Comparative study of growth performance and meat quality of three-line crossbred commercial group from Shanzhongxian and W-line chicken

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ABSTRACT
Growth performance and meat quality of commercial groups from two different three-line crossbreds, SWS and WSS, was compared. All birds were raised under the same condition and body weight was measured at two weeks interval. On d 70, 24 male chickens were randomly selected, and on d 180 and 240, 24 female chickens were randomly selected for euthanised. Carcass performance, meat quality and sensory was determined. At 6–12 weeks of age, body weight of chickens from WSS was higher than that of SWS ($p < .05$). Percentage of breast and leg muscle was higher in WSS as compared with birds from SWS in 70 d males ($p < .05$). At 240 d of age, chickens from WSS exhibited higher semi-eviscerate, breast muscle and liver percentage, lower abdominal fat content ($p < .05$). Male birds at 70 d, shear force, intramuscular fat content (IMF) and L\textsuperscript{*} was higher in SWS ($p < .05$). A higher IMF of breast meat was detected in 180 d SWS female birds ($p < .05$). The appearance acceptability and flavour of WSS male chickens was more preferred by panellists ($p < .05$). The texture of breast meat from 180 d SWS chicken was more preferred ($p < .05$). Soup cooked from 240-d-old chickens was more preferred in SWS crossbred ($p < .05$). The WSS had better growth performance and meat quality in male chickens, while the SWS had more abdominal fat in female chickens which led it more flavour of its soup.

Introduction
Genetic improvement can be achieved through crossbreeding, with or without genetic selection in the parent lines; through upgrading by repeated backcrossing to a superior parent breed, or through within-line selection (Link and Sauer 2016). The effect of crossbreeding is the opposite of the effect of in-breeding. Crossbreeding can be carried out by two-line, three-line or four-line crosses, back crosses or rotational crosses. The crossbreeding approach normally involves a two-line cross between an improved exotic and a local breed, with the aim of combining the better production capacity of the former with the latter’s adaptability to harsh environments. This system also maximises the expression of heterosis or hybrid vigour, in the cross, normally reflected in improved fitness characteristics (Alonso et al. 2009).

In order to retain heterosis in the maternal traits, three-line or four-line crossing has to be applied. In three-line crosses, the crossbred chicken is mated with a third line. Crossbreeding has been a major tool for the development of present-day commercial breeds of Chickens (Adeleke et al. 2012; Alewi et al. 2012), and could likewise be used to improve the rural chicken. Comparatively, little research and development work has been carried out on rural poultry, despite the fact that they are usually more numerous than the commercial chickens in most countries.

A few attempts that have been made to increase productivity include upgrading and crossbreeding with exotic ones, and then leaving the hybrid offspring to natural selection. Njenga (2005) revealed that crossbred offspring of Rhode Island Red and Fayoumi had better level of body weight and higher cost benefit ratio with low mortality as compared to original breeds in Kenya. Using male Fayoumi crossed with female Rhode Island Red birds gained higher body weight than the reciprocal crossbred chickens (Khawaja et al. 2012). The genetic potential of the indigenous chicken could be improved by crossing them with selected but still robust exotic breeds (Woldegiorgis 2015). In Pakistan, Lyallpur Silver Black...
breed was evolved by crossing Desi with three imported breeds; namely White Leghorn, White Cornish and New Hampshire in a four-line crossbreeding programme (Ashraf et al. 2003). Chickens from White Leghorn male crossbred with F1 female (Fayoumi males crossed with Rhode Island Red females) gained better body weight and lower mortality and three-way crossbred chickens of Rural Leghorn showed better FCR and lower mortality than two-way reciprocal crossbred chickens of Fayoumi males crossed with Rhode Island Red females (Khawaja et al. 2013).

The quality of the poultry products can be assessed by several attributes, primarily the sensory (colour, tenderness, flavour, juiciness), physical (muscle yield, water-holding capacity, cooking loss) and chemical (proximate analysis of different portion) attributes of chicken carcasses and meat, which vary with growth rate and body composition (Alonso et al. 2009; Chen et al. 2016). An up gradation programme of Desi chickens was undertaken by Safalaoh (2001), in which the Australorp males were crossed with indigenous female chickens in Malawi, and the progeny of the cross gained sensationally higher body weight, fertility rate, hatchability and early sexual maturity. The beneficial evidence gained from crossbreed provided meaningful information for future crossbreeding work.

