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Impact of piglet birth weight on later rearing performance

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Abstract: The piglet birth weight and its variance within a litter may be considered important traits that influence pig productivity in the first and later stages of rearing. 222 piglets were evaluated from the moment they were born until weaning, and then as fattening pigs until the end of the fattening (n = 207) in three birth weight groups. Negative consequences of an excessively low piglet birth weight were observed, including higher mortality until weaning and a lower average daily gain during suckling. The correlation coefficients between the piglet birth weight and the remaining indicators confirmed the negative impact of the low piglet birth weight, fattening performance and carcass slaughter value (P < 0.01). The regression analysis between the piglet birth weight and the growth rate during the whole rearing phases indicated that only the piglet growth rate from birth to weaning is determined by their birth weight.

Keywords: pigs; body weight at birth; fattening; slaughter traits

The piglet birth weight and its variance within a litter may be considered important traits that influence pig productivity at later stages of rearing. This is increasingly important because an increased litter size is often related to larger differences between the weights of the individual piglets within a litter and a higher frequency of underweight piglets being born, which results in higher losses caused by, e.g., piglet mortality. The reduced piglet birth weight and non-uniformity litters are especially characteristic of hyper-prolific sows. Sows from highly prolific lines produce more piglets than they can suckle. These sows need appropriate management strategies to reduce the mortality of the supernumerary piglets (Houben et al. 2017; Kobek-Kjeldager et al. 2020).

Negative consequences of an excessively low piglet birth weight, involving higher mortality during rearing and a lower average daily gain during suckling and after weaning, were demonstrated by Milligan et al. (2002a), Milligan et al. (2002b), Quiniou et al. (2002), Gondret et al. (2005), Fix et al. (2010), Bocian et al. (2011), Rekiel et al. (2014) and Milewska et al. (2016).

The causes of the uneven growth of the individual animals in a litter during the pigs' embryonic period are complex and relate to numerous aspects of prenatal development (Redmer et al. 2004; Town

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et al. 2004; Wu et al. 2006). An insufficient transplacental supply of oxygen and nutrients compared to the amounts required for the growth of a large litter may, for example, partially inhibit myogenesis and reduce the number of primary muscle fibres. This may lead to a lower average daily gain of the reared and fattened animals, as well as a lower post-slaughter meat content and lower meat quality (Gondret et al. 2005; Rehfeldt and Kuhn 2006; Berard et al. 2008; Rehfeldt et al. 2008).

This study aimed at examining and determining the extent to which the piglets' birth weight may determine their growth potential during rearing and fattening and impact the post-slaughter value of the carcass. An important aspect of the study was to demonstrate the extent to which the variable piglet birth weight impacts the individual growth stages of the fattened pigs. The hypothesis is: The production trait values of the fattened pigs are the result of actions and interactions of various factors. An analysis of the influence of the piglets' body weight at birth allows one to forecast the production capacity of fatteners.

MATERIAL AND METHODS

Research on the animals did not require the consent of the Local Ethical Committee. The slaughter of the experimental animals was carried out in a registered meat processing plant. The studies were part of a routine production cycle in the swine production sector. The major research aim was to analyse the growth rate and carcass quality (Directive No. 2010/63/EU).

The study was conducted using 222 piglets, three-breed crossbreds [F_1(Polish Landrace × Polish Large White) × Pietrain]. They were obtained from 17 sows and 9 boars. The distribution of the sexes in the study population was close to 1 : 1. All the animals were reared, fed, and maintained in accordance with the animal welfare requirements with permanent access to water. The animals were tagged on the first day of their life and observed individually. Detailed observations were conducted from the moment the piglets were born, throughout rearing and fattening, and until slaughter. The boars were castrated in the first week of life. The individual growth from the moment the piglets were born until weaning off (28 days) was studied by weighing at 1, 21, and 28 days of life, and then in the rearing period: at the beginning of the fattening (89 days), at 149 days, and after the fattening period. The piglets were provided permanent access to complete feed for piglets from the 10th day of their life. After weaning (28th day), the piglets remained in farrowing pens for 7 days, and then, as weaner pigs, they were moved to collective pens, 45 piglets each.

