Effects of carcass weight, sex and genotype on meat cuts and carcass trait in pigs

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Keywords: Carcass cuts, Carcass traits, Parameter, Commercial pig, Meat

Posted Date: May 22nd, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-27802/v1>

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Abstract

Background

Pork cutting is a very important processing in promoting economic appreciation in the pig industry chain. The purpose of this study was to investigate the proportion and weight of carcass cuts, and to analyze the effects of breeds or hybrids, sex and carcass weight on meat cuts. Simultaneously, explore the correlation between meat segmentation and carcass traits.

Methods

The sampled pigs were raised in Muyuan Food Co., Ltd. (Henan, China) under constant and consistent feeding environment and uniformly slaughtered at 180 days following standard pig slaughter processing. A total of 2,000 pigs from four genotypes of Landrace (LD), Yorkshire (YK), Landrace × Yorkshire (LY) and Duroc × Landrace × Yorkshire (DLY) were sampled and measured for 19 classes carcass cuts traits including its weights and proportions and 10 carcass traits relating to carcass length and back fat products. Effects of carcass weight, sex and genotype on meat cuts and carcass traits were investigated by linear model using home-made R scripts.

Results

The proportion of the middle cut increasing and proportion of the shoulder and leg cut decreasing as carcass weights increasing. More specifically, proportion of backfat increased the highest and the thickness of four-point backfat was significantly increasing with carcass weights increasing, which hint that fat deposition is the major step in the late growth stage. Besides, the proportion of shoulder cut and backfat in barrows are significantly higher than that in sows, while the leg cut is the opposite. The proportion of the middle cut and shoulder cut are the highest in LD and DLY respectively. We also found that the effects of carcass weight, sex and breed for carcass traits are consistent with cutting meats. Furthermore, the correlation between the proportions of most cutting meats and carcass traits was low.

Conclusions

The effects of carcass weight, sex and genotype on the weight and proportion of most cutting meats and carcass traits reflect the characteristic of breeds and its differential character of growth to fatten developments between sex. The above results laid an important foundation for the breeding of pig carcass composition.

1 Introduction

As a country with a long history of meat production and consumption, China has a variety of ways to cook and eat pork [1–3]. There are specific cooking methods for meat from different parts of carcass to achieve the best flavor [3, 4]. Recently, with the continuous improvement of people's living standards, the people's requirements for pork quality are also constantly increasing [5, 6]. While the current meat sales model is the traditional retail model, the carcass was cut into pieces by individual butchers at will [7, 8]. The difference in sales price of pork in different pieces is relatively small, which neither reflect the differentiation of different quality meats, nor establish a standardized cutting method [9, 10]. In this way, the meat with the highest economic value cannot be fully utilized. In addition, as

the meat with different quality cannot be accurately divided, the cooking method is also limited. Consumers cannot use the best method to cook the meats based on its characteristics of different parts of the pig [4]. Moreover, this will not take full advantage of people's preferences of different parts of pork in different regions in China to enhance the economic value of carcasses. In the new century, fast-paced, high-quality lifestyles and high-standard consumption concepts will inevitably bring new market demands [11]. This requires the division of carcass transfer from the traditional cut at will to the method of standard classification by species and anatomical part [12]. Besides, the weight and quality of the cut product in each part need to be carefully evaluated to form pre-sale small package cuts or freezer cuts [23]. In Asia, more and more pre-packaged chilled and frozen meat are sold in supermarkets and butcher shops [13].

On the other side, pre-sliced and pre-packaged chilled meat and frozen meat are also important measures to control swine epidemic diseases. For example, the outbreak of African swine fever in August 2018 led to rapid and nationwide epidemic because of live pig transportation across provinces and cities in China [13, 24, 30]. In order to effectively cut off this transmission channel, the ministry of agriculture and rural areas prohibition of live pig transportation and switch to pork cold chain transportation. The change of the sales mode of pig has significantly accelerated the process of centralized pork slaughter, standardized quarantine, and cold chain cutting after slaughter. Many large-scale breeding companies have quickly set up slaughterhouses, adding slaughter-cutting processes to the breeding industry chain to maximize their economic value. However, in the process of slaughtering and cutting, the proportion and variation of carcass cut productions, the comparison of cut products between different genotype and sex, and the range of net gain from carcass to cuts productions are rare investigated [17]. Nowadays, research on meat cutting has mainly focused on the cut of beef carcass [18–20]. To clarify the above problems, we sampled and measured 2000 pig carcass cut products of four genotypes from Longda Muyuan Food Co., Ltd. (Henan, China) for systematic investigation. The carcass of each pig was divided into eighteen kinds of cut products, and the weight of each cut product was recorded. In addition, ten carcass performance traits, including carcass length, the length and number of thoracic and lumbar vertebrae, and backfat thickness were also measured. We estimated the ranges of cut products and their proportion and variation in the carcass, explored the differences of segmented products in different genotype and established associations between cut products. This lays the foundation for evaluating the heritability of different cuts and analyzing the genetic mechanism affecting the proportion of cuts.

2 Materials And Methods

- *Ethics statement*

All procedures involving animals followed the guidelines for the care and use of experimental animals approved by the State Council of the People's Republic of China. The ethics committee of Jiangxi Agriculture University specially approved this study.

- *Sampling*

Pigs were raised in Muyuan Food Co., Ltd. (Henan, China) under constant and consistent feeding environment. After 180 days of age, they were uniformly slaughtered in Longda Muyuan Meat Food Co., Ltd. (Henan, China) following standard pig slaughtering and processing. A total of 2,000 pigs were sampled and 1910 pigs were remained after quality control of filtering the incomplete data, including 788 sows and 1122 barrows, of which 265 are Landrace (LD, 95 sows and 170 barrows), 698 are Yorkshire (YK, 435 sows and 263 barrows), 689 are crossbred of LY

(Landrace × Yorkshire, 402 sows and 287 barrows) and 258 are crossbred of DLY (Duroc × Landrace × Yorkshire, 115 sows and 143 barrows).

