered profitability despite minor feed costs.

Conclusions

For both experiments it can be concluded that

- MEAT QUALITY-dominated marketing systems (in terms of higher intramuscular fat contents) have to accept (i.e., pay adequate prices for) more adipose carcasses. This tolerates genotypes with lower body protein synthesis capacity, like fatteners with high Duroc gene proportion, or promotes the use of imbalanced pure on-farm diets. The last mentioned fact is responsible for farm classification as a low external input system. But in fact such marketing systems are uncommon in European pig fattening – regardless of whether in organic or conventional production systems.
- CARCASS QUALITY-dominated organic marketing targets – with the demand for lean meat rich carcasses, as it is the case in the European organic pork-market – require genotypes with high body protein synthesis capacity and diets which supply enough limiting amino acids, in first priority Lysine and in second priority Methionine. Such a modern genotype should not have more than 50% Duroc gene proportion. The 25% Duroc gene portion option seems to be an auspicious alternative: it ensures sufficient lean meat and it simultaneously provides meat quality traits in order to promote marketability. Whereas modern lean meat rich genotypes with high body protein synthesis capacity can be more or less easily produced within the organic farming system, it is more difficult to prepare diets with a high quality amino acid pattern in the same way. Especially the supply of Methionine or of sulphur-containing amino acids requires feed ingredients like soy or soy products which are available regionally or on-farm only in the southern regions of Europe (and Germany). So, in the other parts of Europe or Germany the demand for lean carcasses, respectively the necessity of a high quality amino acid pattern in the diet, shifts the primordial low external input system which is typical for organic farming systems in direction to a high external input system, even if diets of 100% organic origin are used. In consequence, if pure on-farm diets are claimed, adapted carcasses with lower lean meat percentages have to be accepted (and paid!) by the market partners and the customers.

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