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The effects of upgrading and intersecting cross-breeding strategies on the geese economic traits

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Abstract: Routine, upgrading, and intersecting cross-breeding strategies are three methods frequently used in poultry breeding. But, till now, comparative assessment of the effects on the improvement of geese economic traits with these strategies is largely unknown. Here, using Carlos goose and Zi goose, these three strategies were employed and compared. The main economic traits, including egg production capability, egg quality, growth performance, meat production capability, and down feather production capability were all measured systematically. For egg production capability and egg quality, the upgrading group had the highest egg-laying rate, and the intersecting group had the biggest egg size compared with the routine group ($p < 0.05$). No significant difference was observed in the egg shape index ($p > 0.05$). The routine group had the best fertility and hatchability ($p < 0.05$). For growth performance, the intersect group had the biggest hatch weight ($p < 0.05$), and the upgrading group had the fastest growth rate ($p < 0.05$). For meat production capability and down feather production capability, no significant difference was observed ($p > 0.05$). We found that different cross-breeding strategies had different superiority on economic traits. The economic value of each economic trait should be taken into account so that an optimized cross-breeding strategy could be made to get the most of the benefits.

Key words: Carlos goose, Zi goose, upgrading, intersecting, cross-breeding

1. Introduction

Animal breeders have been trying to find effective ways to improve the economic traits of domesticated poultry, and two main approaches are pure-breeding and cross-breeding [1]. The pure-breeding strategy can maximize the potential of one certain economic trait through a long-term and strong artificial selection [2]. The most representative and successful examples are the layer and broiler chickens that almost reach their physiological limits [3]. While the cross-breeding strategy is advantageous to release the potential of both male and female parents, the heterosis is unstable compared with pure-breeding and the improved traits could not be fixed permanently [4]. Cross-breeding of exotic with indigenous poultry breeds can greatly improve their economic traits in a relatively short time to meet the commercial needs [5].

For goose breeding, more attention should be paid to the comprehensive economic value rather than a single trait. To balance meat, egg, and down feather production performances to get the maximum benefit, cross-breeding between different goose breeds is the better choice [6]. Zi goose is native to Northeast China and is famous for its excellent egg production performance [7,8]. But it has poor meat production performance, which impacts the overall income of farmers. In contrast, the weight of Carlos goose is nearly two times more than Zi goose, but the poor reproductive performance limits the rapid expansion of the goose population. Choosing an optimized cross-breeding strategy to improve the economic traits of these two goose species will help the farmers to gain more benefits. Most studies mainly focused on one-generation of cross-breeding and one trait improvement, but it could only partially reach the potential of the geese. To better balance their performances, routine, upgrading, and intersecting cross-breeding strategies were used in our study. To identify which strategy is the best, growth performance, and meat, egg, down feather production capabilities were measured systematically and compared among the three groups. Overall, our results showed that upgrading and intersecting cross-breeding strategies can significantly improve the main economic traits of the geese by 10% to 20%.

2. Materials and methods

2.1. Animal care

All the experiments were approved by the Animal Care Ethics Committee of Jilin Agricultural University (Changchun, Jilin, China).

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2.2. Animals and experimental design

The Carlos geese were introduced from Hungary by Jilin Agricultural University. Both Carlos and Zi geese were raised under the same conditions in our goose breeding base affiliated with Jilin Agricultural University.

All these geese were divided into three groups. Group I was Carlos♂ × Zi♀ (routine), Group II was Carlos♂ × F1♀ (upgrading), and Group III was F1♂ × F1♀ (intersecting). Each group had three replicates, and twenty geese in each replicate (male:female = 1:4).

2.3. Measurements of growth performance, and meat, egg, down production capabilities

For egg production capability and egg quality, the egg-laying rate (total egg number at each stage/30 days/48 geese), average egg weight (total egg weight/total egg number), egg shape index (width of egg/length of egg), fertility (number of fertile eggs/number of total eggs), and hatchability (number of hatched eggs/number of fertile eggs) were measured in all three groups during different stages. When the egg-laying geese reached their stable status, the data were collected for three months. The first month is the early stage, the second is the middle stage, and the third is the late stage.

