BF-1786
[1-9]

RESEARCH ARTICLE Indian Journal of Animal Research

A Study on Changes of Carcass, Bones and Muscles of Ningxiang Pigs

Wei Zhang[1#], Yinglin Peng[1,2#], Qingming Cui[2], Yitong Chang[1], Yuan Deng[2], Chen Chen[2], Yingying Liu[1,2]

10.18805/IJAR.BF-1786

ABSTRACT

Background: Ningxiang pigs are known for tasty meat and high intramuscular fat content. Currently, the slow growth rate and low lean meat rate of Ningxiang pigs have greatly restricted the development of its market. Therefore, the objective of this study is to explore the changes in carcass traits, meat quality, visceral organ weight indices, bones and muscles development with slaughter ages of Ningxiang pigs.

Methods: The experiment used 0, 60, 120, 180, 240, 300 and 360 days old Ningxiang pigs as the research objects, and 6 castrated male pigs in each group were randomly selected. The carcass traits, meat quality, visceral organs weights and skeletal muscle weights were measured. The correlation between carcass traits and meat quality were analyzed by bivariate analysis, and the regression equations between slaughter ages and these indicators were established.

Result: The results showed that pre-slaughter weight and weights of carcass, head, feet, skeleton and muscle, loin eye area, cooking yield, marbling and the large intestine weight index at 0 d, backfat thickness at 60 d, fat percentages at 60 and 120 d, and the lean meat percentage at 240 d, redness at 120 d of Ningxiang pigs were lowest, the heart, lung, kidney and small intestine weight percentages were highest at 0 d (P<0.05). Carcass traits and meat quality had different significant correlation at different slaughter ages. So the indices of carcass, meat quality, bones and muscles of Ningxiang pigs changed with slaughter ages. In general, the overall performance of 300 d Ningxiang pigs is better.

Key words: Carcass traits, Correlation analysis, Muscle, Ningxiang pig, Slaughter ages.

INTRODUCTION

The growth and development of animal muscles are related to the change of carcass performance and meat quality characteristics in livestock and poultry, which has a direct influence on the improvement of multiple performance indices and the economic benefits of animals (Chen *et al*., 2019). Ningxiang pigs, one of the four most renowned pig breeds in China, are known for tasty meat, high intramuscular fat and unsaturated fatty acid content (Gong *et al*., 2021; Li *et al*., 2021). Studies have shown that the distributions and depositions of bones, muscles and fat in animals present dynamic changes throughout the growth process, and these changes greatly affect the carcass traits and meat quality of animals (Guo *et al*., 2021; Malgwi *et al*., 2022; Zhang *et al*., 2024). Ilavarasan *et al*. (2017) showed that the muscle quality of young pigs was better than that of adult pigs. Guo *et al*. (2021) confirmed a significant increase in muscle pH_{24} and redness value in black-covered pigs with increasing body weight.

In recent years, the supply and demand of pork in the market is far from meeting the needs of consumers, so entrepreneurs to introduce many fast-growing and high-yielding breeds for hybrid improvement, so as to obtain greater economic benefits. With the continuous improvement of the scientific breeding system, the unique and outstanding traits such as bright red flesh color, tasty meat and thin muscle fibers of Ningxiang pigs was gradually excavated, which made the number of purebred individuals increase. Currently, there is a lack of research on the correlation between carcass traits and meat quality in Ningxiang pigs. Therefore, the experiment was conducted to study the changes of carcass, bones, and muscles, correlation analysis of carcass and meat quality and regression equations between slaughter ages and these indices of Ningxiang pigs.

[1]College of Animal Science and Technology, Hunan Agricultural University, Changsha, Hunan, China.
[2]Hunan Institute of Animal and Veterinary Science, Changsha, Hunan, China.
[#]These authors contributed equally to this work.

Corresponding Author: Yingying Liu; Chen Chen, College of Animal Science and Technology, Hunan Agricultural University, Changsha, Hunan, China; Hunan Institute of Animal and Veterinary Science, Changsha, Hunan, China.
Email: hunaulyy_2006@126.com; 2004chch@163.com

How to cite this article: Zhang, W., Peng, Y., Cui, Q., Chang, Y., Deng, Y., Chen, C. and Liu, Y. (2024). A Study on Changes of Carcass, Bones and Muscles of Ningxiang Pigs. Indian Journal of Animal Research. DOI: 10.18805/IJAR.BF-1786.

Submitted: 11-03-2024 **Accepted:** 30-04-2024 **Online:** 05-06-2024

MATERIALS AND METHODS

Experimental animals

The animal experiment conducted in this study was approved by the Institutional Animal Care and Use Committee of Hunan Agricultural University and was conducted in accordance with the Chinese Guideline for Ethical Review of Animal Welfare (ACC2019006, Changsha, China). The study was completed in Hunan Institute of Animal and Veterinary Science from 2022 to 2023. Forty-two castrated male Ningxiang pigs in seven developmental ages (0, 60, 120, 180, 240, 300, and 360 d) were used in this study. Six healthy individuals with similar body weight were selected for weighting and slaughtering in each developmental age. Seven groups of pigs were half-sibs, and the six samples in each developmental age were full-sibs. All the experimental pigs were reared under the standard environmental conditions in Hunan Liushahe Ecological Animal Husbandry Co., Ltd.

