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# EFFECT OF PIGLET BIRTH WEIGHT ON SELECTED CHARACTERISTICS OF PORK*

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**Abstract**

**The objective of the study was to determine how different birth weights of piglets influence some chemical and physical characteristics of pig meat. Piglets were grouped according to birth weight: ≤1.30 kg (group I), 1.31–1.70 kg (group II), ≥1.71 kg (group III). Animals were reared and fattened under standardized housing and feeding conditions. Tests were conducted with 60 samples of meat (20 per group) collected from the right side of the carcasses (*M. longissimus lumborum*) of three-breed crosses of (Polish Landrace × Polish Large White) × Duroc (barrows to gilts, 1:1), which were slaughtered at about 180 days of age. Determinations were made of basic chemical composition, colour of meat, drip loss, shear force value, and fatty acid profile. It was found that the birth weight of the piglets affects meat colour (redness), crude fat content and the proportion of some fatty acids (C16:1, C20:1 *n-9*, C20:2 *n-6*, C20:5 *n-3*).**

**Key words: piglets, body weight, fatteners, meat quality**

A common problem in pig farming is the increasing proportion of piglets with low birth weight, which is due to increased litter size and fetal intrauterine undernutrition (Zhu et al., 2006; Campos et al., 2012; Rekiel et al., 2014). As a result of intrauterine growth retardation (IUGR) piglets are born weak and show digestive disorders and slower rate of growth, with often greater fatness at the end of fattening and lower quality of meat raw material (Wu et al., 2006; Oksbjerg et al., 2013).

Selection for prolificacy, development of dam lines with high reproductive performance and the widespread use of maternal heterosis have increased the number of piglets born while reducing their birth weight. Over the last 20 to 30 years, these changes were observed in Switzerland, France, Poland and other countries (Bee et al., 2007; Mucha, 2013). The correlations between litter size and mean piglet birth

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weight (r = –0.46), estimated by Milligan et al. (2002) (cited from Rekiel et al., 2014), and between the number of piglets born alive and their weight on day 21 (r = –0.40), estimated by Canario et al. (2010) (cited from Rekiel et al., 2014) confirm that the problem, important from an economic and productive viewpoint, does exist. In light weight piglets, insufficient delivery of maternal oxygen and nutrients to the fetus will reduce compensatory growth after birth (Foxcroft et al., 2006). However, some authors suggest that lower birth weight of the piglets, lower muscle weight and differences in chemical body composition and histological structure of muscle can be compensated during the maternal nursing period and during the later period of growth (Rehfeldt et al., 2011, 2012). Prenatal nutritional deficiency as well as fetal myogenesis conditions have an effect on adaptive and developmental changes, on structural, physiological and metabolic changes, and on the postnatal growth of piglets. The coefficient of genetic correlation estimated by Canario et al. (2010) (cited from Rekiel et al., 2014) between neonatal weight and piglet weight on day 21 ($r_G$ = +0.59) and the highly significant coefficient of correlation between piglet birth weight and the growth rate of growing pigs, obtained by Bocian et al. (2011) show that the body weight of newborn piglets should be actively controlled and optimized.

Fertility is related to the feeding of females (especially pregnant females), fetal muscle fibre development, birth weight of offspring, piglet growth rate and feed conversion, and the slaughter value of fatteners (Rehfeldt and Kuhn, 2006; Oksbjerg et al., 2013). Higher birth weight of piglets has a positive effect on daily weight gains of offspring and carcass traits, including carcass lean content and ham and loin muscle proportion (Heyer et al., 2004). Lawlor et al. (2007) reported that the feeding level of pregnant sows had no effect on birth and weaning weights of piglets and on carcass weight, but found carcass lean content to be higher in pigs with higher birth weights compared to lighter animals. It was found that the meat from pigs with lower birth weight contains more intramuscular fat (Bérard et al., 2008) and is characterized by greater drip loss (Bérard et al., 2008; Rehfeldt et al., 2008), and reduced tenderness (Gondret et al., 2005; Bérard et al., 2008).

