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Body weight-associated variability in muscular and adipose carcass traits of immunocastrated pigs

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Abstract

This study quantified the association between final body weight and muscular and adipose carcass traits in immunocastrated pigs slaughtered at a common age. Data from 24 immunocastrated males slaughtered at 177 days of age, 28 days after the second anti-GnRH vaccination, were analyzed using simple linear regression. For descriptive comparisons, pigs were retrospectively classified into lower and higher body-weight classes (n = 12 each). Final body weight was positively associated with backfat thickness (R^2 = 0.368), loin fat area (R^2 = 0.409), loin eye area (R^2 = 0.233), and muscle depth (R^2 = 0.308; all $P \leq 0.023$), explaining 23.3–40.9% of the observed variation in these traits. Heavier pigs exhibited greater muscular and adipose carcass measurements, whereas carcass yield, lean meat percentage, and technological meat quality traits did not differ significantly between weight classes. These findings indicate that final body weight accounts for only part of the individual variability in carcass tissue measurements among immunocastrated pigs slaughtered at a common age.

Introduction

Immunocastration (IC) is an alternative to surgical castration that addresses animal welfare concerns and controls boar taint through immunization against gonadotropin-releasing hormone (GnRH) (Batorek et al. 2012; Zalewska et al. 2026). Before effective immunization, pigs exhibit growth characteristics similar to entire males, whereas suppression of testicular activity after the second vaccination alters nutrient partitioning, favoring lipid deposition while muscle growth may continue (Dunshea et al. 2013; Muniz et al. 2019).

Previous studies have investigated the effects of slaughter weight on carcass composition and pork quality (Fàbrega et al. 2011; Trefan et al. 2013; Zhdanov et al. 2025). However, comparisons between different target slaughter weights do not fully characterize naturally occurring body-weight variation among pigs slaughtered at a common age. Quantifying the proportion of variation in muscular and adipose carcass traits explained by final body weight may therefore provide additional insight into individual differences in carcass development.

This study aimed to quantify the associations between final body weight and muscular and adipose carcass traits, emphasizing the proportion of variation explained by body weight, and to evaluate technological meat quality in immunocastrated pigs slaughtered at a common age. We hypothesized that greater final body weight would be associated with increased muscular and adipose carcass measurements.

Material and methods

The analysis used the experimental dataset published by Muniz et al. (2021), comprising 24 immunocastrated male pigs (Agroceres × Topigs). No additional animal procedures were performed; animal management and experimentals procedures were described in the original publication. Pigs received diets formulated for each growth phase and were slaughtered at 177 days of age.

Immunocastration consisted of two 2-mL subcutaneous doses of an anti-GnRH vaccine (Vivax®, Zoetis, Brazil) at 121 and 149 days of age, with slaughter occurring 28 days after the second vaccination.

Final body weight was recorded at slaughter and analyzed as a continuous variable. For descriptive comparisons, pigs were retrospectively classified into lower (LBw ≤ 135.9 kg; n = 12) and higher (HBw ≥ 136.0 kg; n = 12) body-weight classes, representing naturally occurring variation rather than experimental treatments.

Carcass measurements included hot and cold carcass weights, carcass yield, lean meat percentage, loin fat area, backfat thickness, loin eye area, and muscle depth. Ham pH was measured at 45 min and 24 h postmortem. Instrumental color (L*, a*, b*), shear force, and water-holding capacity, assessed through drip, thawing, and cooking losses, were determined in the *Longissimus lumborum* muscle.

Statistical analyses were performed using R 4.3.1. Simple linear regressions evaluated associations between final body weight and backfat thickness, loin fat area, loin eye area, and muscle depth, with R^2 quantifying the proportion of explained variation. Model assumptions were assessed through residual diagnostics, and HC3 robust standard errors were applied when required. Body-weight classes were compared using a general linear model, with class as the fixed effect and individual pig as the experimental unit. Class comparisons were interpreted descriptively, with statistical significance set at $P < 0.05$.

Results

Final body weight was positively associated with all muscular and adipose carcass traits evaluated (Table 1). The regression models explained 23.3–40.9% of the observed variation in these characteristics ($R^2 = 0.233–0.409$). The body-weight class comparison showed that HBw pigs were 13.28 kg heavier than LBw pigs and exhibited greater hot and cold carcass weights, loin fat area, backfat thickness, loin eye area, and muscle depth (Table 2). No significant differences were observed in carcass yield, lean meat percentage, pH, instrumental color, shear force, or water-holding capacity, including drip, thawing, and cooking losses.