Shanzhongxian chicken, with strong disease-resistance, special body shape and feather colour, was hybrid from two local breeds. However, the commercial generation crossed from only two breeds has several limitations for marketing. First, because there is only one generation for propagation, it is insufficient to supply enough broilers from the two-line crossbred as compared with three-line crossbred. Second, the simple crossbred method made it difficult to protect the breed. In addition, the production performance and meat quality of broilers from the two-line crossbred still need to be further improved by using three-line crossbred. In this study, a third breed, W, was used as the first male or female parent to make cross or reciprocal cross. Growth performance and meat quality was assessed in commercial birds from the two three-line crossbreeds.

Materials and methods

The study protocol used in the current experiment was approved and conducted in accordance with the Institute Animal Care and Use Committee of Anhui Agricultural University, China.

Experimental design

Three-line crossbred 1 (SWS): We use female birds from maternal of Shanzhongxian chicken crossbred with male birds of W line, and the female of the offspring was kept and crossbred with male birds from paternal of Shanzhongxian chicken. The female offspring was raised till 240 days and the male offspring was raised for 70 days.

Three-line crossbred 2 (WSS): We use male birds from maternal of Shanzhongxian chicken crossbred with female birds of W line, and the female of the offspring was kept and crossbred with male birds from paternal of Shanzhongxian chicken. The female offspring was raised till 240 days and the male offspring was raised for 70 days.

Male and female birds were separately raised under normal conditions of light and temperature at the breeding farm (Huadong Poultry Breeding Co., Ltd., Anhui, China). Shanzhongxian chicken at the same age was raised under normal conditions of light and temperature and fed the same diets formulated according to requirements of slow growing broilers recommended by the NRC (1994). Body weight was recorded with 2 weeks interval till 12 weeks of age. On day 70, a total of 24 male chickens, randomly selected from the two three-crossbreds, were slaughtered. On day 180 and 240, 24 female chickens from each age, randomly selected from the two three-crossbreds were slaughtered. The eviscerated weight, breast muscle and leg muscle was weighed according to Chen et al. (2017).

Shear force

A 10 g breast muscle (pectoralis major) was manually trimmed, 45 min after muscles been separated, into a long strip (3 cm long × 1 cm wide × 1 cm thick) parallel to the direction of muscle fibre were cut from the cranial side of each sample. Samples were then sheared perpendicular to the muscle fibre using a texture analyser (C-LM3B type digital tenderness instrument, Beijing Longde Biotechnology Co. Ltd., China) according to Cai et al. (2018). Each sample was measured three times along the muscle fibre.

pH and meat colour

The pH of broiler muscle samples was determined three centimetres inside the cranial site 24 h post-mortem using a pH metre (FE20, Mettler Toledo International Inc., Sweden) with an attached penetrating probe (InLab Solids Pro-ISM, Mettler Toledo). The colour of broiler breast muscle was determined at
the bone side (to avoid scalding effects) at three different locations 24 h post-mortem using a chroma metre (ADCI-WSI, Beijing Chentaike instrument Co., Ltd., China) with an 10 mm port size, 10° observer and illuminant D65, and expressed as CIE $L^*$ (lightness), $a^*$ (redness) and $b^*$ ( yellowness).

**Drip loss**

Drip loss (%) was determined according to the following steps: Another 10 g muscle (W1) was manually trimmed into a long strip (3 cm long $\times$ 1 cm wide $\times$ 1 cm thick) parallel to the direction of muscle fibre were cut from another breast side of each sample. The sample was hanged along the muscle fibre in a sealed bag at 4°C fridge for 24 h, and then weighed again (W2). The drip loss was calculated according to formula: drip loss (%) = (W1 – W2)/W1 $\times$ 100.

**Dry matter determination**

Intramuscular fat (IMF) content was determined by a Soxhlet solvent extraction system (SOX416, Hanon Instrument Co., Ltd., China) according to Chen et al. (2017). In brief, a plate was baked for 12 h in an oven and cooled down in a dryer for 30 min and weighed and recorded as empty weight (A1). Muscle sample was (visible fat and tendons was manually removed) minced. A 30 g minced muscle sample was placed on the dried plate and weighed (A2). The sample was then baked in oven under 65°C till final weight (A3). Dry matter (DM) was calculated as (A2 – A3)/(A3 – A1) $\times$ 100.