The results of studies on the quantitative and qualitative evaluation of carcasses are thus inconsistent, which justifies the need for further research in this area. Accordingly, the aim of this study was to determine if different birth weights of piglets can influence some chemical and physical characteristics of pig meat.

## Material and methods

### Ethics statement

The study was approved by the 3rd Local Ethics Committee.

### Animals

Tests were conducted with samples of meat taken from the right side of the carcasses of three-breed crosses (Polish Landrace × Polish Large White) × Duroc assigned to three groups. Animals were grouped according to birth weight: ≤1.30 kg (group I), 1.31–1.70 kg (group II), ≥1.71 kg (group III). Piglets were reared with their mothers from birth to 35 days, and in group pens from weaning to 70 days of age (litter/pen). Next, 60 pigs of both sexes (20 animals each from groups I, II and III) (barrows to gilts, 1:1) were selected and fattened under uniform environmental conditions. Piglets, weaners and fatteners were fed *ad libitum* complete diets (12.5 MJ ME and 156 g crude protein/1 kg feed).

**Slaughter procedures**

At the end of fattening about 180 days of age (body weight 100.0±5.6 kg), animals were slaughtered according to standard procedures. Following 24-hour chilling of half-carcasses at +4°C, samples of *M. longissimus lumborum* were collected for further analyses.

**Analysis**

Determinations were made of basic chemical composition (dry matter, protein, fat and ash) (AOAC, 1990), colour of meat, drip loss, shear force value, and fatty acid profile. Fatty acid methyl esters were prepared and analysed in muscle lipid fraction by gas chromatography in accordance with EN-ISO 5508 and EN-ISO 5509 standards (Hewlett Packard 6890 Series GC System chromatograph) (PN-ISO 5509, 1996; PN-ISO 5508, 1996).

Meat colour parameters were measured using the CIELAB system (Konica Minolta Chroma Meter CR-400/410). Meat colour was determined by cutting a 2 cm thick slice of muscle and taking measurements at 3 points. The result was averaged.

Drip loss was determined by placing an approx. 300 g sample of meat in a polyethylene bag, which was kept under cold storage conditions (+4°C) for 24 h. After this time, the exudate was poured off and its amount was expressed as percentage of sample weight (Prange et al., 1977).

Shear force was measured with a tensiometer (Zwick 1120, Germany), equipped with a Warner-Bratzler blade. Meat samples of approx. 150 g were roasted at 180°C until the temperature at the geometric centre of the sample reached 76°C. The samples were cooled at room temperature (18–22°C) and placed in a cooler (+4°C). After 24 h, three 20 × 20 × 20 mm cubes were excised from the slice. Determinations were made transversely across the muscle fibres until the sample was cut completely. This provided the maximum force needed to shear the sample. A crosshead speed of 30 mm/min was applied until an initial tension of 2 N was reached, and 50 mm/min was used during the test proper.

**Statistical analysis**

Statistical analysis was performed by one-factor analysis of variance using the IBM SPSS Statistics 21 program (2013). The statistical model used in the calculations was as follows:

$$Y_{ij} = \mu + d_i + e_{ij}$$

where:

$Y_{ij}$ – ij[th] observation,

$\mu$ – overall mean,

$d_i$ – effect of i[th] group,

$e_{ij}$ – random error.

Significance of differences between groups was tested using Duncan's test. Results were presented in tables as mean values of parameters, standard errors of the means and the statistical significance of the group.

## Results

Group affiliation of the piglets only caused small differences in the analysed meat traits (Table 1). Significant differences between the groups were found for crude fat content and a* value of meat colour. Highest redness was found for meat samples of pigs from group I. The result for group I was significantly higher than the results for groups II (P≤0.01) and III (P≤0.05).