Table 1
Linear associations between final body weight and carcass tissue measurements in immunocastrated pigs

Variable	Regression slope (β)	95% CI	P-value	R^2
Backfat thickness, mm	0.196	0.083–0.310	0.0017	0.368
Loin fat area, cm^2	0.205	0.096–0.314	0.0008	0.409
Loin eye area, cm^2	0.406	0.062–0.751	0.023[a]	0.233
Muscle depth, mm	0.228	0.077–0.379	0.0049	0.308

β, regression slope representing the change in each carcass characteristic per kilogram of final body weight; CI, 95% confidence interval; R^2, coefficient of determination.

[a] For loin eye area, statistical inference was based on heteroscedasticity-consistent HC3 robust standard errors (SE = 0.166; P = 0.023). The association was also significant using conventional standard errors (P = 0.017) and after logarithmic transformation (P = 0.015). For loin fat area, the association remained significant after excluding the two most influential observations (β = 0.187 cm^2/kg; P = 0.004).

Table 2
Carcass characteristics and meat quality of immunocastrated pigs, classified according to body weight

Trait	LBw	HBw	SEM	P-value
Carcass characteristics				
Body weight, kg	128.97	142.25	1.24	< 0.001
Hot carcass weight, kg	92.19	101.55	1.10	< 0.001
Cold carcass weight, kg	87.77	97.13	1.09	< 0.001
Carcass yield, %	71.48	71.46	0.37	0.969
Lean meat, %	60.26	59.20	0.56	0.193
Loin fat area, cm^2	19.06	22.34	0.57	0.001
Backfat thickness, mm	12.16	15.18	0.61	0.002
Loin eye area, cm^2	57.40	63.85	1.73	0.015
Muscle depth, mm	72.86	76.06	0.84	0.013
Meat quality				
pH 45 min	6.57	6.58	0.08	0.928
pH 24 h	5.93	5.98	0.06	0.567
L*	55.01	55.87	1.04	0.573
a*	6.49	6.52	0.43	0.958
b*	12.73	13.28	0.44	0.391
Shear force, N	33.83	37.17	3.73	0.550
Water-holding capacity				
Drip loss, %	2.65	3.13	0.32	0.318
Thawing loss, %	7.13	5.92	1.15	0.473
Cooking loss, %	24.82	25.43	1.28	0.745

LBw, lower body weight (≤ 135.9 kg; n = 12); HBw, higher body weight (≥ 136.0 kg; n = 12); SEM, standard error of the mean. Weight classes were defined retrospectively and should be interpreted descriptively. L*, lightness: a*, redness: b*, yellowness. Shear force values and SEM were converted from kilogram-force (kgf) to newtons (N), using 1 kgf = 9.80665 N.

Discussion

The moderate explanatory power of final body weight (R^2 = 0.233–0.409) indicates that live weight captures only part of individual variation in muscular and adipose carcass traits. This may reflect distinct

tissue maturation patterns, with protein deposition approaching maturity earlier than lipid accretion (Kouba and Sellier 2011; Muniz et al. 2026). Kang et al. (2026) likewise observed wide variation in R^2 (0.04–0.66) for simple regressions predicting pork primal-cut weights, with generally better performance from multivariable models. Although the outcomes differ, these findings underscore the limitations of using weight alone to characterize carcass composition.

Greater body weight was associated with both muscular and adipose measurements, rather than fatness alone. Following the second anti-GnRH vaccination, suppressed testicular activity modifies feed intake and nutrient partitioning, favoring lipid deposition while muscle growth may continue (Muniz et al. 2019). This transition may help explain greater loin eye area, muscle depth, backfat thickness, and loin fat area in heavier pigs (Dunshea et al. 2013; Muniz et al. 2021; Škrlep et al. 2020), although deposition rates were not measured.

Whereas previous studies compared immunocastrated pigs slaughtered at different target weights (Zhdanov et al. 2025), the present findings concern naturally occurring weight differences at a common slaughter age and 28 days after the second vaccination. Genetic potential, nutrient utilization, physiological maturity, and production conditions may contribute to unexplained variation (Asanger et al. 2025), but their individual effects were not estimated.

These findings suggest that incorporating complementary carcass measures could improve characterization beyond live weight. Rombouts et al. (2025) reported improved lean meat percentage estimation when additional carcass parameters and nonlinear relationships were included. Despite larger muscle and fat measurements, carcass yield, lean meat percentage, and technological meat quality did not differ significantly between weight classes. This absence of detected differences does not demonstrate equivalence. The small sample (n = 24) and observational design limit causal inference and generalization.

Conclusion

Final body weight was positively associated with muscular and adipose carcass traits in immunocastrated pigs slaughtered at a common age, explaining 23.3–40.9% of the observed variation in these characteristics. Heavier pigs exhibited greater muscular and adipose carcass measurements, whereas carcass yield, lean meat percentage, and technological meat quality did not differ significantly between body-weight classes.

Declarations

The authors have contributed equally

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with language editing and to improve the clarity, conciseness, and organization of selected sections. The authors subsequently reviewed and edited the manuscript and take full responsibility for its content.

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