For growth performance, the weight of each progeny from all three groups was measured once a week with an electronic scale.

For meat production capability, body weight before slaughter (12h fast but free access to water), slaughter weight, half-eviscerated weight, eviscerated weight, breast muscle weight, and thigh muscle weight were all measured at the 70 days after hatch (ten geese from each group, male:female = 1:1) with an electronic scale. Rates of slaughter, half-eviscerated, eviscerated, breast muscle, and thigh muscle were then calculated respectively.

For down feather production capability, down feathers were taken from the breast and abdomen of the geese at 70 days and 120 days after hatch. The weight of thousand down feathers and length of down feathers were measured with electronic balance and vernier caliper respectively.

2.4. Statistical analysis

The experimental grouping follows the RCBD (randomized complete block design) rule. All the data were analyzed by SPSS 23.0 software using the one-way ANOVA procedure and Duncan's multiple range tests. These data after processing were shown as mean ± SEM (standard error of the mean). The value $p > 0.05$ means that no significant difference, and $p < 0.05$ means that the difference is statistically significant.

3. Results

3.1. Comparison of egg production capability and egg quality

During the egg-laying period, the egg-laying rate of Group II was significantly higher than the other two groups by 27% and 26%, respectively on average ($p < 0.05$) (Table 1). For average egg weight, Groups II and III were significantly higher than Group I by 15% and 26% at the early stage ($p < 0.05$), by 13% and 19% at the middle stage ($p < 0.05$). There was no significant difference between Groups II and III until the late stage ($p < 0.05$) (Table 2). Different cross-breeding strategies showed no effects on the egg shape index ($p > 0.05$) (Table 3).

Group I had the best fertility and hatchability, Group II had the worst overall. For fertility, there was no significant difference between Group I and III ($p > 0.05$), but both of them were higher than Group II by 11% and 10% at the early stage ($p > 0.05$), by 18% and 20% at the late stage ($p < 0.05$) (Table 4). For hatchability, Group I was the highest during the whole period, 25% and 13% more than Groups II and III respectively on average ($p < 0.05$) (Table 5).

3.2. Comparison of growth performance

Group III had the biggest hatch weight ($p < 0.05$) and this superiority lasted for only two weeks. After the 2nd week, the weight of Group II surpassed Group III until the end of

Table 1. Comparison of egg-laying rate among different cross-breeding strategies.

Egg-laying rate (%)	Group I	Group II	Group III
Early stage	21.24 ± 1.96^{b}	49.30 ± 2.26^{a}	44.02 ± 0.71^{a}
Middle stage	53.12 ± 2.13^{a}	57.14 ± 1.78^{a}	42.91 ± 2.07^{b}
Late stage	51.43 ± 1.78^{a}	53.28 ± 2.12^{a}	40.07 ± 1.82^{b}
Average	41.93 ± 1.43^{b}	53.26 ± 2.39^{a}	42.33 ± 2.47^{b}

Note. All the data in the table were shown as mean ± SEM (standard error of the mean). Different superscripts indicated there was a significant difference comparing one to another in the same line ($p < 0.05$). The same superscript indicated no significant difference ($p > 0.05$). Group I was Carlos♂ × Zi♀ (routine), Group II was Carlos♂ × F1♀ (upgrading), and Group III was F1♂ × F1♀ (intersecting).

Table 2. Comparison of average egg weight among different cross-breeding strategies.