Carcass traits

Pre-slaughter body weight (BW) and weights of head, feet, carcass, carcass length, backfat thickness, and loin eye area at the 10^{th} rib were measured immediately after slaughter (Ministry of Agriculture of the People's Republic of China, 1987). Carcass straight length was measured from the first rib to the end of the pubic bone. Carcass oblique length was measured between the articulation of the first rib and the sternum to the end of the pubic bone. Backfat thickness using a vernier caliper, and the average measurements at three points: the first rib, last rib, and last lumbar vertebra were recorded. The left side of each carcass was weighed and then physically dissected into skin, skeletal muscle, fat and bone for the evaluation of carcass characteristics. These components were weighed, and the weights were multiplied by 2 to calculate the percentage of the whole carcass that each component constituted. The dressing percentage was calculated as carcass weight divided by pre-slaughter weight. Weights of skeletal muscles and bones were also recorded after carcass segmentation.

Visceral

After removing other tissues from the surface of internal organs, they were directly weighed and recorded (expressed as the percentage of pre-slaughter weight).

Meat quality

The 45 min pH (pH_{45}) and 24 h pH (pH_{24}) values at postmortem were measured in triplicate at the 6^{th} to 7^{th} rib position by using hand-held pH meter. Instrumental color measurements of lightness, redness, and yellowness were taken in triplicate at the 10th rib interface by using a Konica Minolta Chroma Meter with an 8 mm measuring port, D65 illuminant. On the slaughter ages, approximately 100 g fresh LD muscle was weighed and placed in a Whirl-Pak bag, suspended in a 4°C cooler for 24 h, reweighed, and drip loss was recorded. The muscle sample was weighed and covered in a container before cooking. Immediately after cooking for 45 min at 100°C, the sample was removed from the container and dried with a paper towel, then reweighed. Cooking yield = (cooked weight/raw weight)×100. After being placed in a plastic bag and cooked in an 80°C water bath until the internal temperature reached 70°C, muscle samples were cooled to room temperature, then measured using a texture analyzer equipped with a Warner-Bratzler shear force device (200 mm/min crosshead speed). Three samples with a diameter of 1.27 cm and a length of approximately 2 cm were cut with a cylindrical core borer from each of the cooked steaks, and then were sheared vertically to the muscle fibers to record the shear force value. Marbling was scored based on the procedure recommended by the National Pork Producers Council (NPPC) (2000), ranging from 1 (devoid) to 5 (abundant), 0.5 points were allowed between two scores. Meat quality of 0-day old piglets was not tested due to the small size of the LD muscle in newborn piglets.

Statistical analysis

After the test data were recorded and processed in Excel 2010, SPSS 21.0 and SAS 8.2 were used for significance analysis of all the original data and bivariate correlation analysis was conducted for carcass traits and meat quality indices at each age, and then regressions were fitted.

RESULTS AND DISCUSSION

Effect of slaughter ages on carcass traits and meat quality of ningxiang pigs

The study found that there was no significant change in skin percentage, the redness at 120-day age was significantly lower than that at other slaughter ages, shear force and drip loss increase first and then decrease with slaughter ages, the lean meat percentage, bone percentage, lightness and yellowness decreased gradually with slaughter ages, while other carcass and meat quality of Ningxiang pigs increased significantly (P<0.05). The results of lowest lean meat percentage on 240-day age in this study were inconsistent with the changing trend of the growth and development of pigs, which may be caused by the change of factors such as feeding management and environment. Carcass correlation analysis results were basically consistent with those of Ayuso *et al*. (2016) and Virgili *et al*. (2003), meat quality results were roughly similar to Virgili *et al*. (2003), indicating that the changes of these indices in the growth process of Ningxiang pigs were consistent with the growth law of pigs. However, the backfat thickness, loin eye area, shear force value, redness, lightness and yellowness results were different from Borah *et al*. (2016) and Ortiz *et al*. (2021), which may be due to the fact that muscle quality varies according to inherent differences such as breed, environment and sex in pigs (Table 1).

Effect of slaughter ages on visceral organs weight and weights of bones and muscles of ningxiang pigs

In this experiment, the results demonstrated a significant decrease in the weight percentages of the heart, liver, lung,

Table 1: Means of carcass traits and meat quality of ningxiang pigs at different slaughter ages.