- *Slaughter procedure and carcass cutting method*

In the slaughterhouse, the pigs were electrically stunned, exsanguinated, washed, removed heads and feet, peeled, eviscerated, splitted, weighted and stored following the standard commercial slaughtering procedures. In the cold storage, ten carcass characteristics traits including carcass straight length and oblique length, number and length of thoracic and lumbar, backfat thicknesses at shoulder, 6th~7th rib, waist and hip were measured. After 24-hour acid excretion, the carcass was divided into three sections (Shoulder cut, Middle cut, Leg cut) and fourteen commercial products (boston shoulder, picnic shoulder, shoulder ribs, arm bones, shoulder bones, loin, pork belly, ribs, chine bones, backfat, boneless leg, tenderloin, leg bones and pelvis) in the subdividing workshop. The cutting process (Fig. 1) and the cutting products (Fig. 2) are shown in the figure.

- *Statistical analyses*

In the R (version 3.5.3) software, descriptive statistical analysis of the phenotypic data is performed using the *stat.desc* function in *pastecs* package, including maximum, minimum, mean, and coefficient of variation, etc.. The *aov* (analysis of variance, ANOVA) and *LSD.test* (multiple comparisons) function was used to analyze the variance of the phenotype in different weight, sex and genotype. Moreover, the results of ANOVA and multiple comparisons were plotted using the *ggplot2* package [21].

We divided the samples into high, middle, and low groups based on the mean (μ) and standard deviation (s) of the carcass weight in the entire population. Carcass weights of the individuals more than $\mu+s$ was classified as high carcass weight group, and less than $\mu-s$ were classified as low carcass weight group, while the rest individuals were classified as middle carcass weight group. Before analyzing the effects of sex, genotype and carcass weight on the cutting meat, we used a linear model to correct the phenotype data[22,23]. The model used was:

[Please see the supplementary files section to view the equation.] (Eq.1)

Where y represents the phenotypic value; A, B, C represents the fixed effect indicator matrix; w is the fixed effects of the carcass weight (high, middle, low); s is the fixed effects of the sex (female or male); p is the fixed effects of the four genotypes (LD, YK, LY, DLY); e is the residual that conforms to the normal distribution. Calculate the value of A, B and C by Equation 1. When correcting the influence of sex, y is used as the corrected phenotype value. The same method is used to correct carcass weight and group effects.

3 Results And Discussion

- *Descriptive statistics of traits*

From the descriptive statistics (Table 1 and SFig. 1), we find that the three sections (Shoulder cut, Middle cut, Leg cut) are similar in size, and their proportions are around 33%. Among the carcass cutting products, the largest piece is the boneless leg, which has an average proportion (the proportion is the ratio of cutting product in the whole carcass) of 24.73%, and the average weight and standard deviation are 8.77kg and 0.92, ranging from 6.24kg to 12.32kg. The second and third products are picnic shoulder and pork belly, with an average proportion of 18.1% and 13.7%, and the corresponding average weight and standard deviation are 6.42kg and 0.79 and of 4.87kg and 0.73, respectively. The total proportion of the above three cutting products reaches 56.53%, which is higher than the sum

of the remaining cutting meats. Furthermore, there are some high economic value products that play a significant role in improving the overall value of the entire carcass cuts, such as boston shoulder, shoulder ribs, loin, ribs, tenderloin, etc. Among them, tenderloin has the smallest proportion, 0.97%, but it is the best quality meat in pork. For details of the weight, proportion, range and standard deviation of cutting products are listed in the Table 1. In carcass traits (Supplementary Table 1), the number of thoracic vertebrae and lumbar vertebrae ranged from 14 to 17 and 4 to 7, respectively. This may be the main reason for the large variation in carcass length, thoracic and lumbar length. In addition, the differences between the thicknesses of the backfat in the four positions are significant, and the order of the average thickness of the four-point backfat is Shoulder > 6th_7th rib > Waist > Hip.

To furthermore investigation into the variation of the cutting products, the coefficient of variation (CV) of weight and proportion of the cutting products were calculated. As expected, CV of weight is relatively large than CV of proportion, most of which is higher than 10%. The highest CV of proportion is backfat, which is 26.9% and the lowest CV of proportion is leg cut with the value of 1.4%. Similarly, the CV of carcass traits (except for the thickness of the backfat) ranges from 3% to 9%, while the CV of the backfat thickness ranges from 18% to 28% (Supplementary Table 1). The CV of the backfat of hip is the largest, with a value of 27.36%. In summary, the cutting meats and carcass traits vary greatly among different individuals, and they are affected by various factors such as carcass weight, sex, genotype, environment and so on.

- *The effect of carcass weight*

The carcass cuts products are significantly impacted by carcass weight (Table 2; $P < 0.01$). Unsurprisingly, the weight of all cutting meat increase with the increase of carcass weight. In contrast, carcass weight has a dissimilar effect on the proportion of cutting meat, which has a significant negative effect on most bone products (shoulder ribs, arm bones, shoulder bones, chine bones, leg bones and pelvis, except for ribs), shoulder cut and leg cut, while has a significant positive effect on pork belly, backfat and middle cut (SFig.2). The products with the largest increase in proportion are pork belly and backfat (increasing 1.19% and 0.81%), and the largest declining are the leg bones, ribs and arm bones (decreasing 0.53%, 0.39% and 0.34%). In the three block products, with the increase of carcass weight, the proportion of the middle cut increases significantly (the rise was 1.69%), and the proportion of the shoulder cut and leg cut decrease significantly (the falling-offs were 0.82% and 0.87%). No significant effects are observed for most meat products impacted by carcass weight (boston shoulder, picnic shoulder, loin, boneless leg and tenderloin, except for pork belly and backfat) ($P > 0.05$). This is consistent with the development and growth of pigs. At the beginning of the growth stage, the pigs are mainly growing the bone and muscles, and the proportion of muscle and bone products increases as the pig grows up. At the late stage of growth, the bone growth is mature and the feeding energy is mainly used for muscle growth and fat deposition. The proportion of muscles and bones is decreasing with the increase of carcass weight. [24,25] The proportion of middle cut significantly increases as it mainly contains fat and muscles. As the middle cut is the most valuable production, it hints us to properly extend the pig growth stage would gain more net economic values.