**IMF content**

A filter paper was baked under 105°C for 8 h and weighed (A4). The baked meat sample (about 2 g) from the above was then minced and wrapped in the baked filter paper, baked for 8 h at 105°C, after cooled down in a dryer for 30 min, the sample was weighed again (A5). The baked meat (in filter paper) was then submitted for fat extraction by ethyl extractor (SOX416, Hanon Instrument Co., Ltd., China). After the fat been completely extracted, the meat (in filter paper) was baked again to a final weight (A6). IMF was calculated as (A5 – A6)/(A5 – A4) $\times$ 100.

**Cooking method**

Male and female broiler birds were cooked individually. In brief, each eviscerated chicken was cooked by immersing it in boiled water for about 15–20 min till the meat was well done. The cooked eviscerated chicken was then cooled down for 10–15 min under room temperature and the breast fillet was cut into $1 \times 1 \times 3$ cm$^3$ cuboids without skin on the surface. The cuboids were kept in a thermostat container until the panellist evaluated the samples. For soup cooking, one bird (semi-eviscerated) was put into 500 mL water (totally immersed) and boiled for 1 h. Soup was cooled down at room temperature till 60–70°C for taste panel. Each panellist was served with two piece of breast meat or two cups of soup about 50 mL.

**Consumer sensory analysis**

Three consumer-based sensory panels ($n = 30–45$, from undergraduate students, graduate students and faculty and staff) were conducted to evaluate the tendency and testability of male and female broiler meat and female soup. Panellists were asked to evaluate the sample’s taste, appearance, flavour and texture using a nine-point hedonic scale (Schilling et al. 2015). Acceptability of appearance was defined as product liking in respect to panellists’ preferences. Acceptability of texture was defined as product liking in respect to juicy. Acceptability of flavour was defined as product liking in respect to meat smelling. Each panellist was allowed to evaluate six samples (meat or soup) with three samples from each crossbred in each time. Sample providing was randomised. Water was provided to expectorate panellists rinse their mouths between each sample.

**Statistical analysis**

$T$ test was used to compare all the data from the two crossbreds (SAS9.3, Statistical Analysis Software, Care, NC). Data were expressed as mean ± standard error. Significant difference was set as $p < .05$.

**Results and discussion**

**Growth performance of birds from the two crossbreds**

There was no significant difference in body weight of chickens from the two crossbreds before their 4 weeks of age ($p > .05$). At 6–12 weeks of age, the body weight of chickens from WSS was significantly higher than that of SWS crossbred ($p < .05$, Table 1). The body weight of male birds from WSS was about 1 kg (Table 2), which was more suitable for marketing according to local habit of cooking young cocks around 1 kg. The body weight at slaughter age of male birds was about one kilogram, which is far lower
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**Table 1.** Body weight of birds from the two crossbreds, g (n = 60).

| Item     | 0 d       | 2 weeks   | 4 weeks   | 6 weeks   | 10 weeks  | 12 weeks  |
|----------|-----------|-----------|-----------|-----------|-----------|-----------|
| SWS      | 31 ± 2    | 114 ± 11  | 285 ± 27  | 480± 43   | 841± 38   | 967± 27   |
| WSS      | 30 ± 2    | 117 ± 12  | 289 ± 30  | 540± 50   | 871± 46   | 1088± 53  |
| p value  | .119      | .091      | .628      | <.0001    | .006      | .002      |

Body weight was recorded with same number of male and female birds.

Within a column different superscripts are significantly different (p < .05).

SWS means male birds from maternal of Shanzhongxian chicken crossbred with male birds of W line, and the female of the offspring was kept and crossbred with male birds from paternal of Shanzhongxian chicken.

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Comparing the slaughter performance of male birds at 70 d of age between the two crossbreds, body weight was significantly higher in WSS than that of birds from SWS (p < .05). No significant difference was observed in percentage of carcase, semi-eviscerate, eviscerate, heart, liver, head, feet, gizzard and abdominal fat between the two crossbreds (p > .05).

However, the percentage of breast and leg muscle was significantly higher in WSS as compared with birds from SWS (p < .05, Table 2).