Average egg weight (g)	Group I	Group II	Group III
Early stage	143.78 ± 8.25^{b}	164.81 ± 7.^{2}5^{a}	180.55 ± 4.82^{a}
Middle stage	132.63 ± 2.11^{b}	150.50 ± 9.77^{a}	157.47 ± 7.69^{a}
Late stage	131.64 ± 3.42^{b}	141.87 ± 4.16^{b}	163.46 ± 5.73^{a}
Average	136.02 ± 4.59^{b}	152.39 ± 7.06^{b}	167.16 ± 6.08^{a}

Note. All the data in the table were shown as mean ± SEM (standard error of the mean). Different superscripts indicated that there was a significant difference when compared to each other in the same line ($p < 0.05$). The same superscript indicated no significant difference ($p > 0.05$). Group I was Carlos♂ × Zi♀ (routine), Group II was Carlos♂ × F1♀ (upgrading), and Group III was F1♂ × F1♀ (intersecting).

Table 3. Comparison of egg shape index among different cross-breeding strategies.

Egg shape index	Group I	Group II	Group III
Early stage	0.68 ± 0.01	0.66 ± 0.02	0.66 ± 0.01
Middle stage	0.67 ± 0.01	0.67 ± 0.01	0.66 ± 0.01
Late stage	0.68 ± 0.01	0.68 ± 0.01	0.66 ± 0.02

Note. All the data in the table were shown as mean ± SEM (standard error of the mean). No superscript indicated no significant difference was observed among these three groups ($p > 0.05$). Group I was Carlos♂ × Zi♀ (routine), Group II was Carlos♂ × F1♀ (upgrading), and Group III was F1♂ × F1♀ (intersecting).

Table 4. Comparison of fertility among different cross-breeding strategies.

Fertility (%)	Group I	Group II	Group III
Early stage	86.18 ± 5.11^{a}	77.65 ± 4.31^{a}	85.47 ± 2.31^{a}
Middle stage	84.71 ± 4.26^{a}	81.33 ± 5.42^{a}	84.65 ± 1.87^{a}
Late stage	78.95 ± 1.97^{a}	66.67 ± 3.75^{b}	80.00 ± 6.11^{b}
Average	83.28 ± 3.78^{a}	75.22 ± 4.49^{a}	83.37 ± 3.43^{a}

Note. All the data in the table were shown as mean ± SEM (standard error of the mean). Different superscripts indicated there was a significant difference comparing one to another in the same line ($p < 0.05$). The same superscript indicated no significant difference ($p > 0.05$). Group I was Carlos♂ × Zi♀ (routine), Group II was Carlos♂ × F1♀ (upgrading), and Group III was F1♂ × F1♀ (intersecting).

our experiments ($p < 0.05$). The weight of Group I was the smallest during all the stages (Table 6).

3.3. Comparison of meat production capability

All the indexes of meat production capability showed no significant differences among the three groups ($p > 0.05$) (Table 7).

3.4. Comparison of down feather production capability

Different cross-breeding strategies did not affect the down feather production capability of each group ($p > 0.05$) (Table 8).

4. Discussion

4.1. Growth performance and meat production capability

Recently, the cross-breeding strategy has become an important way to improve the economic traits of goose in China. Most of the previous studies focused on growth performance and meat production capability. For example, cross-breeding of Yangzhou goose and Landes goose or Huoyan goose and Sichuan goose could result in greater body weight [9,10]. The offspring derived from cross-breeding of Canada goose and White Koluda goose had

Table 5. Comparison of hatchability among different cross-breeding strategies.

Hatchability (%)	Group I	Group II	Group III
Early stage	80.24 ± 2.95^{a}	68.43 ± 1.76^{b}	71.34 ± 3.67^{ab}
Middle stage	91.56 ± 7.32^{a}	70.62 ± 2.19^{b}	80.21 ± 3.71^{a}
Late stage	86.59 ± 6.63^{a}	67.17 ± 3.47^{b}	76.13 ± 4.85^{a}
Average	86.13 ± 5.63^{a}	68.74 ± 2.47^{b}	75.89 ± 4.08^{b}

Note. All the data in the table were shown as mean ± SEM (standard error of the mean). Different superscripts indicated there was a significant difference comparing one to another in the same line ($p < 0.05$). The same superscript indicated no significant difference ($p > 0.05$). Group I was Carlos♂ × Zi♀ (routine), Group II was Carlos♂ × F1♀ (upgrading), and Group III was F1♂ × F1♀ (intersecting).