- *The effect of sex*

As can be seen from Table 3 and Supplementary Fig.3, the barrow is significantly heavier than sow on the weight of most cutting meats except for ribs, chine bones and pelvis. In the comparison of proportion of cutting meat between barrow and sow, the results are distinct. Sex has the greatest impact on backfat, and the proportion of backfat in barrow was 0.47% more than that of sow, which is equivalent to an increase of 15.51% of the backfat. Followed by the loin, contrary to the backfat, the proportion of backfat in sow was 0.3% more than that in barrow. Moreover, in the study of [26,27], it was also found that the proportion of loin in sows was significantly higher than that in barrow,

while the proportion of backfat was the opposite. As loin and backfat are main parts of middle cut products and there are no significant differences on the proportion of middle cut between barrow and sow. It seems that the barrows are fatter than sows, which is out of our expectations, and is conflicting with the findings of Álvarez-Rodríguez & Teixeira [17]. Recall the fact that the barrow is significantly heavier than sow on the weight of most cutting meats, which means the weight of carcass would have the same result. We herein test the differences of carcass weight between barrows and sows and significant differences were detected (P value = 2.18×10^{-8}). As barrows and sows were under same feeding time, we hypothesis that the higher proportion of fat in barrow than sow is because of the asynchrony of growth and development between the two sexes. It seems that barrows grow faster than sows and reach fattening stage earlier. To confirm this hypothesis, the four traits including picnic shoulder, pork belly, boneless leg and backfat were conducted regression analysis with body weight respectively. It can be seen from Fig. 3 that the weight and proportion of the backfat in the barrow is heavier than that in the sow under the same carcass weight. And as the carcass weight increases, the weight and proportion of backfat in the barrow increases faster than that in the sow. However, as the carcass weight increases, the weight and proportion of the pork belly in the sow grows faster than that in the barrow, while the sow's picnic shoulder and boneless leg grow at a rate similar to that of the barrow, and the trend of the proportion of picnic shoulder and boneless leg in barrows and sows is close to the same level. Results hint that barrows growing faster and reaching fattening stage earlier than sows prompts us that it's better to breed the pigs separately by sex. The barrow should be slaughtered several days earlier than sows to decrease the fattening time and to provide products with more uniform specifications according to the market demand in different regions. In the three sections of carcass, the proportion of shoulder cut of the sow was higher and the proportion of leg cut was lower than that of the barrow. This means that the main increasing part are the shoulder cut at the growth stage and are the leg cut at the fattening stage during pig development. As different market regions of China have different demands for carcass cutting products, we can adjust the time of pigs come out to the market to fit the requirements.

- *The effect of genotype*

As shown in Table 4 and Supplementary Fig.4, there are significant differences between genotype on the weight of almost all cutting meats and proportion of cutting meats. And the order of average slaughter weight of the four species is: DLY > YK > LD > LY. DLY is significantly heavier than LD and LY, also YK is significantly heavier than LY. In the weight and proportion of most cutting products, DLY differs greatly from the other three genotypes. Among the three cut products, the largest different section is the middle cuts, with the order of LD > YK = LY > DLY for the four genotypes and the proportion of LD being 1.17% higher than that of DLY. Following the proportion of the shoulder cut are reverse among the four genotypes and DLY is 0.89% higher than that in LD. The proportion of the leg cut is no significant difference among the four genotypes. The proportion differences reflect the differences in body structure between LD and DLY. LD is famous for the body length, so the proportion and weight of middle cut and its derivative products are higher and heavier than other genotypes. LY is a hybrid of LD and YK, and its proportion of cutting meats is often between the two. There are also others cutting products with large differences (such as pork belly, picnic shoulder, backfat and boston shoulder) between LD and DLY which were mainly from the shoulder and middle cut. Of which, pork belly is the product with the largest difference in proportion, with the proportion of LD being 0.8% higher than that of DLY. Their differences of these cutting products in DLY and LD varieties are consistent with the differences of the section where they are from.

- *The effects of slaughter weight, sex and genotype on the carcass performance*

Similarly, the sex has an extremely significant effect on most of carcass traits (Supplementary Table 2). We found that barrows were shorter in length (including straight length and oblique length of carcass, thoracic and lumbar length), but were heavier in carcass weight and thicker backfat than sows. This is consistent with the results of [27,30,26]. This also confirmed our hypothesis from the other side that the different growth curves between barrows and sows. The growth rate of barrows is faster while the growing stage of sows is longer. The barrows start to deposit fat earlier than sows in the later stage, which results in heavier carcass weight and more backfat. The sows still keep growing and developing at the time of barrows' starting of fat deposition, which results of longer body length and lighter carcass weight. This is also in keeping with cutting products results that gilts have higher proportion of ribs and loin and lower proportion of backfat than barrows. Similar to effect of carcass weight, thoracic length explained about 95% of extra increase of straight length in sows. Therefore, we believe that the effect of gender on straight length is mainly concentrated on the effect of the thoracic length. In the backfat thickness, the four-point backfat of the barrows is significantly thicker than that of the sows. This explains why the proportion of backfat in barrows is significantly higher than that in sows, and the proportion of loin, ribs and chine bones in sows are significantly higher than that in barrows.