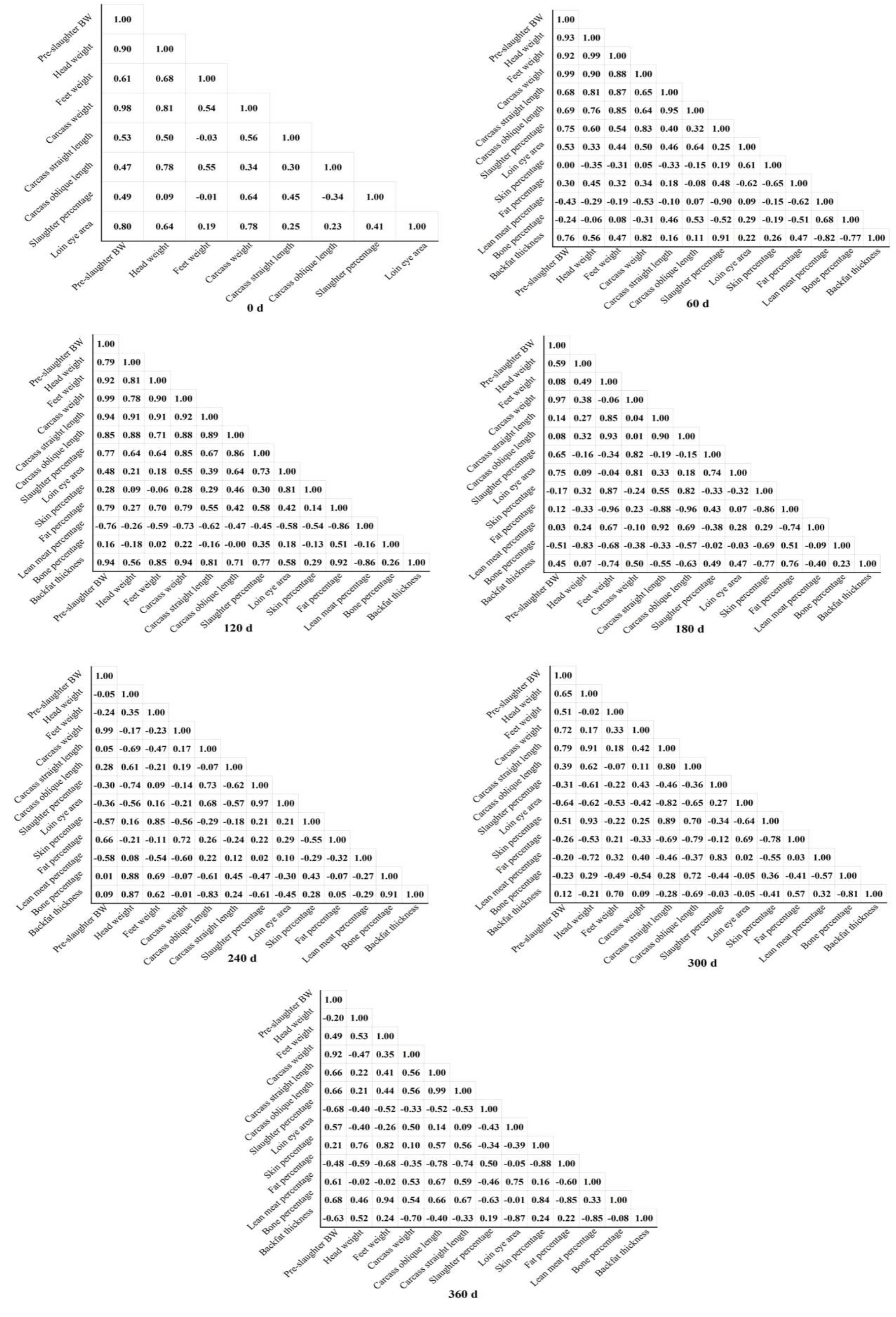
Item	0 d	60 d	120 d	180 d	240 d	300 d	360 d
Pre-slaughter BW (kg)	0.98±0.04^{g}	17.44±0.66^{f}	34.08±1.54^{e}	53.70±1.24^{d}	73.65±1.46^{c}	93.68±1.09^{b}	109.18±1.29^{a}
Head weight (kg)	0.22±0.01^{e}	1.38±0.04^{d}	2.71±0.11^{c}	4.25±0.15^{b}	4.48±0.19^{b}	5.69±0.15^{a}	5.49±0.63^{a}
Feet weight (kg)	0.05±0.00^{f}	0.50±0.02^{e}	0.84±0.06^{d}	1.13±0.08^{c}	1.19±0.04^{c}	1.80±0.05^{b}	2.41±0.12^{a}
Carcass weight (kg)	0.65±0.03^{g}	11.64±0.51^{f}	23.52±1.32^{e}	37.08±1.12^{d}	53.58±1.02^{c}	70.77±0.87^{b}	81.43±0.75^{a}
Carcass straight length (cm)	18.42±0.41^{g}	48.50±0.59^{f}	62.22±1.70^{e}	71.92±1.39^{d}	78.50±1.28^{c}	85.33±1.45^{b}	89.75±0.80^{a}
Carcass oblique length (cm)	15.52±0.21^{g}	41.22±0.65^{f}	53.17±1.75^{e}	62.17±1.27^{d}	67.33±1.67^{c}	73.08±1.00^{b}	77.08±0.85^{a}
Dressing percentage (%)	66.28±0.55^{d}	66.66±0.53^{d}	68.85±0.89^{c}	69.00±0.68^{c}	72.75±0.23^{b}	75.56±0.68^{a}	74.60±0.38^{a}
Backfat thickness (mm)	-	16.85±1.07^{e}	21.57±1.65^{d}	31.01±1.54^{c}	42.62±2.01^{b}	44.03±1.99^{b}	49.65±0.78^{a}
Loin eye area (cm^2)	0.52±0.02^{e}	7.15±0.37^{d}	11.48±0.59^{c}	15.96±0.80^{b}	16.25±0.88^{b}	17.21±0.92^{b}	19.87±0.97^{a}
Skin percentage (%)	-	13.93±1.01	13.85±0.50	11.69±1.16	11.54±0.51	12.59±0.63	13.06±0.74
Fat percentage (%)	-	25.11±1.28^{c}	28.52±1.07^{c}	35.22±2.11^{b}	37.98±1.61^{ab}	38.08±0.60^{ab}	39.65±0.98^{a}
Lean meat percentage(%)	-	49.70±0.69^{a}	48.13±1.19^{a}	44.56±0.80^{b}	36.55±1.07^{d}	40.99±0.50^{c}	39.52±0.45^{c}
Bone percentage (%)	-	11.26±0.38^{a}	10.67±0.43^{a}	10.39±0.42^{a}	9.83±1.06^{ab}	8.34±0.30^{bc}	7.77±0.07^{c}
pH_{45}	-	6.54±0.08^{bc}	6.50±0.11^{c}	6.76±0.05^{ab}	6.68±0.07^{abc}	6.64±0.03^{abc}	6.79±0.04^{a}
pH_{24}	-	5.73±0.05^{bc}	5.72±0.05^{bc}	5.67±0.03^{c}	5.83±0.05^{ab}	5.91±0.06^{a}	5.93±0.02^{a}
Shear force value (kgf)	-	2.62±0.24^{d}	4.04±0.24^{bc}	3.79±0.25^{c}	6.39±0.44^{a}	4.60±0.38^{bc}	4.87±0.22^{b}
Lightness	-	46.42±0.40^{a}	46.59±0.65^{a}	44.34±1.02^{ab}	45.06±1.03^{a}	42.23±0.77^{bc}	41.27±0.54^{c}
Redness	-	9.22±0.37^{a}	7.11±0.50^{b}	8.81±0.46^{a}	8.96±0.54^{a}	9.51±0.35^{a}	8.78±0.42^{a}
Yellowness	-	6.65±0.25^{a}	5.11±0.31^{bc}	5.58±0.19^{b}	5.22±0.35^{b}	5.13±0.21^{bc}	4.43±0.13^{c}
Cooking yield (%)	-	61.12±1.76^{c}	62.93±0.81^{c}	62.93±0.83^{c}	67.25±0.44^{b}	67.73±0.66^{ab}	70.80±1.46^{a}
Drip loss (%)	-	1.68±0.16^{b}	2.60±0.26^{a}	3.01±0.47^{a}	1.19±0.09^{bc}	1.15±0.33^{bc}	0.75±0.03^{c}
Marbling (score)	-	1.58±0.08^{c}	1.80±0.10^{bc}	2.03±0.15^{b}	3.52±0.08^{a}	3.50±0.13^{a}	3.30±0.13^{a}