Table 1. Chemical composition and physical traits of *M. longissimus lumborum* depending on piglets' body weight at birth

| Traits | Group | | | SEM[1] | P |
|---|---|---|---|---|---|
| | I | II | III | | |
| | piglet body weight at birth (kg) | | | | |
| | ≤1.30 | 1.31–1.70 | ≥1.71 | | |
| Chemical composition (%): | | | | | |
| dry matter | 26.8 | 26.8 | 26.5 | 0.11 | 0.532 |
| total protein | 21.9 | 21.7 | 21.4 | 0.10 | 0.137 |
| fat | 1.6 A | 2.0 | 2.5 B | 0.12 | 0.019 |
| ash | 1.1 | 1.1 | 1.1 | 0.02 | 0.653 |
| Drip loss (%) | 2.6 | 2.6 | 2.5 | 0.21 | 0.967 |
| Lightness (L*) | 48.7 | 48.7 | 48.8 | 0.52 | 0.992 |
| Value a* | 8.6 Aa | 7.6 B | 7.5 b | 0.18 | 0.008 |
| Value b* | 3.9 | 3.6 | 3.8 | 0.26 | 0.855 |
| Shear force (N) | 108.7 | 105.8 | 95.6 | 5.66 | 0.684 |

a, b – mean values in rows with different letters differ significantly (P≤0.05).
A, B – mean values in rows with different letters differ significantly (P≤0.01).
[1] – Standard error of the mean.

Crude fat content of the meat samples was highest in group III and was highly significantly different from that in group I (P≤0.01) (Table 1).

Shear force, a* value and crude protein content were highest in pigs from group I, intermediate in pigs from group II and lowest in those from group III (Table 1). The opposite trend was noted for crude fat. Piglets with medium birth weights generally showed intermediate values of meat parameters (Table 1).

The fatty acids which showed greatest differences in the fatty acid profile of pigs with different birth weights were C16:1, C20:1 *n-9*, C20:2 *n-6*, and C20:5 *n-3*; these differences were significant at P≤0.05 and P≤0.01. The *n-6/n-3* fatty acid ratio was on the verge of statistical significance between the groups (Table 2).

Table 2. Fatty acids profile in *M. longissimus lumborum* depending on piglets' body weight at birth

| Fatty acids | Group | | | SEM[1] | P |
|---|---|---|---|---|---|
| | I | II | III | | |
| | piglet body weight at birth (kg) | | | | |
| | ≤1.30 | 1.31–1.70 | ≥1.71 | | |
| C14:0 | 1.35 | 1.32 | 1.34 | 0.012 | 0.342 |
| C16:0 | 24.19 | 24.16 | 24.17 | 0.135 | 0.992 |
| C17:0 | 0.17 | 0.16 | 0.17 | 0.007 | 0.537 |
| C18:0 | 12.57 | 13.01 | 12.71 | 0.130 | 0.187 |
| C20:0 | 0.17 | 0.18 | 0.15 | 0.005 | 0.124 |
| SFA | 38.44 | 38.82 | 38.54 | 0.257 | 0.720 |
| C16:1 | 3.62 A | 3.36 B | 3.26 B | 0.049 | 0.004 |
| C17:1 | 0.17 | 0.15 | 0.17 | 0.007 | 0.338 |
| C18:1 t9 | 0.17 | 0.17 | 0.17 | 0.004 | 0.901 |
| C18:1 c9 | 46.04 | 46.34 | 47.09 | 0.519 | 0.743 |
| C18:1 c11 | 2.85 | 2.45 | 1.95 | 0.415 | 0.687 |
| C20:1 n9 | 0.80 Aa | 0.88 b | 0.92 B | 0.015 | 0.003 |
| MUFA | 53.64 | 53.35 | 53.56 | 0.369 | 0.912 |
| C18:2 *n-6* | 5.15 | 5.17 | 5.41 | 0.180 | 0.860 |
| C20:2 *n-6* | 0.24 A | 0.25 a | 0.29 Bb | 0.005 | 0.011 |
| C20:3 *n-6* | 0.13 | 0.15 | 0.14 | 0.006 | 0.444 |
| C20:4 *n-6* | 0.80 | 0.80 | 0.78 | 0.039 | 0.975 |
| C22:4 *n-6* | 0.17 | 0.17 | 0.17 | 0.008 | 0.924 |
| PUFA *n-6* | 6.49 | 6.54 | 6.79 | 0.193 | 0.846 |
| C18:3 *n-3* | 0.19 | 0.19 | 0.19 | 0.012 | 0.980 |
| C20:3 *n-3* | 0.05 | 0.07 | 0.05 | 0.005 | 0.131 |
| C20:5 *n-3* | 0.07 A | 0.09 B | 0.08 | 0.004 | 0.012 |
| C22:5 *n-3* | 0.11 | 0.11 | 0.11 | 0.005 | 0.912 |
| C22:6 *n-3* | 0.05 | 0.05 | 0.06 | 0.003 | 0.378 |
| PUFA *n-3* | 0.47 | 0.51 | 0.48 | 0.017 | 0.463 |
| *n-6/n-3* | 13.9 | 13.1 | 14.2 | 0.213 | 0.051 |
| MUFA/PUFA | 7.88 | 8.37 | 7.56 | 0.326 | 0.585 |
| MUFA/SFA | 1.40 | 1.38 | 1.41 | 0.018 | 0.778 |
| PUFA/SFA | 0.18 | 0.18 | 0.19 | 0.006 | 0.662 |