As for the effect of variety on carcass traits, we can find that the longest carcass straight length is LD, which is significantly longer than the other three groups (Supplementary Table 3). Moreover, the differences in carcass length between LD and the other three groups are mainly caused by the differences of the number and length of thoracic. This is consistent with the result that the proportion of middle segment in LD is significantly higher than that in other genotypes. For the backfat thicknesses traits, the front three points (shoulder, 6th-7th rib and waist) of DLY have the thickest backfat, while the proportion of backfat in DLY is the lowest. The possible reason is that LD is the longest and DLY is the shorter of straight length and proportion of backfat is mainly from the middle cut, the increment of backfat by increase of body length higher than that by increase of backfat thickness.

- *Correlation between cutting products and carcass traits.*

We conducted a correlation analysis between the proportion of cutting meats and carcass traits. It can be found that the correlations of most carcass cuts and carcass traits were relatively low ($r < 0.3$, Fig. 4 and Supplementary Table 4). The strong correlation pairs were correlations between picnic shoulder and shoulder cut ($r = 0.68$), pork belly and middle cut ($r = 0.68$), boneless leg and leg cut ($r = 0.87$). This is because these cutting products are the highest proportions from the three preliminary cutting section. Among carcass traits, the correlation between four-point backfat thickness is high (correlation coefficient $r > 0.41$) while is lowly correlated to other carcass performance traits. The four-point backfat thickness has a medium positive correlation with the segmented product in the middle cut (pork belly, backfat and middle cut), with the correlation coefficient between 0.27 and 0.60. The backfat of hip is moderately negatively correlated with arm bones and leg bones, with correlation coefficients of -0.25 and -0.46, respectively. However, the correlation between other carcass traits with cutting products are low, and the correlation coefficients are less than 0.3.

4 Conclusions

We determined the proportion and weight of each cutting product in carcasses from multi-population (Landrace, Yorkshire, Landrace × Yorkshire and Duroc × Landrace × Yorkshire). The use of Bluetooth electronic scales and electronic tag recognition technology improving the efficiency of the measurement on the slaughterhouse division line and ensuring the accuracy of the experimental data collection.

Variance analysis find that the carcass weight, gender and genotypes have significant effects on carcass traits and carcass cutting products. We clarify the changes of proportion of the cutting production with the increase of carcass weight by combining the pig growth and development curves. We conjecture that the abnormal phenomena of higher proportion of fat in barrow than sow is because of the asynchrony of growth and development between the two sexes. We also found that LD has the highest proportion of the middle cut and its cuts (including loin, pork belly, chine bones, backfat) as it were the longest body length and thoracic length in the four genotypes. Correlation study between carcass traits and carcass cutting products help us to further understand the changes of proportion of cutting productions with carcass weight, sex and genotypes.

This study shows that there is still great potential for improvement in the breeding of various carcass cuts.

Declarations

Ethics approval and consent to participate: Not applicable.

Consent for publication: Not applicable.

Availability of data and material:

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interest:

The authors declare that they have no conflict of interest.

Funding:

This work was supported by Special Funds for Scientific and Technological Innovation Strategy in Guangdong Province [grant number No.2018B020203003] and National Natural Science Foundation of China [grant number 31760656] and Guangdong Sail Plan Introduction of Innovative and Entrepreneurship Research Team Program [grant number No. 2016YT03H062].

Authors' contributions:

Lei Xie: Methodology, Software, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Visualization. **Jiangtao Qin:** Methodology, Investigation, Data Curation. **Xi Tang:** Investigation. **Dengshuai Cui:** Investigation. **Shijun Xiao:** Conceptualization, Methodology, Supervision, Project administration, Funding acquisition. **Zhiyan Zhang:** Conceptualization, Methodology, Validation, Formal analysis, Writing - Review & Editing, Supervision, Project administration, Funding acquisition. **Lusheng Huang:** Conceptualization, Methodology, Resources, Supervision, Project administration, Funding acquisition.

Acknowledgements:

The authors would like to acknowledge the Special Funds for Scientific and Technological Innovation Strategy in Guangdong Province, National Natural Science Foundation of China, and Guangdong Sail Plan Introduction of Innovative and Entrepreneurship Research Team Program for their financial support. Special thanks are given to

Muyuan Food Co., Ltd. (Henan, China) and Longda Muyuan Meat Food Co., Ltd. (Henan, China) for providing the pig and meat samples.

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References

1. Liu R, Xing L, Zhou G, Zhang W. What is meat in China? *Animal Frontiers*. 2017;7(4):53 – 6. 'doi':10.2527/af.2017.0445.
2. Zeng W, Wen W, Deng Y, Tian Y, Sun H, Sun Q. Chinese ethnic meat products: Continuity and development. *MEAT SCI*. 2016;120:37–46. 'doi':10.1016/j.meatsci.2016.04.007.
3. Nam K, Jo C, Lee M. Meat products and consumption culture in the East. *MEAT SCI*. 2010;86(1):95–102. 'doi':10.1016/j.meatsci.2010.04.026.
4. Ho HF. ETHNIC MEAT PRODUCTS | China. In: Jensen WK, 'editor'. *Encyclopedia of Meat Sciences*. Oxford: Elsevier; 2004. pp. 441–4.
5. Wang S. XWYZ. Safe and high quality chilled meat. *Meat Industry*. 2011;361:50–1.
6. Meng B, Wang X, Zhang J, Wang H, Zhang H, Jiang W. China Meat Products Development Trend. *Meat industry*. 2011(08):6–8.
7. Liu H. DS. China pork consumption situation and outlook. *Agriculture Outlook*. 2010;52:35–8.
8. Gong SL, Yang YS, Shen H, Wang XY, Guo HP, Bai L. Meat handling practices in households of Mainland China. *FOOD CONTROL*. 2011;22(5):749 – 55. 'doi':10.1016/j.foodcont.2010.11.009.
9. Li J, Zhang P, Sun X, Wang X, Si D. Research on the Current Situation of Standard System of Meat and Meat Products in China. *Meat Research*. 2017;31(05):56–60.
10. Xiong L, Li J, Li D. The current status of China's meat and meat product regulations and standards system. *Meat Research*. 2011;25(05):46–53.
11. Grunert KG. Future trends and consumer lifestyles with regard to meat consumption. *MEAT SCI*. 2006;74(1):149–60. 'doi':https://doi.org/10.1016/j.meatsci.2006.04.016.