Means in a row with same superscript do not differ significantly (P>0.05).

Table 2: Mean visceral organ weights (as percentage of pre-slaughter weight) and weights of bones and muscles (in grams) of Ningxiang pigs at different ages of slaughter.

Item	0 d	60 d	120 d	180 d	240 d	300 d	360 d
Heart weight percentage	0.68±0.04^{a}	0.50±0.02^{b}	0.37±0.01^{cd}	0.38±0.01^{c}	0.31±0.01^{cd}	0.32±0.03^{cd}	0.31±0.02^{d}
Liver weight percentage	2.79±0.12^{a}	2.63±0.03^{a}	2.10±0.08^{b}	1.80±0.09^{c}	1.56±0.03^{d}	1.39±0.04^{de}	1.23±0.03^{e}
Spleen weight percentage	0.12±0.01^{c}	0.26±0.02^{a}	0.19±0.02^{b}	0.15±0.01^{c}	0.14±0.01^{c}	0.14±0.00^{c}	0.13±0.01^{c}
Lungs weight percentage	1.55±0.07^{a}	1.25±0.04^{b}	1.18±0.07^{b}	1.17±0.11^{b}	0.93±0.05^{c}	0.88±0.05^{c}	0.81±0.01^{c}
Kidneys weight percentage	0.98±0.05^{a}	0.69±0.02^{b}	0.49±0.02^{c}	0.47±0.02^{c}	0.37±0.01^{d}	0.30±0.02^{de}	0.28±0.01^{e}
stomach weight percentage	0.73±0.05^{bc}	0.89±0.05^{ab}	1.03±0.08^{a}	0.88±0.04^{ab}	0.79±0.05^{bc}	0.68±0.05^{c}	0.69±0.04^{c}
Small intestine weight percentage	3.59±0.26^{a}	3.10±0.25^{b}	2.29±0.07^{c}	1.98±0.13^{c}	1.41±0.10^{d}	1.12±0.09^{d}	0.97±0.02^{d}
Large intestine weight percentage	1.30±0.25^{b}	2.52±0.11^{a}	2.71±0.11^{a}	2.92±0.17^{a}	2.39±0.19^{a}	2.38±0.19^{a}	2.47±0.21^{a}
Pectoral muscle (g)	1.25±0.20^{e}	79.00±5.27^{d}	128.42±7.11^{d}	192.50±7.16^{c}	230.67±7.40^{c}	366.08±21.87^{b}	495.33±39.42^{a}
Ocular muscle (g)	8.18±0.45^{f}	258.83±5.78^{e}	471.00±21.80^{d}	723.25±37.95^{c}	952.08±58.06^{b}	1135.08±54.97^{a}	1181.58±21.49^{a}