The animals received the complete feed used on the farm (Table 1) in accordance with the recommendations (Grela and Skomial 2014). The fattening was completed when the body mass reached 120 kg. The animals had unlimited access to a loose feed dispenser and permanent access to water. After the fattening was finished, the animals were transported to a slaughterhouse, where they were slaughtered in accordance with the applicable standards and laws (Ministry of Agriculture and Rural Development 2004). The carcass meat content was assessed using an IM-03 device, approved for use in small slaughterhouses.

The results were analysed in three groups depending on the piglet birth weight. Group I included piglets with the lowest birth weight up to 1.2 kg (n = 59), group II – piglets with a body weight from 1.2 kg to 1.7 kg (n = 101), and group III – piglets with the highest weight, over 1.7 kg (n = 62). The results were statistically processed by calculating an arithmetic mean (x) and a standard deviation (s) for each trait. In order to determine the impact of the piglet birth weight on the rearing and fattening performance, a one-way analysis of variance (ANOVA) was performed. The following levels of significance were established: significant P < 0.05 and highly significant P < 0.01. The following linear model was used:

$$y_{ij} = \mu + \alpha_i + \varepsilon_{ij} \quad (1)$$

where:
y_{ij} – dependent variable;
i – main effect (range of the piglet birth weight);
j – random error;
μ – overall mean;
α_i – main effect: of the i^{th} range of the piglet birth weight (i = I < 1.2 kg, II 1.21–1.7 kg, III > 1.7 kg);
ε_{ij} – random error.

For the groups created, as a result of dividing the study material according to the factors included in the model of the analysis of variance, the least significant differences (LSD) were studied for the pairs of the means for the items.

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Table 1. The nutritional value of the feed mixtures

Composition of feed mixture	Fattening period			
	15 to 30 kg	30 to 50 kg	50 to 70 kg	70 to 110 kg
Ground wheat (%)	27	15	10	0.0
Ground barley (%)	32.05	20	20	20
Ground triticale (%)	18	23.5	40	48
Soybean meal (%)	15	17.5	16.5	14
Ground oat (%)	0.0	10	10	15
Ground maize (%)	0.0	10	0.0	0.0
Fish meal (%)	2	0.0	0.0	0.0
Mineral feed for weaners[a] (%)	4	0.0	0.0	0.0
Mineral feed for porkers[b] (%)	0.0	3	2.5	2.5
Soybean oil (%)	1.5	1	1	0.5
Acidulant feed (%)	0.3	0.0	0.0	0.0
Presan FX 650 (%)	0.15	0.0	0.0	0.0
Metabolisable energy (MJ/kg)	13.13	13.12	13.19	12.98
Crude protein (g)	172	167	165	155

[a]Composition: metabolisable energy, 6.94 MJ/kg; crude protein, 185.1 g; crude fibre, 21.3 g; crude ash, 584.2 g; crude fat, 7.8 g; Ca, 150 g; P, 50 g; Na, 45 g; lysine, 105 g; methionine, 20 g; threonine, 23 g; tryptophan, 2 g. The vitamin-micromineral per kilogram of the complete diet: vitamin A (3a672a retinyl acetate), 400 000 IU; vitamin D3 (3a671 cholecalciferol), 50 000 IU; vitamin E (3a700 *all-rac-α*-tocopheryl acetate), 2 500 IU; Mn, 1 650 mg [as 3b502 manganese (II) oxide]; Mn, 350 mg (as 3b506 manganese chelate of glycine hydrate); Cu, 1 250 mg [as 3b405 copper (II) sulfate pentahydrate]; Cu, 1 250 mg (as 3b409 dicopper trihydroxide); Fe, 4 500 mg [as 3b103 iron (II) sulfate monohydrate]; Zn, 2 060 mg (as 3b603 zinc oxide); Zn, 940 mg (as 3b607 zinc chelate of glycine hydrate – solid); J, 30 mg (as 3b201 potassium iodide); Se, 15 mg (as 3b801 sodium selenite); [b]Composition: metabolisable energy, 7.4 MJ/kg; crude protein, 179.1 g; crude fibre, 0.3 g; crude ash, 732.2 g; crude fat, 6.0 g; Ca, 179.6 g; P, 25.6 g; Na, 64 g; lysine, 120 g; methionine, 20 g; threonine, 30 g; tryptophan, 3.5 g. The vitamin-micromineral per kilogram of the complete diet: vitamin A (3a672a retinyl acetate), 260 000 IU; vitamin D3 (3a671 cholecalciferol), 80 000 IU; vitamin E (3a700 *all-rac-α*-tocopheryl acetate), 2 200 IU; Mn, 1 980 mg [as 3b502 manganese (II) oxide]; Mn, 419 mg (as 3b506 manganese chelate of glycine hydrate); Cu, 729 mg [as 3b405 copper (II) sulfate pentahydrate]; Cu, 270 mg (as 3b409 dicopper trihydroxide); Fe, 4 799 mg [as 3b103 iron (II) sulfate monohydrate]; Zn, 3 591 mg (as 3b603 zinc oxide); Zn, 1 200 mg (as 3b609 zinc hydroxychloride, monohydrate; J, 42.13 mg (as 3b201 potassium iodide); Se, 11.99 mg (as 3b801 sodium selenite)