12. Zhou G, Zhang W, Xu X. China's meat industry revolution: Challenges and opportunities for the future. *MEAT SCI.* 2012;92(3):188–96. <https://doi.org/10.1016/j.meatsci.2012.04.016>. 'doi:'.
13. Wang HH, Chen J, Bai J, Lai J. Meat packaging, preservation, and marketing implications: Consumer preferences in an emerging economy. *MEAT SCI.* 2018;145:300–7. 'doi:'<https://doi.org/10.1016/j.meatsci.2018.06.022>.
14. Li X, Tian K. African swine fever in China. *VET REC.* 2018;183(9):300. 'doi:'10.1136/vr.k3774.
15. Zhou X, Li N, Luo Y, Liu Y, Miao F, Chen T, et al. Emergence of African Swine Fever in China, 2018. *TRANSBOUND EMERG DIS.* 2018;65(6):1482-4. 'doi:'10.1111/tbed.12989.
16. Wang T, Sun Y, Qiu H. African swine fever: an unprecedented disaster and challenge to China. *INFECT DIS POVERTY.* 2018;7(1):111. 'doi:'10.1186/s40249-018-0495-3.
17. Álvarez-Rodríguez J, Teixeira A. Slaughter weight rather than sex affects carcass cuts and tissue composition of Bisaro pigs. *MEAT SCI.* 2019;154:54–60. 'doi:'10.1016/j.meatsci.2019.04.012.
18. Jung EY, Hwang YH, Joo ST. Muscle profiling to improve the value of retail meat cuts. *MEAT SCI.* 2016;120:47–53. 'doi:'<https://doi.org/10.1016/j.meatsci.2016.04.012>.
19. Pfeiffer KD, Voges KL, King DA, Griffin DB, Savell JW. Innovative wholesale carcass fabrication and retail cutting to optimize beef value. *MEAT SCI.* 2005;71(4):743–52. <https://doi.org/10.1016/j.meatsci.2005.05.023>. 'doi:'.
20. Lorenzo JM, Guedes CM, Agregán R, Sarriés MV, Franco D, Silva SR. Prediction of foal carcass composition and wholesale cut yields by using video image analysis. *ANIMAL.* 2018;12(1):174 – 82. 'doi:'10.1017/S1751731117001537.
21. Wickham H. *ggplot2: Elegant Graphics for Data Analysis*. New York: Springer-Verlag; 2016.
22. Hoffman GE. Correcting for Population Structure and Kinship Using the Linear Mixed Model: Theory and Extensions. *PLOS ONE.* 2013;8(10):e75707.
23. Zhou X, Stephens M. Genome-wide efficient mixed-model analysis for association studies. *NAT GENET.* 2012;44(7):821-4. 'doi:'10.1038/ng.2310.
24. Gerrard DE, Mills EW, Forrest JC, Judge M, Merkel RA, Aberle ED. *Principles of meat science*. Fifth edition ed: Dubuque, IA: Kendall Hunt Publishing Company; 2012.
25. Lonergan SM, Topel DG, Marple DN. Chapter 6 - Growth curves and growth patterns. In: Lonergan SM, Topel DG, Marple DN. "editors". *The Science of Animal Growth and Meat Technology*. Second Edition): Academic Press; 2019. pp. 71–109.
26. Morales JI, Cámara L, Berrocoso JD, López JP, Mateos GG, Serrano MP. Influence of sex and castration on growth performance and carcass quality of crossbred pigs from 2 Large White sire lines1. *J ANIM SCI.* 2011;89(11):3481-9. 'doi:'10.2527/jas.2010-3357.
27. Latorre MA, Lázaro R, Gracia MI, Nieto M, Mateos GG. Effect of sex and terminal sire genotype on performance, carcass characteristics, and meat quality of pigs slaughtered at 117 kg body weight. *MEAT SCI.* 2003;65(4):1369–77. 'doi:'[https://doi.org/10.1016/S0309-1740\(03\)00059-7](https://doi.org/10.1016/S0309-1740(03)00059-7).
28. Kouba M, Bonneau M. Compared development of intermuscular and subcutaneous fat in carcass and primal cuts of growing pigs from 30 to 140 kg body weight. *MEAT SCI.* 2009;81(1):270–4. 'doi:'<https://doi.org/10.1016/j.meatsci.2008.08.001>.
29. Shields RJ, Mahan DC, Graham PL. Changes in swine body composition from birth to 145 kg. *J ANIM SCI.* 1983;57(1):43–54. 'doi:'10.2527/jas1983.57143x.

30. Correa JA, Faucitano L, Laforest JP, Rivest J, Marcoux M, Gariépy C. Effects of slaughter weight on carcass composition and meat quality in pigs of two different growth rates. MEAT SCI. 2006;72(1):91 – 9.
'doi:'10.1016/j.meatsci.2005.06.006.

Tables

Table 1

Descriptive statistics of carcass cut weights and proportions.