Semimembranous muscle (g)	5.08±0.46^{e}	157.92±10.39^{d}	231.50±9.90^{c}	402.67±15.44^{b}	424.17±12.95^{b}	543.58±42.89^{a}	508.33±37.06^{a}
Psoas major muscle (g)	1.89±0.15^{e}	47.42±2.02^{d}	66.58±3.34^{d}	126.17±6.45^{c}	177.67±9.67^{b}	163.33±12.02^{b}	213.33±6.67^{a}
Skull (g)	81.96±2.09^{f}	437.42±14.02^{e}	772.67±34.48^{d}	1048.75±46.71^{c}	1461.67±91.30^{b}	2173.33±54.39^{a}	2114.50±115.72^{a}
Cervical vertebrae (g)	8.80±0.77^{f}	97.00±5.80^{e}	154.33±6.26^{d}	226.92±13.47^{c}	245.33±6.48^{c}	495.00±32.19^{b}	544.17±21.68^{a}
Thoracic vertebrae (g)	19.96±0.78^{g}	229.67±13.69^{f}	358.58±20.04^{e}	532.83±37.33^{d}	903.33±36.02^{c}	1141.83±41.19^{b}	1345.33±35.24^{a}
Lumbar spine (g)	8.73±0.44^{e}	127.42±5.77^{d}	234.50±12.96^{c}	389.33±13.02^{b}	412.00±20.52^{b}	610.42±18.76^{a}	620.50±31.13^{a}
Sacral vertebrae (g)	3.48±0.14^{e}	48.42±1.80^{d}	82.92±3.72^{c}	123.92±2.13^{b}	202.50±17.62^{a}	180.33±18.09^{a}	180.67±10.84^{a}
Brachial bone (g)	5.29±0.25^{e}	58.42±3.21^{d}	96.67±4.81^{cd}	137.33±8.66^{c}	204.42±31.91^{b}	226.92±14.28^{b}	275.25±8.85^{a}
Carpal bone (g)	0.87±0.12^{f}	10.58±0.54^{ef}	15.50±1.45^{de}	23.83±1.96^{d}	40.50±5.73^{c}	72.00±5.71^{b}	100.50±6.15^{a}
Thigh bone (g)	4.22±0.15^{g}	52.67±2.05^{f}	75.92±3.74^{e}	107.67±4.88^{d}	180.50±4.19^{c}	211.08±5.22^{b}	233.42±14.27^{a}

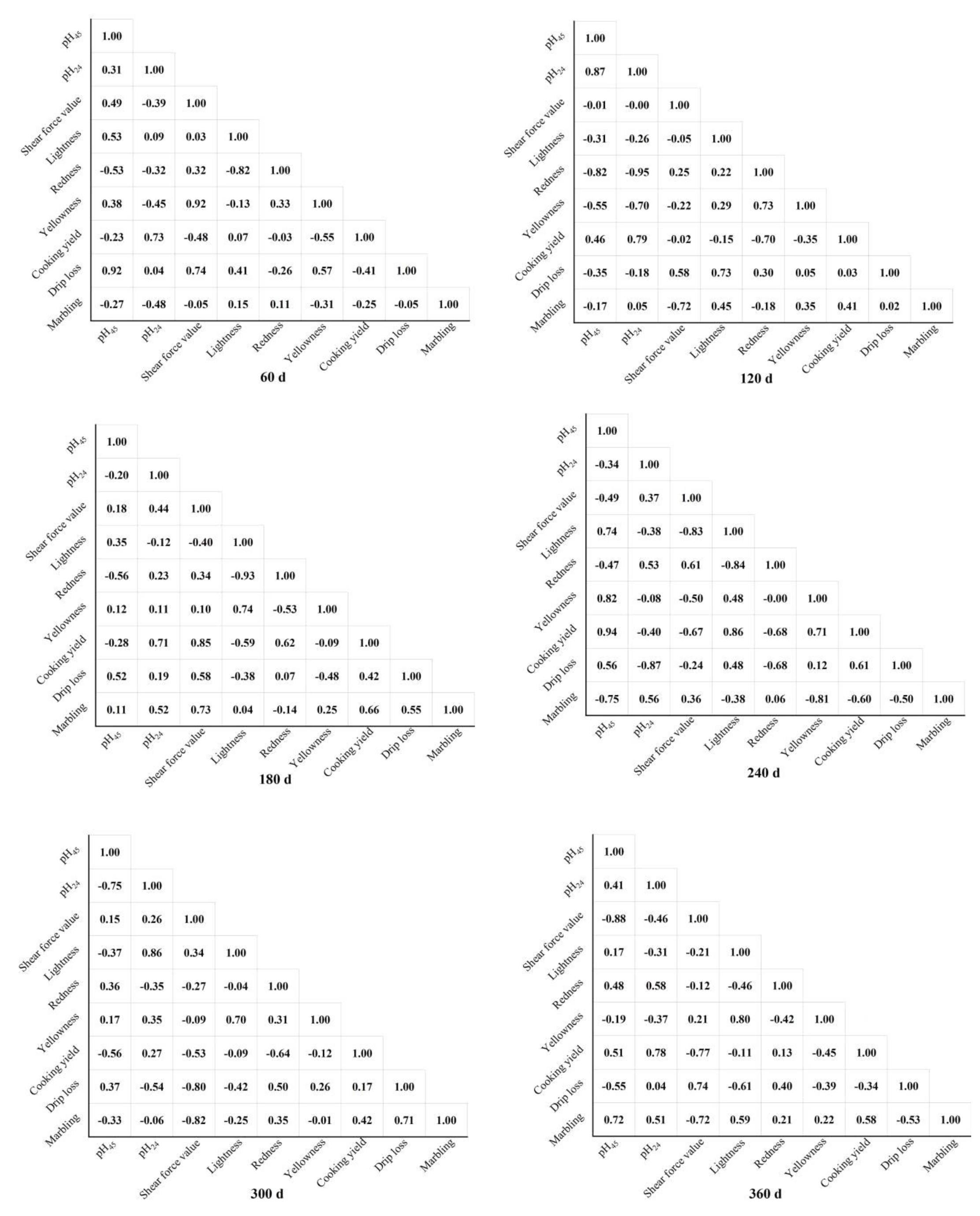
Means within a row with same superscript do not differ significantly (P>0.05).