No significant difference was observed for slaughter performance between the two crossbreds in female chickens at their 180 d of age (p > .05), although a digitally higher body weight in WSS chickens (Table 3). At 240 d of age, chickens from WSS exhibited higher body weight, semi-eviscerate, breast muscle, and liver percentage (p < .05). No significant difference was observed in percentage of carcase, eviscerate, leg muscle, heart, head, foot, and gizzard (p > .05). A significantly lower abdominal fat content was detected in chickens from reversed crossbred as compared with crossbred chickens (p < .05, Table 3). It was still not clear which caused the differential organ weight while the two groups were raised under the same condition and with the same nutrition of feed. It is obvious that the semi-eviscerate and eviscerate was lower in females at 240 d of age as compared with females at 180 d of age, which might be caused by the rapid development of ovary and oviduct (Chen et al. 2017).

**Table 2.** Slaughter performance of male birds from the two crossbreds at 70 d of age.

| Item         | Body weight, g | Carcase | Semi-eviscerate | Eviscerate | Breast muscle | Leg muscle |
|--------------|----------------|---------|-----------------|------------|---------------|------------|
| SWS          | 861           | 89.4    | 81.3            | 68.7       | 12.3          | 20.9       |
| WSS          | 943           | 89.5    | 79.1            | 63.3       | 14.1          | 22.6       |
| SEM          | 0.21          | 0.45    | 0.39            | 0.88       | 0.12          | 0.19       |
| p value      | .0001         | .006    | .002            | .0001      | .006          | .002       |

Within a column different superscripts are significantly different (p < .05).

SWS means female birds from maternal of Shanzhongxian chicken crossbred with male birds of W line, and the female of the offspring was kept and crossbred with male birds from paternal of Shanzhongxian chicken.

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Meat quality of birds from the two crossbreds

Meat quality of male birds from the two crossbreds at 70 d of age

Comparing meat quality between the two crossbreds, shear force was higher in SWS and lower in WSS (p < .05). The IMF was higher in WSS, lower in SWS crossbred (p < .05). Breast meat colour after 24 h storage under 4 °C showed that a* was higher and L* was lower in WSS as compared with SWS crossbred (p < .05). There was no significant difference in drip loss, pH, and b* value between the two crossbreds (p > .05) (Table 4).
Table 3. Slaughter performance of female birds from the two crossbreds at 180 and 240 d of age.

| Age   | Hybridization | Body weight, g | Carcase | Semi-evviscerate | Evviscerate | Breast | Leg | Heart | Liver | Head | Foot | Gizzard | Abdominal fat |
|-------|---------------|----------------|---------|------------------|-------------|--------|-----|-------|-------|------|------|---------|---------------|
| 180   | SWS           | 1341b          | 90.900  | 77.800           | 64.200      | 17.400 | 19.800 | 0.490 | 2.750 | 4.340 | 3.580 | 2.030    | 5.230         |
|       | WSS           | 1427a          | 91.500  | 76.700           | 63.900      | 17.600 | 19.700 | 0.520 | 2.730 | 4.560 | 3.700 | 1.740    | 5.120         |
| 240   | SWS           | 1315b          | 87.890  | 65.300           | 54.100      | 23.400 | 25.600 | 0.650 | 3.010 | 5.550 | 3.960 | 2.520    | 5.470         |
|       | WSS           | 1427a          | 91.180  | 72.000           | 59.700      | 20.500 | 22.300 | 0.560 | 2.520 | 4.900 | 3.930 | 2.520    | 4.770         |
|SEM    | 18.600        | 4.200          | 4.968   | 7.458            | 2.936       | 3.351  | 0.096  | 0.344 | 0.768 | 0.539 | 0.601 | 1.779    |               |
|       | 240 SWS       | 7.0            | 0.420   | 0.286            | 0.349       | 0.434  | 0.212  | 0.442 | 0.322 | 0.359 | 0.465 | 0.201    | 0.972         |
|       | WSS           | 1427a          | 91.500  | 76.700           | 63.900      | 17.600 | 19.700 | 0.520 | 2.730 | 4.560 | 3.700 | 1.740    | 5.120         |
|       |               | 18.600         | 4.200   | 4.968            | 7.458       | 2.936  | 3.351  | 0.096  | 0.344 | 0.768 | 0.539 | 0.601    | 1.779         |

Table 4. Meat quality of male birds from the two crossbreds at their 70 d of age.