The simple correlations (R_{xy}) between the piglet birth weight and the remaining indicators were calculated. To estimate the impact of the piglet birth weight on their growth rate, the simple regressions between the piglet birth weight (y) and the piglet weight at weaning (x_1), the fattening pig weight at the beginning of the fattening (x_2), and the weight at slaughter (x_3) were calculated. A linear regression was calculated using the method of least squares. The linear regression equation is as follows:

$$y_i = b_0 + b_1 x_i + e_i \tag{2}$$

where:

y_i – dependent variable;

b_0 – intercept of the regression equation;

b_1 – linear regression slope;

x_i – independent variable ($i = x_1, x_2, x_3$);

e_i – standard estimation error.

The significance of the regression model evaluation metrics was verified using the F-test. STATISTICA v13.3 (StatSoft, Kraków) computer software was used to perform the calculations.

RESULTS

A total of 222 pigs from 17 litters were assigned to three groups (I, II, and III) depending on the piglet birth weight. There were 59 piglets with the lowest birth weight of less than 1.2 kg (group I), 101 with

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Table 2. Piglets number in the groups and mortality during rearing

Trait	Body weight at birth (kg)		
	I	II	III
	< 1.2	1.2–1.7	> 1.7
Number of piglets (n/%)			
At birth	59/26.58	101/45.49	62/27.93
At 21 day	52	97	61
At weaning, 28 day	51	95	61
Mortality of piglets (n/%)			
From 1–21 day	7/11.86	4/3.96	1/1.61
From 1–28 day	8/13.56	6/5.94	1/0.45

a medium birth weight (group II), and 62 with the highest birth weight over 1.7 kg (group III) (Table 2).

The highest piglet mortality was observed among the pigs with the lowest birth weight and amounted to 11.86% during the first 21 days of life and 13.56% in the period from birth to weaning (28 days). The mortality among the pigs with the medium birth weight was half as much as in group I, whereas the lowest mortality was observed in the group with the highest birth weight (0.45%).

Table 3 demonstrates the changes in the weight of the three piglet groups from birth to slaughter. The most evident differences were observed at birth. The body weight of the lightest piglets was half as much as the body weight of the heaviest piglets. After weaning at 28 days, the differences between the two extreme groups were much lower and further decreased with age during rearing and fattening. At slaughter, the average differences in the body weight between the groups amounted to 3.21% (group I *vs* II), 1.78% (group II *vs* III) and 5.09% (group I *vs* III).

The growth rate, evaluated on the basis of the average daily gains (ADG), varied the most during the period from birth to weaning ($P < 0.01$) (Table 4). The differences between the groups in the further stages of growth decreased. During rearing, from 28 to 89 days, the differences in the growth rate occurred between the piglets with the lowest weight and the piglets from group II and III ($P < 0.01$), while during the first two months of fattening, significant differences were observed between group I