Cuts name	Class	n	Weight (kg)				Proportion (%)			
			min	max	mean ± s.d.	coef.var	min	max	mean ± s.d.	coef.var
Boston shoulder	Muscle	1824	0.88	2.98	1.62 ± 0.31	18.8%	2.47	8.47	4.53 ± 0.75	16.5%
Picnic shoulder	Muscle	1825	3.82	9.20	6.56 ± 0.77	11.7%	11.79	22.36	18.37 ± 1.27	6.9%
Shoulder ribs	Bone	1825	1.07	3.30	2.18 ± 0.31	14.1%	3.52	8.74	6.11 ± 0.76	12.4%
Arm bones	Bone	1824	0.71	1.37	1.01 ± 0.1	9.4%	1.94	3.95	2.83 ± 0.26	9.2%
Shoulder bones	Bone	1825	0.44	1.19	0.76 ± 0.11	14.1%	1.22	3.15	2.13 ± 0.29	13.5%
Shoulder cut	/	1825	8.33	16.15	12.13 ± 1.17	9.6%	26.99	40.52	33.98 ± 1.64	4.8%
Loin	Muscle	1825	1.55	3.76	2.52 ± 0.34	13.3%	4.95	10.14	7.08 ± 0.71	10.0%
Pork belly	Muscle	1825	2.22	7.71	4.78 ± 0.73	15.2%	8.15	18.77	13.35 ± 1.24	9.3%
Ribs	Bone	1805	0.87	2.37	1.56 ± 0.21	13.8%	2.81	6.08	4.35 ± 0.46	10.5%
Chine bones	Bone	1805	1.00	2.57	1.70 ± 0.24	13.8%	3.19	6.97	4.77 ± 0.54	11.4%
Backfat	Fat	1824	0.07	2.51	1.09 ± 0.35	31.8%	0.45	6.40	3.03 ± 0.82	26.9%
Middle cut	/	1825	7.06	17.01	11.65 ± 1.45	12.4%	25.58	38.82	32.58 ± 1.81	5.5%
Boneless leg	Muscle	1825	6.19	12.45	8.93 ± 0.91	10.2%	17.84	30.52	24.99 ± 1.15	4.6%
Tenderloin	Muscle	1736	0.14	0.60	0.34 ± 0.06	16.6%	0.35	1.50	0.95 ± 0.13	13.8%
Leg bones	Bone	1804	1.11	1.93	1.49 ± 0.12	7.7%	3.13	5.59	4.20 ± 0.32	7.5%
Pelvis	Bone	1586	0.71	2.03	1.24 ± 0.19	15.3%	2.21	5.60	3.47 ± 0.49	14.2%
Leg cut	/	1825	8.67	15.69	11.94 ± 1.10	9.2%	25.31	40.21	33.44 ± 1.38	4.1%
Half carcass	/	1825	25.59	47.85	35.72 ± 3.32	9.3%				

s.d. = Standard deviation

coef.var = Coefficient of variation

Table 2

The weight and proportion of carcass cuts were affected by carcass weight.

Cuts name	Weight (kg)			Proportion (%)			P value	
	High	Middle	Low	High	Middle	Low	Weight	Proportion
n	297	1209	319	297	1209	319	\	\
Boston shoulder	1.86 ± 0.30 ^a	1.62 ± 0.28 ^b	1.41 ± 0.23 ^c	4.52 ± 0.73	4.52 ± 0.77	4.60 ± 0.70	5.19E-79	0.21
Picnic shoulder	7.53 ± 0.56 ^a	6.56 ± 0.57 ^b	5.67 ± 0.47 ^c	18.49 ± 1.22 ^a	18.37 ± 1.28 ^{ab}	18.26 ± 1.26 ^b	<1.00E-100	0.08
Shoulder ribs	2.41 ± 0.29 ^a	2.18 ± 0.28 ^b	1.97 ± 0.28 ^c	5.93 ± 0.69 ^c	6.10 ± 0.73 ^a	6.32 ± 0.85 ^b	2.05E-77	1.22E-09
Arm bones	1.08 ± 0.09 ^a	1.01 ± 0.08 ^b	0.93 ± 0.09 ^c	2.66 ± 0.23 ^c	2.83 ± 0.24 ^a	3.00 ± 0.28 ^b	1.76E-94	2.73E-63
Shoulder bones	0.81 ± 0.11 ^a	0.76 ± 0.10 ^b	0.70 ± 0.09 ^c	2.01 ± 0.27 ^c	2.13 ± 0.28 ^a	2.24 ± 0.27 ^b	1.32E-42	7.80E-23
Shoulder cut	13.69 ± 0.76 ^a	12.13 ± 0.79 ^b	10.68 ± 0.72 ^c	33.6 ± 1.54 ^c	33.95 ± 1.62 ^a	34.42 ± 1.74 ^b	<1.00E-100	3.05E-09
Loin	2.85 ± 0.30 ^a	2.52 ± 0.28 ^b	2.21 ± 0.25 ^c	7.02 ± 0.66 ^b	7.07 ± 0.72 ^{ab}	7.15 ± 0.70 ^a	<1.00E-100	0.08
Pork belly	5.68 ± 0.57 ^a	4.79 ± 0.52 ^b	3.92 ± 0.44 ^c	13.87 ± 1.13 ^a	13.39 ± 1.21 ^c	12.68 ± 1.2 ^b	<1.00E-100	8.72E-34
Ribs	1.78 ± 0.18 ^a	1.55 ± 0.18 ^b	1.36 ± 0.16 ^c	4.38 ± 0.42	4.34 ± 0.45	4.38 ± 0.50	<1.00E-100	0.25
Chine bones	1.91 ± 0.21 ^a	1.69 ± 0.21 ^b	1.51 ± 0.19 ^c	4.70 ± 0.49 ^b	4.75 ± 0.54 ^a	4.89 ± 0.58 ^b	<1.00E-100	3.15E-05
Backfat	1.39 ± 0.34 ^a	1.10 ± 0.30 ^b	0.78 ± 0.26 ^c	3.37 ± 0.76 ^a	3.08 ± 0.78 ^c	2.56 ± 0.79 ^b	<1.00E-100	8.84E-37
Middle cut	13.62 ± 1.00 ^a	11.66 ± 0.93 ^b	9.78 ± 0.82 ^c	33.34 ± 1.61 ^a	32.64 ± 1.75 ^c	31.65 ± 1.82 ^b	<1.00E-100	9.42E-32
Boneless leg	10.17 ± 0.59 ^a	8.92 ± 0.61 ^b	7.78 ± 0.5 ^c	24.98 ± 1.07	24.98 ± 1.17	25.07 ± 1.16	<1.00E-100	0.40
Tenderloin	0.39 ± 0.06 ^a	0.34 ± 0.05 ^b	0.29 ± 0.04 ^c	0.94 ± 0.14	0.95 ± 0.13	0.95 ± 0.13	2.02E-98	0.70
Leg bones	1.60 ± 0.10 ^a	1.50 ± 0.10 ^b	1.39 ± 0.10 ^c	3.94 ± 0.26 ^c	4.19 ± 0.27 ^a	4.47 ± 0.31 ^b	<1.00E-100	<1.00E-100
Pelvis	1.36 ± 0.17 ^a	1.24 ± 0.18 ^b	1.11 ± 0.16 ^c	3.35 ± 0.42 ^c	3.47 ± 0.51 ^a	3.56 ± 0.48 ^b	2.87E-62	3.11E-06
Leg cut	13.46 ± 0.67 ^a	11.94 ± 0.72 ^b	10.52 ± 0.60 ^c	33.05 ± 1.21 ^c	33.41 ± 1.38 ^a	33.92 ± 1.36 ^b	<1.00E-100	1.09E-14