| Age   | Hybridization | Shear force, N | Drip loss, % | pH | IMF, % | a* | b* | L* |
|-------|---------------|----------------|-------------|-----|--------|----|----|----|
| 180   | SWS           | 42.050a        | 7.120       | 6.320 | 2.310b | 4.680b | 8.650 | 56.620a |
|       | WSS           | 34.700b        | 6.200       | 6.360 | 3.250b | 5.610b | 8.230 | 54.030a |
|       | Pooled SEM    | 3.005          | 0.327       | 0.051 | 0.251  | 0.282  | 0.671 | 1.054  |
|       |               | 0.008          | 0.112       | 0.050 | 0.488  | 0.048  | 0.203 | 0.954  | 0.670 | 0.949 | 0.084 | 0.033 |

Table 5. Meat quality of female birds from the two crossbreds at their 180 and 240 d of age.

| Age   | Hybridization | Shear force, N | Drip loss, % | pH | IMF, % | a* | b* | L* |
|-------|---------------|----------------|-------------|-----|--------|----|----|----|
| 180   | SWS           | 32.400         | 12.110a     | 5.760a | 1.550a | 3.260 | 5.420 | 50.080a |
|       | WSS           | 36.150         | 10.900b     | 5.480b | 1.420b | 3.890 | 5.020 | 51.240b |
|       | Pooled SEM    | 1.313          | 0.244       | 0.085 | 0.181  | 0.231  | 0.145 | 1.072  |
|       |               | 0.179          | 0.027       | 0.032 | 0.026  | 0.114  | 0.182 | 0.045  |
| 240   | SWS           | 36.510         | 10.080      | 5.540  | 1.380  | 2.040 | 7.850 | 50.360  |
|       | WSS           | 34.410         | 9.650       | 5.510  | 1.710  | 2.560 | 6.780 | 49.650  |
|       | Pooled SEM    | 2.006          | 0.373       | 0.092  | 0.195  | 0.124  | 0.368 | 1.542  |
|       |               | 0.466          | 0.442       | 0.839  | 0.266  | 0.088  | 0.075 | 0.126  |

Meat quality of female birds from the two crossbreds at 180 and 240 d of age.

A higher drip loss, pH, and IMF content were detected from the crossbred female birds as compared with reverse crossbred birds at their 180 d of age (p < .05). A lower L* was observed in crossbred females as compared with reverse crossbred birds at 180 d of age (p < .05), and no difference was observed in shear force between the two crossbreds (p > .05). The meat quality exhibited no significant difference between the two crossbreds at their 240 d of age (p > .05) (Table 5).

Lower shear force and higher IMF were considered as more tender of meat (Wolcott et al. 2009), and the latter also was connected with flavour of meat (Hopkins et al. 2006). In this experiment, a higher IMF and lower shear force was both detected in WSS, which suggested that W line could be used as the first maternal in three-line crossbreeding to promote meat quality in male birds. However, maternal of Shanzhongxian should be used as the first maternal to produce higher IMF content in female offspring.
These might be caused by long traditional selection of birds under specific human habitats.

**Consumer acceptability of chicken fillet and hen soup from the two crossbreds**

Consumers rated breast meat and soup from the two crossbreds between like or slightly like with respect to appearance, flavour, texture, aroma, and overall acceptability (Table 6). The appearance acceptability and flavour of reverse crossbred male chickens at their 70 d of age were more preferred by panellists ($p<.05$), and the others, texture, aroma, and overall, were between like moderately and like very much ($p>.05$). As to chickens at their 180 d of age, the texture of breast meat from crossbred was more preferred as compared with reverse crossbred chickens ($p<.05$), and no other differences existed between the two groups ($p>.05$). The aroma of breast meat from the reverse crossbred chickens was liked slightly more than crossbred chickens ($p<.05$), but no other differences occurred between the two crossbreds. Chicken soup from the two crossbreds at their 180 d of age exhibited no difference and was arranged between like moderately and like very much. As to the soup cooked from chickens at their 240 d of age, the appearance acceptability was more likely accepted in reverse crossbred ($p<.05$). However, the flavour and the overall acceptability were more preferred in chickens from crossbred ($p<.05$). A higher IMF content in breast meat may lead to much more flavour and thus more acceptable which detected in male chickens from WSS crossbred (Chartrin et al. 2006).

Under long time fat deposition between meat fibre, higher IMF content in female SWS only demonstrated that selection on Shangzhongxian chicken resulted in more abdominal fat content in female chickens which led it more flavour of its soup.

**Conclusions**

In conclusion, the WSS crossbreeding method resulted in better growth performance and meat quality of male chickens, while the SWS crossbreeding method resulted in more abdominal fat content in female chickens which led it more flavour of its soup.

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**Disclosure statement**

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