Table 3. Body weight of the piglets and porkers during the experiment

Trait	Body weight at birth (kg)		
	I	II	III
	< 1.2	1.2–1.7	> 1.7
Body weight (kg)			
At birth	$1.07^{A} \pm 0.15$	$1.51^{B} \pm 0.10$	$1.91^{C} \pm 0.14$
On 21 day	$5.09^{A} \pm 1.03$	$6.23^{B} \pm 0.90$	$7.07^{C} \pm 1.37$
At weaning, 28 day	$6.83^{A} \pm 1.08$	$8.11^{B} \pm 1.10$	$9.02^{C} \pm 1.47$
At the beginning of fattening	$29.02^{A} \pm 2.50$	$32.01^{B} \pm 2.37$	$33.25^{C} \pm 3.08$
After 2 months	$79.97^{A} \pm 3.08$	$82.36^{B} \pm 2.85$	$83.92^{C} \pm 3.53$
At finish	$117.96^{A} \pm 7.70$	$121.75^{Ba} \pm 4.83$	$123.96^{Bb} \pm 4.73$
Differences in body weight at slaughter (%)			
Groups I–II	3.21		
Groups II–III			1.78
Groups I–III		5.09	

Significance of the differences: $^{A–C}P < 0.01$; $^{ab}P < 0.05$

Table 4. Average daily gain until weaning and during the fattening

Trait	Body weight at birth (kg)		
	I	II	III
	< 1.2	1.2–1.7	> 1.7
Average daily gain (g)			
From 1–21 day	$191^{A} \pm 45.9$	$224^{B} \pm 42.0$	$245^{C} \pm 53.9$
From 1–28 day	$205^{A} \pm 37.0$	$235^{B} \pm 38.4$	$254^{C} \pm 51.4$
From 28–89 day	$250^{A} \pm 26.4$	$268^{B} \pm 27.5$	$273^{B} \pm 26.9$
Fattening 2 months	$848^{a} \pm 30.2$	$838^{b} \pm 25.6$	844 ± 27.7
Total fattening	936 ± 80.2	942 ± 56.4	954 ± 70.3
Growth rate from birth to slaughter (g)	$634^{A} \pm 41.4$	$650^{Ba} \pm 30.1$	$662^{Bb} \pm 28.5$
Fattening period (days)	95.20 ± 5.41	95.49 ± 4.36	95.44 ± 5.57
Age at finish (days)	184.41 ± 3.58	185.00 ± 3.53	184.27 ± 3.21

Significance of the differences: $^{A–C}P < 0.01$; $^{ab}P < 0.05$

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Table 5. Carcass characteristics

Trait	Body weight at birth (kg)		
	I	II	III
	< 1.2	1.2–1.7	> 1.7
Hot carcass weight (kg)	$92.94^{A} \pm 6.07$	$95.98^{Ba} \pm 3.65$	$97.65^{Bb} \pm 3.68$
Slaughter yield (%)	78.79 ± 0.28	78.84 ± 0.96	78.76 ± 0.11
Carcass meat content (%)	57.75 ± 1.86	57.76 ± 1.91	57.65 ± 2.00

Significance of the differences: $^{AB}P < 0.01$; $^{ab}P < 0.05$

and II only ($P < 0.05$). Throughout the entire fattening period, lasting 95 days, the average daily gains were high and similar in all the groups and exceeded 900 g/day.

The slaughter evaluation of the tested groups of pigs only included the warm carcass weight, the slaughter performance, and the percentage carcass meat content (Table 5). Only the carcass weight differed among the groups, and it was the lowest in the pigs with the lowest birth weight when compared with groups II and III ($P < 0.01$). The slaughter performance was high and similar in all three groups, as was the carcass meat content, exceeding 57%.

The calculated simple correlations between the piglet birth weight and their body weight at the particular stages of growth and at slaughter (Table 6) were highly significant ($P < 0.01$). However, the growth rate evaluated on the basis of the average daily gains significantly correlated with the initial body weight at the first period of growth, i.e., until weaning. Within the second month of piglets life and during the fattening phase, the growth rate was not determined by the initial body weight of the piglets ($r = -0.045$; $r = 0.070$). A significant impact of the piglet birth weight on the warm carcass weight ($P < 0.01$) was demonstrated, but there were no significant relationships between the birth weight and the other carcass parameters.