The data in the table are mean ± standard deviation.

Within each row, containing different letter (a, b, c, d) denote statistical differences between groups ($P < 0.05$). P_value represents the significance of multiple comparisons, when $p < 0.05$, it means that the difference between carcass weight levels is significant.

Table 3

The weight and proportion of carcass cuts were affected by sex.

Cuts name	Weight (kg)		Proportion (%)		P_value	
	Sow	Barrow	Sow	Barrow	Weight	Proportion
n	1099	726	1099	726	\	\
Boston shoulder	1.62 ± 0.29	1.69 ± 0.33	4.53 ± 0.72	4.61 ± 0.79	9.34E-07	0.03
Picnic shoulder	6.56 ± 0.74	6.80 ± 0.81	18.37 ± 1.20	18.59 ± 1.37	1.41E-10	3.18E-04
Shoulder ribs	2.18 ± 0.30	2.24 ± 0.32	6.11 ± 0.75	6.11 ± 0.77	1.75E-04	0.89
Arm bones	1.01 ± 0.09	1.05 ± 0.10	2.83 ± 0.26	2.87 ± 0.27	1.86E-16	4.16E-03
Shoulder bones	0.76 ± 0.11	0.79 ± 0.10	2.13 ± 0.30	2.17 ± 0.27	1.99E-09	0.01
Shoulder cut	12.13 ± 1.12	12.57 ± 1.23	33.98 ± 1.62	34.35 ± 1.68	1.32E-14	2.18E-06
Loin	2.52 ± 0.33	2.48 ± 0.35	7.08 ± 0.71	6.78 ± 0.70	0.01	6.28E-18
Pork belly	4.78 ± 0.73	4.91 ± 0.73	13.35 ± 1.28	13.36 ± 1.18	3.13E-04	0.77
Ribs	1.56 ± 0.21	1.56 ± 0.22	4.35 ± 0.46	4.27 ± 0.45	0.37	2.21E-04
Chine bones	1.70 ± 0.23	1.72 ± 0.24	4.77 ± 0.56	4.70 ± 0.52	0.09	7.10E-03
Backfat	1.09 ± 0.33	1.29 ± 0.38	3.03 ± 0.78	3.50 ± 0.87	3.99E-32	7.43E-32
Middle cut	11.65 ± 1.4	11.96 ± 1.51	32.58 ± 1.81	32.61 ± 1.81	7.61E-06	0.69
Boneless leg	8.93 ± 0.87	9.06 ± 0.96	24.99 ± 1.10	24.75 ± 1.22	1.88E-03	1.18E-05
Tenderloin	0.34 ± 0.06	0.33 ± 0.06	0.95 ± 0.13	0.91 ± 0.13	0.01	4.08E-11
Leg bones	1.49 ± 0.11	1.52 ± 0.12	4.2 ± 0.31	4.17 ± 0.32	5.94E-07	0.09
Pelvis	1.24 ± 0.19	1.22 ± 0.18	3.47 ± 0.50	3.35 ± 0.48	0.22	4.38E-06
Leg cut	11.94 ± 1.06	12.09 ± 1.16	33.44 ± 1.3	33.03 ± 1.48	4.79E-03	7.21E-10
Half carcass	35.72 ± 3.20	36.61 ± 3.50			2.18E-08	

The data in the table are mean ± standard deviation.

The P_value represents the significance of the analysis of variance, when $p < 0.05$, it means that the difference between sexes is significant.

Table 4

The weight and proportion of carcass cuts were affected by genotype.