The digits of the lower triangle represented Pearson correlation coefficient.

Fig 1: Correlation analysis of main carcass traits of ningxiang pigs at different stages.

kidney and small intestine of Ningxiang pigs as slaughter ages, the weight percentage of large intestine increased significantly at 0-60 days. The spleen weight percentage increased significantly at 0-60 days, decreased significantly at 60-120 days, which was similar to the results of Jia *et al*. (2022) (Table 2). However, previous studies on the effects of different slaughter ages on the changes of visceral organ weight percentages are still lacking, and the evaluation of visceral organ weight percentages is an important biological characteristic used to assess the functional strength and developmental level of internal organs during the body growth process (Al-Khalaifa *et al*., 2019; Zhang *et al*.,



The digits of the lower triangle represented Pearson correlation coefficient.

Fig 2: Correlation coefficients of meat quality of ningxiang pigs at different ages.

2021). Therefore, it is very important for breeding work and future market development to explore the variation law of visceral organ weights at different slaughter ages.

The results in this experiment revealed the weights of bones and muscles such as pectoral muscle, skull, lumbar spine of Ningxiang pigs significant increased with slaughter ages, which was roughly the same as the results of Zeng *et al*. (2022) (Table 2). Previous studies on the effects of different slaughter ages on the changes of bones and muscles weights are still lacking. However, compared to imported pig breeds, local pig breeds generally exhibit slower growth rates (Chen *et al*., 2023). Therefore, in the process of livestock production, the study of the change law of skeletal muscle weights with the increase of slaughter ages can lay a theoretical foundation for the improvement of economic benefits of livestock and poultry.

Correlations between various carcass traits at different ages of slaughter

The correlation coefficients between various carcass traits at different slaughter ages are presented in Fig 1.

In line with the findings of Guo *et al.* (2021) and Wang *et al*. (2023), our experiment demonstrated significant positive correlations between pre-slaughter BW, dressing percentages at 60-day, 120-day and 180-day age and carcass weight in Ningxiang pigs. Pre-slaughter BW is one of the easiest indicators to measure and the data acquisition cost is low. Therefore, according to pre-slaughter BW, breeders can indirectly and quickly predict other important carcass indicators, especially dressing percentage and carcass weight, which will have important guiding significance for the selection of pigs with good carcass performance.

The correlation coefficients between various meat quality at different slaughter ages are presented in Fig 2. The pH_{45} of Ningxiang pigs in different slaughter ages was respectively correlated with shear force, pH_{24}, drip loss and yellowness. The study results were consistent with the results of Wang *et al*. (2023). Research on the correlation of meat quality can enable breeders to indirectly select the related traits by measuring the main meat quality, which not only provides convenience for the determination of meat quality for breeders, but also provides a certain reference for the selection of pigs with excellent meat quality.

Regression analysis of carcass traits, visceral organ weight percentage, skeletal muscle weights, meat quality and slaughter ages of ningxiang pigs

In the study, there were significant regressions between the slaughter ages and these indices during the growth process of Ningxiang pigs (P<0.01) (Table 3). The study of Guo *et al*. (2021) are basically consistent with this experiment results, which were different from those of meat quality, might be due to the differences of animal species, slaughter weight and other basic factors, or related to differences in the speed of muscle color change caused

Table 3: Regression equations for performance indices and slaughter ages of Ningxiang pigs.