Table 6. Correlation coefficients between the piglet body weight at birth and the growth rate and slaughter traits

Trait	Body weight at birth (kg)
Body weight (kg)	
On 21 day	0.620**
At weaning, 28 day	0.606**
At the beginning of fattening	0.552**
At 2 months	0.467**
At finish	0.352**
Growth rate (g/day)	
On 1–21 day	0.419**
On 1–28 day	0.427**
At 2 months of fattening	−0.045
Total fattening period	0.070
Growth rate at birth to slaughter (g)	0.300**
Hot carcass weight (kg)	0.348**
Dressing yield (%)	−0.060
Carcass meat content (%)	−0.029

**Significance at $P < 0.01$

The simple regression equations between the piglet birth weight and the fattening pig weight at the beginning of the fattening gave lower results than in the case of the piglet weight at weaning at 28 days (Table 7), which indicates that it is only the piglet growth rate from birth to weaning that is determined by their birth weight.

DISCUSSION

The negative impact of the low birth weight of the piglets on their further development and growth has already been studied. The uneven, in the opin-

Table 7. Regression equations and coefficients between the piglet body weight at birth and at weaning, the fattening period and the growth rate during weaning

Trait	Body weight at birth (y)	
	regression equation	regression coefficient
Body weight (kg)		
At weaning, 28 day (x_1)	$y = 0.421\,588 + 0.138\,021x_1 + 0.268\,0$	0.363**
At the beginning of fattening (x_2)	$y = -0.365\,075 + 0.060\,046x_2 + 0.280\,7$	0.301**
At finish (x_3)	$y = -0.841\,254 + 0.019\,567x_3 + 0.314\,2$	0.124**

**Significance at $P < 0.01$

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ion of researchers, growth of embryos and foetuses may be caused by an insufficient transplacental supply of nutrients from the mother's body, contributing to intrauterine growth retardation (IUGR) (Vallet and Freking 2005; Wu et al. 2006; Foxcroft et al. 2009).

According to Wu et al. (2004), 15–20% of piglets are born with a body weight below 1.1 kg, and their survivability and further development are considerably reduced. The results of other studies (Quiniou et al. 2002) also indicated that the percentage of small piglets with a body weight below 1 kg in the most numerous out of the 965 studied litters amounted to 23%, with only 7% in smaller litters of up to 9 piglets. In these studies, around 27% of the studied piglets weighed 1.07 kg on average. They were also characterised by high mortality rates. Piglet mortality during the period from birth to weaning amounted to 13.56%. The remaining animals were better prepared for survival and competition with their peers. Presumably, the mortality of the weakest and lightest piglets in a litter contributed to the fact that the later stages of growth in this group did not differ considerably from the growth of the piglets with higher birth weights. This conclusion is supported by the lack of significant correlations between the birth weight and the average daily gains during the fattening, and this also corroberates to the birth weight the birth weight.

This corroborates the fact that, after eliminating the weakest individuals, the ability of the remaining piglets to take up, digest, and absorb the feed was the same in all the animals during the fattening period.

Insufficient foetal nutrition at an early development phase may disturb the myogenesis, which leads to permanent negative consequences for the histological structure of the muscles of adult animals (Dwyer et al. 1994; Nissen et al. 2004; Town et al. 2004; Rehfeldt et al. 2008). These changes may determine the carcass meat content and meat quality.

However, the observation in the current experiment that the carcass value and carcass meat concentration were not different among the groups indicates that the carcass value is not determined by the birth weight.

It is possible that piglets with a low birth weight suffering from IUGR (intrauterine growth retardation) are the pigs that died during rearing, or that their foetal development was not exposed to myogenesis disturbances.

The results of the studies by Bocian et al. (2011) demonstrated that the growth rate was, to a larger extent, correlated to the birth weight during the period from birth to weaning and during the fattening period, which indicates that the growth and development of the animals during the fattening period is more likely to be independent of the birth weight.

In conclusion, the analysis of the relationships between the piglet birth weight and rearing and fattening performance demonstrated that the losses during the rearing of the piglets until weaning were the highest (13.5%) in the group of piglets with the lowest birth weight. The growth rate from birth to weaning was determined by the birth weight, whereas the growth rate in the first and second fattening phase was not significantly related to the piglet birth weight.

Conflict of interest

The authors declare no conflict of interest.

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