a, b – mean values in rows with different letters differ significantly (P≤0.05).
A, B – mean values in rows with different letters differ significantly (P≤0.01).
[1] – Standard error of the mean.

Mean values denoted by different small letters in the same line differ statistically significantly at P≤0.05, and those denoted by capital letters differ statistically significantly at P≤0.01.

## Discussion

Our results support the findings of other authors (Bérard et al., 2008), who compared selected meat quality traits of littermates with different birth weights and observed higher redness for the muscles of lighter piglets compared to muscle colour intensity in heaviest piglets (P<0.01).

Our results did not confirm the results of other authors (Bee et al., 2007; Karunarante et al., 2007), who concluded that carcasses from animals with lower birth weights have lower carcass meat content and higher content of fat and tissues other than muscle tissue. According to Gondret et al. (2006), the higher adiposity of light vs. heavy birth weight pigs is due to greater activity of fatty acid synthase (FAS) and malic enzyme in backfat and enlarged diameter of subcutaneous adipocytes. Lipid content in *semitendinosus* muscle was 12% greater for light compared to heavy birth weight pigs, but no such differences were confirmed for *longissimus dorsi* (LD) muscle. Most authors agree that fat content of muscle tissue and carcass fatness are interrelated. Lower birth weight corresponds to higher carcass fat content. Lawlor et al. (2007) reported no significant differences in backfat thickness between three birth weight groups of piglets: high (1.81 kg), medium (1.51 kg) and low (1.14 kg).

Among the few studies that analyse basic chemical characteristics, most attention has been given to sensory attributes of meat (Gondret et al., 2005; Rehfeldt and Kuhn, 2006; Rehfeldt et al., 2008; Beaulieu et al., 2010). In our study, the smallest differences between the means of meat traits occurred for colour (L* and b*), drip loss, dry matter and ash content of meat. Similar conclusions were reached by Bérard et al. (2008), who found that drip loss and cooking loss were not significantly different between pigs with different birth weights. In another experiment (Beaulieu et al., 2010) piglet birth weight had no effect on the physical characteristics of meat, namely drip loss, tenderness and colour of meat. Rehfeldt et al. (2008) observed that the meat of low birth weight pigs was characterized by greater drip loss, while Gondret et al. (2005) and Bérard et al. (2008) also reported decreased tenderness.