Cuts name	Weight (kg)				Proportion (%)				P_value	
	LD	YK	LY	DLY	LD	YK	LY	DLY	Weight	Proportion
n	240	667	670	248	240	667	670	248	\	\
Boston shoulder	1.69 ± 0.30 ^a	1.68 ± 0.29 ^a	1.71 ± 0.31 ^a	1.62 ± 0.34 ^b	4.86 ± 0.77 ^{ab}	4.76 ± 0.74 ^b	4.92 ± 0.73 ^a	4.53 ± 0.81 ^c	7.88E-04	5.20E-11
Picnic shoulder	6.18 ± 0.74 ^c	6.42 ± 0.77 ^b	6.24 ± 0.79 ^c	6.56 ± 0.74 ^a	17.72 ± 1.41 ^d	18.15 ± 1.21 ^b	17.93 ± 1.29 ^c	18.37 ± 1.21 ^a	1.81E-10	4.81E-09
Shoulder ribs	2.01 ± 0.30 ^c	2.08 ± 0.31 ^b	2.05 ± 0.31 ^c	2.18 ± 0.28 ^a	5.77 ± 0.79 ^c	5.90 ± 0.77 ^b	5.89 ± 0.76 ^b	6.11 ± 0.66 ^a	9.26E-10	1.24E-05
Arm bones	0.95 ± 0.10 ^c	0.97 ± 0.09 ^b	0.96 ± 0.10 ^c	1.01 ± 0.10 ^a	2.72 ± 0.26 ^c	2.77 ± 0.26 ^b	2.77 ± 0.27 ^b	2.83 ± 0.26 ^a	2.29E-13	9.86E-05
Shoulder bones	0.70 ± 0.11 ^b	0.70 ± 0.10 ^b	0.70 ± 0.11 ^b	0.76 ± 0.10 ^a	2.01 ± 0.31 ^{bc}	1.98 ± 0.29 ^c	2.03 ± 0.29 ^b	2.13 ± 0.27 ^a	2.89E-14	4.62E-11
Shoulder cut	11.53 ± 1.09 ^c	11.85 ± 1.14 ^b	11.67 ± 1.22 ^c	12.13 ± 1.16 ^a	33.09 ± 1.83 ^c	33.53 ± 1.58 ^b	33.54 ± 1.67 ^b	33.98 ± 1.58 ^a	5.69E-09	1.09E-07
Loin	2.51 ± 0.31	2.50 ± 0.34	2.51 ± 0.35	2.52 ± 0.31	7.20 ± 0.73 ^a	7.08 ± 0.70 ^b	7.22 ± 0.71 ^a	7.08 ± 0.69 ^b	0.85	3.23E-04
Pork belly	4.96 ± 0.79 ^a	4.89 ± 0.69 ^a	4.76 ± 0.75 ^b	4.78 ± 0.71 ^b	14.15 ± 1.51 ^a	13.81 ± 1.21 ^b	13.62 ± 1.22 ^c	13.35 ± 1.13 ^d	2.01E-04	1.49E-12
Ribs	1.46 ± 0.21 ^c	1.53 ± 0.20 ^{ab}	1.51 ± 0.21 ^b	1.56 ± 0.25 ^a	4.19 ± 0.45 ^b	4.32 ± 0.42 ^a	4.33 ± 0.45 ^a	4.35 ± 0.57 ^a	8.35E-06	1.32E-04
Chine bones	1.70 ± 0.25 ^a	1.71 ± 0.23 ^a	1.67 ± 0.25 ^b	1.70 ± 0.22 ^{ab}	4.88 ± 0.58 ^a	4.86 ± 0.53 ^a	4.79 ± 0.57 ^b	4.77 ± 0.5 ^b	2.75E-03	0.02
Backfat	1.19 ± 0.35 ^a	1.12 ± 0.34 ^b	1.10 ± 0.35 ^b	1.09 ± 0.34 ^b	3.38 ± 0.87 ^a	3.14 ± 0.80 ^b	3.14 ± 0.82 ^b	3.03 ± 0.81 ^b	7.11E-03	2.80E-05
Middle cut	11.8 ± 1.43 ^a	11.76 ± 1.41 ^a	11.54 ± 1.51 ^b	11.65 ± 1.40 ^{ab}	33.75 ± 1.98 ^a	33.22 ± 1.77 ^b	33.08 ± 1.81 ^b	32.58 ± 1.74 ^c	0.02	2.37E-11
Boneless leg	8.62 ± 0.84 ^b	8.75 ± 0.87 ^b	8.67 ± 0.97 ^b	8.93 ± 0.91 ^a	24.71 ± 1.1 ^b	24.75 ± 1.15 ^b	24.88 ± 1.16 ^a	24.99 ± 1.18 ^a	3.38E-04	7.55E-03
Tenderloin	0.34 ± 0.05 ^b	0.35 ± 0.06 ^a	0.35 ± 0.06 ^a	0.34 ± 0.06 ^b	0.97 ± 0.14 ^b	1.00 ± 0.14 ^a	1.00 ± 0.13 ^a	0.95 ± 0.12 ^b	1.13E-03	4.82E-06
Leg bones	1.42 ± 0.11 ^c	1.44 ± 0.11 ^b	1.44 ± 0.12 ^b	1.49 ± 0.13 ^a	4.08 ± 0.30 ^c	4.09 ± 0.32 ^c	4.15 ± 0.32 ^b	4.20 ± 0.29 ^a	3.87E-13	4.91E-06
Pelvis	1.21 ± 0.19 ^{ab}	1.23 ± 0.20 ^a	1.19 ± 0.18 ^b	1.24 ± 0.19 ^a	3.48 ± 0.50	3.48 ± 0.54	3.41 ± 0.44	3.47 ± 0.48	3.88E-04	0.11
Leg cut	11.56 ± 1.03 ^c	11.74 ± 1.04 ^b	11.62 ± 1.17 ^c	11.94 ± 1.12 ^a	33.16 ± 1.36 ^b	33.25 ± 1.35 ^{ab}	33.38 ± 1.40 ^a	33.44 ± 1.42 ^a	1.39E-04	0.04
Half carcass	34.89 ± 3.08 ^{bc}	35.35 ± 3.21 ^{ab}	34.82 ± 3.53 ^c	35.72 ± 3.28 ^a					5.51E-04	

The data in the table are mean ± standard deviation.

Within each row, containing different letter (a, b, c, d) denote statistical differences between genotypes (P < 0.05). P_value represents the significance of multiple comparisons, when p < 0.05, it means that the difference between genotypes is significant.

LD = Landrace, YK = Yorkshire, LY = Landrace × Yorkshire, DLY = Duroc × Landrace × Yorkshire.

Figures

Figure 1

[See figure]

Figure 2

[See figure]

Figure 3

[See figure]

Figure 4

[See figure]

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