Item	Regression equation	R^2
Pre-slaughter BW (kg)	$Y=-0.1510+0.2947X+3.7213\times10^{-5}X^2$	0.999
Carcass weight (kg)	$Y=-0.3712+0.1975X+9.8246\times10^{-5}X^2$	0.997
Carcass straight length (cm)	$Y=22.0643+0.3845X-0.0006X^2$	0.981
Carcass oblique length (cm)	$Y=18.5327+0.3336X-0.0005X^2$	0.982
Dressing percentage (%)	$Y=65.7213+0.0237X+1.1336\times10^{-5}X^2$	0.917
Loin eye area (cm^2)	$Y=0.9900+0.1038X-0.0002X^2$	0.979
Fat percentage (%)	$Y=17.7460+0.1238X-0.0002X^2$	0.972
Backfat thickness (mm)	$Y=5.3860+0.1733X-0.0001X^2$	0.972
Cooking yield (%)	$Y=59.3460+0.0300X+2.4802\times10^{-6}X^2$	0.982
Heart weight percentage (%)	$Y=0.6584-0.0026X+4.6312\times10^{-6}X^2$	0.954
Liver weight percentage (%)	$Y=2.8737-0.0069X+6.4891\times10^{-6}X^2$	0.986
Lung weight percentage (%)	$Y=1.5027-0.0029X+2.6433\times10^{-6}X^2$	0.945
Kidney weight percentage (%)	$Y=0.9451-0.0040X+6.1379\times10^{-6}X^2$	0.972
Small intestine weight percentage (%)	$Y=3.6611-0.0122X+1.2720\times10^{-5}X^2$	0.993
Pectoral muscle (g)	$Y=19.6132+0.5299X+0.0021X^2$	0.985
Ocular muscle (g)	$Y=-16.8842+4.9100X-0.0041X^2$	0.994
Semimembranous muscle (g)	$Y=-2.5411+2.6971X-0.0034X^2$	0.977
Cervical vertebrae (g)	$Y=24.7282+0.7038X+0.0022X^2$	0.955
Thoracic vertebrae (g)	$Y=19.5990+2.7150X+0.0030X^2$	0.990
Lumbar spine (g)	$Y=1.5198+2.2083X-0.0012X^2$	0.978
Brachial bone (g)	$Y=5.4660+0.8124X-0.0002X^2$	0.994
Carpal bone (g)	$Y=4.3597-0.0246X+0.0008X^2$	0.991
Thigh bone (g)	$Y=1.9740+0.7064X-5.1009\times10^{-5}X^2$	0.968

Note: X is the slaughter ages and Y is the corresponding performance indicators.

by feeding management and environment. Previous studies on the regression analysis between visceral organ weight, skeletal muscle weights and slaughter ages were still lacking, however, the development degree of these indicators will also affect the economic benefits of livestock and poultry, so exploring the regression analysis between them were of great significance for the future development of pig industry (Cho *et al*., 2019; Shen *et al*., 2021; Ma *et al*., 2022).

CONCLUSION

The carcass traits, visceral organ weight percentages, weights of bones and muscles, and meat quality of Ningxiang pigs exhibited different changes as slaughter ages, and there were correlation among carcass traits and meat quality. The weight percentages of spleen, stomach and large intestine respectively reached the highest at 60-day, 120-day and 180-day-age, while the other organs weight percentages tended to be stable after sexual maturity (120~150 d) and body maturity (180~240 d). This study systematically analyzed the biological characteristics of the carcass traits and meat quality of Ningxiang pigs at different slaughter ages.

ACKNOWLEDGEMENT

Thanks for the financial support of the Natural Science Foundation of Hunan Province (2022JJ30317; 2021JJ30386), Hunan Innovation Platform and Talent Plan Project (2022NK4145), Science and Technology Major Project of Hunan Province (2021NK1009), Scientific and Technological Achievements Transformation and Industrialization Plan of Hunan Province (2022GK4016).

Conflict of interest

Authors declare no conflict of interest.

REFERENCES

Al-Khalaifa, H., Al-Nasser, A., Al-Surayee, T., Al-Kandari, S., Al-Enzi, N., Al-Sharrah, T., Ragheb, G., Al-Qalaf, S. and Mohammed, A. (2019). Effect of dietary probiotics and prebiotics on the performance of broiler chickens. Poultry Science. 98(10): 4465-4479.

Ayuso, M., Fernández, A., Núñez, Y., Benítez, R., Isabel, B., Fernández, A.I., Rey, A.I., González-Bulnes, A., Medrano, J.F., Cánovas, Á., López-Bote, C.J. and Óvilo, C. (2016). Developmental stage, muscle and genetic type modify muscle transcriptome in pigs: Effects on gene expression and regulatory factors involved in growth and metabolism. PloS One. 11(12): e0167858. https://doi.org/10.1371/journal.pone.0167858.

Borah, P., Bora, J.R., Borpuzari, R.N., Haque, A., Bhuyan, R. and Hazarika, S. (2016). Effect of age, sex and slaughter weight on productive performance,carcass characteristics and meat quality of crossbred (Hampshire × Assam local) pigs. Indian Journal of Animal Research. 50(4): 601-605. doi: 10.18805/ijar.11250.

Chen, C., Deng, Y., Ren, H.B., Zhu, J., Cui, Q.M., Hu, X.G. and Peng, Y.L. (2023). Evaluation of growth performance, carcass characteristics and meat quality of Shaziling pigs and its hybrids crossbred with Berkshire pigs. Indian Journal of Animal Research. 57(3): 381-385. doi: 10.18805/IJAR.BF-1419.

Chen, F.X., Wu, P.F., Shen, M.M., He, M.L., Chen, L., Qiu, C., Shi, H.Q., Zhang, T., Wang, J.H., Xie, K.Z., Dai, G.J., Wang, J.Y. and Zhang, G.X. (2019). Transcriptome analysis of differentially expressed genes related to the growth and development of the Jinghai yellow chicken. Genes. 10(7): 539. https://doi.org/10.3390/genes10070539.