Bérard et al. (2008) tested the hypothesis that birth weight influences meat quality through postmortem proteolytic changes in muscles. Compared to heavy piglets, light piglets were characterized by significantly higher ($P \leq 0.01$) redness of LD muscle with no differences in drip loss and cooking loss. *Semitendinosus* muscle of the ham was more tender in pigs with medium compared to low and high birth weights. The same authors found the postmortem degradation of intramuscular proteins to increase tenderness of meat (Bérard et al., 2008). Other authors (Beaulieu et al., 2010) reported that differences in birth weight have a significant effect on intramuscular fat content but cause no major changes in drip loss, tenderness or lightness of meat. Intramuscular fat content and drip loss are higher for meat obtained from light compared to heavier animals. The results of other authors indicate that the meat of pigs with low birth weights was also characterized by higher drip loss (Rehfeldt et al., 2008) and reduced tenderness (Gondret et al., 2005; Bérard et al., 2008). Larger myofibre cross-sectional area may adversely affect meat tenderness evaluated by sensory analysis (Gondret et al., 2006). Muscles with a small number of fibres and a large diameter show a tendency for higher postmortem pH decline and greater drip loss, and these two traits reduce meat tenderness (Lengerken et al., 1997). In turn, Maltin et al. (1997) emphasize that greater diameter of fast-twitch oxidative-glycolytic fibres modifies texture traits towards greater instrumental shear force.

In pigs, saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) are biosynthesized while polyunsaturated fatty acids (PUFA) have to be supplied through diet (Enser et al., 2000). Limited dietary energy intake reduces the body's synthesis of SFA and MUFA (Daza et al., 2007), which increases the proportion of PUFA in the fatty acid profile of pork. In addition to diet composition (Raes et al., 2004), the fatty acid profile of pig muscles is influenced by genetic factors, including the breed (De Smet et al., 2004; Żak and Pieszka, 2009), housing conditions and the proportions of different muscle fibre types (Andrés et al., 2001). The oxidative properties of muscle fibres are correlated negatively to SFA content and positively to MUFA content (Hernández et al., 1998; Lauridsen et al., 1999). The higher the content of oxidative muscle fibres is in meat, the higher the level of MUFA and the lower the level of SFA. When analysing the muscle fibres from the loin of pigs depending on their birth weight, mean muscle fibre area was found to increase in the groups of pigs with lower compared to higher birth weights, and this especially concerned slow-twitch oxidative fibres (Beaulieu et al., 2010). Bee (2004) found that the proportion of fast-twitch oxidative glycolytic fibres in the light portion of the *semitendinosus* muscle was significantly higher in heavier (23.9%) than in lighter piglets (19.2%) while the proportion of fast-twitch glycolytic fibres tended to increase ($P<0.06$). These results explain the highest content of monounsaturated fatty acid C16:1 in the meat of pigs from group I in our study. Determination of the proportion of different fibre types in muscle tissue was not the subject of the present study, which means that this interpretation of the results is only based on the literature data. The highest content of C20:1 *n-9* fatty acid in pigs from group III is contrary to expectations and literature data (Andrés et al., 2001; Bee, 2004; Rehfeldt et al., 2008). Production of litters with uniform birth weights might be beneficial for optimizing fattening and the quality of meat (Rehfeldt et al., 2008).

The results of the present study concerning the effect of piglet birth weight on meat quality traits indicate that this relationship holds in particular for meat colour (a* value), crude fat content and the proportion of some fatty acids (C16:1, C20:1 *n-9*, C20:2 *n-6*, and C20:5 *n-3*). The positive correlation of birth weight and muscle fibre type with fatty acid profile of pork, reported in the literature, suggests that further studies should be directed towards histological analysis of muscles from pigs differing in birth weight.

Birth weight of pigs had no effect on the dry matter, protein and ash content of *longissimus lumborum* muscle samples. The crude fat content of pig meat samples was dependent on the weight of newborn piglets. Meat colour was associated with birth weight; a* value was highest in samples of meat from lightest piglets. The birth weight of piglets has a limited impact on fatty acid profile; significant relationships only concerned some fatty acids (C16:1, C20:1 *n-9*, C20:2 *n-6*, and C20:5 *n*-3). Our findings show that it is appropriate to reduce variation in piglet birth weights, because this might make the quality of meat more consistent.

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