Cho, I.C., Park, H.B., Ahn, J.S., Han, S.H., Lee, J.B., Lim, H.T., Yoo, C.K., Jung, E.J., Kim, D.H., *et al*. (2019). A functional regulatory variant of MYH3 influences muscle fiber-type composition and intramuscular fat content in pigs. Plos Genetics. 15(10): e1008279. doi: 10.1371/journal.pgen.1008279.

Gong, Y., He, J., Li, B., Xiao, Y., Zeng, Q.H., Xu, K., Duan, Y.H., He, J.H. and Ma, H.M. (2021). Integrated analysis of lncRNA and mRNA in subcutaneous adipose tissue of ningxiang pig. Biology. 10(8): 726. doi: 10.3390/biology10080726.

Guo, J.F., Lin, H.C., Xie, J.T., Wang, Y.P. and Li, G.L. (2021). Effects of different slaughter weight on carcass and meat quality of Black-covered pigs (in Chinese). Swine Production. 36: 53-56.

Ilavarasan, R. and Abraham, J.J.R. (2017). The meat quality attributes and nutritional composition of three way synthetic pigs meat as influenced by age at slaughter. Indian Journal of Animal Research. 52(3): 464-469. doi: 10.18805/ijar.v0iOF.7825.

Jia, Y.S., Qu, X.Y., Li, Y., Liao, M. and Jiang, W.W. (2022). Study on the growth and development of body weight and internal organs of Guangxi Yao chickens (in Chinese). Guangdong Journal of Animal and Veterinary Science. 47(5): 6-12.

Li, B., Yang, J.Z., He, J., Peng, X., Zeng, Q.H., Song, Y.K., Xu, K. and Ma, H.M. (2021). Characterization of the whole transcriptome of spleens from Chinese indigenous breed Ningxiang pig reveals diverse coding and non-coding RNAs for immunity regulation. Genomics. 113(4): 2468-2482.

Ma, M.T., Cai, B.L., Kong, S.F., Zhou, Z., Zhang, J., Zhang, X.Q. and Nie, Q.H. (2022). PPARGC1A is a moderator of skeletal muscle development regulated by miR-193b-3p. International Journal of Molecular Sciences. 23(17): 9575. doi: 10.3390/ijms23179575.

Malgwi, I.H., Giannuzzi, D., Gallo, L., Halas, V., Carnier, P. and Schiavon, S. (2022). Influence of slaughter weight and sex on growth performance, carcass characteristics and ham traits of heavy pigs fed ad-libitum. Animals. 12(2): 215. https://doi.org/10.3390/ani12020215.

Ministry of Agriculture of the People's Republic of China, (1987). Performance Measurement Technology Regulations for Chinese Lean pig. Beijing, China: China Standard Press.

National Pork Producers Council, (2000). Pork composition and quality assessment procedures (1st ed). Des Moines, IA, USA: National Pork Producers Council (NPPC).

Ortiz, A., González, E., García-Torres, S., Gaspar, P. and Tejerina, D. (2021). Do animal slaughter age and pre-cure freezing have a significant impact on the quality of Iberian dry-cured pork loin? Meat Science. 179: 108531. doi: 10.1016/j.meatsci. 2021.108531.

Shen, X.M., Tang, J., Ru, W.X., Zhang, X.Y., Huang, Y.Z., Lei, C.Z., Cao, H., Lan, X.Y. and Chen, H. (2021). CircINSR regulates fetal bovine muscle and fat development. Frontiers in Cell and Developmental Biology. 8: 615638. https://doi.org/10.3389/fcell.2020.615638.

Virgili, R., Degni, M., Schivazappa, C., Faeti, V., Poletti, E., Marchetto, G., Pacchioli, M.T. and Mordenti, A. (2003). Effect of age at slaughter on carcass traits and meat quality of Italian heavy pigs. Journal of Animal Science. 81(10): 2448-2456.

Wang, Y.B., Zhang, H.L., Yan, E.F., He, L.J., Guo, J.X., Zhang, X. and Yin, J.D. (2023). Carcass and meat quality traits and their relationships in Duroc × Landrace × Yorkshire barrows slaughtered at various seasons. Meat Science. 198: 109117. doi: 10.1016/j.meatsci.2023.109117.

Zeng, Z.Y., Huang, L.R., Gu, C.S. and Yu, J. (2022). Study on the pattern of growth, organ development and meat quality of Mahuang broilers (in Chinese). Animal Husbandry and Veterinary Medicine. 54: 32-39.

Zhang, Q.Y., Zhang, S., Cong, G.L., Zhang, Y.J., Madsen, M.H., Tan, B.J. and Shi, S.R. (2021). Effects of soy protein concentrate in starter phase diet on growth performance, blood biochemical indices, carcass traits, immune organ indices and meat quality of broilers. Animals: An Open Access Journal from MDPI. 11(2): 281. doi: 10.3390/ani11020281.

Zhang, W., Gao, X., Cui, Q.M., Chen, C., Liu, Y.Y. and Peng, Y.L. (2024). Research progress on analyzing the muscle growth and development of pigs based on omics technologies (in Chinese). Chinese Journal of Animal Science. 1-12.