Table 6. Comparison of body weight among different cross-breeding strategies.

Weight of offspring (g)	Group I	Group II	Group III
Hatch weight	74.30 ± 6.18^{b}	89.43 ± 7.34^{b}	104.26 ± 9.26^{a}
1st week	197.25 ± 9.86^{c}	237.32 ± 14.06^{b}	300.59 ± 10.38^{a}
2nd week	480.37 ± 21.41^{b}	682.90 ± 57.20^{a}	795.74 ± 34.06^{a}
3rd week	878.20 ± 46.30^{b}	1160.40 ± 60.02^{a}	1190.81 ± 64.24^{a}
4th week	1395.42 ± 75.21^{a}	1540.74 ± 102.30^{a}	1534.31 ± 97.37^{a}
5th week	1740.08 ± 93.53^{b}	2040.15 ± 170.45^{a}	2020.17 ± 100.20^{a}
6th week	2275.66 ± 110.25^{a}	2593.63 ± 230.40^{a}	2532.22 ± 176.55^{a}
7^{h} week	2741.54 ± 105.26^{b}	3180.46 ± 130.08^{a}	3017.94 ± 160.64^{ab}
8th week	3123.30 ± 96.89^{b}	3568.50 ± 87.30^{a}	3380.15 ± 100.41^{ab}
9th week	3348.26 ± 142.93^{b}	3780.09 ± 107.70^{a}	3590.06 ± 202.10^{ab}
10th week	3480.67 ± 201.33^{a}	3960.33 ± 206.38^{a}	3740.28 ± 210.42^{a}

Note. All the data in the table were shown as mean ± SEM (standard error of the mean). Different superscripts indicated there was a significant difference comparing one to another in the same line ($p < 0.05$). The same superscript indicated no significant difference ($p > 0.05$). Group I was Carlos♂ × Zi♀ (routine), Group II was Carlos♂ × F1♀ (upgrading), and Group III was F1♂ × F1♀ (intersecting).

relatively greater slaughter yields [11]. Cross-breeding of indigenous goose and exotic goose could have greater heterosis, such as Carlos goose and Yangzhou goose [12].

Consistent with previous studies, our results also showed that the cross-breeding strategy was helpful to improve growth performance. But in our study, the meat production capability was not improved significantly. Also, we found that upgrading and intersecting cross-breeding strategies were superior to routine one-generation cross-breeding. These two cross-breeding strategies were better ways to develop the potential of parental economic traits.

4.2. Egg production capability and egg quality

Our results showed that the upgrading cross-breeding group had better and more stable egg-laying performance, and both upgrading and intersecting groups had bigger average egg weights, especially the intersect group suggesting these two strategies were better ways for improving egg quality.

There is a big variation in fertility among different goose breeds (53.8% to 84.72%) [13–16]. Heavy breeds have lower fertility, which can be improved by cross-breeding with small high-yield breeds [17]. Zi goose has excellent egg-laying performance and is always used as the female parent in the cross-breeding system. Our results showed that upgrading and intersecting groups could not provide further improvement of fertility and hatchability compared with one-generation routine cross-breeding. So, different cross-breeding strategies had different effects on different economic traits.

Table 7. Comparison of slaughter performance among different cross-breeding strategies.

Index	Group I	Group II	Group III
Body weight before slaughter (kg)	3.48 ± 0.25	3.96 ± 0.21	3.74 ± 0.36
Slaughter weight (kg)	3.01 ± 0.15	3.34 ± 0.18	3.28 ± 0.22
Half-eviscerated weight (kg)	2.67 ± 0.17	3.10 ± 0.19	2.65 ± 0.24
Eviscerated weight (kg)	2.32 ± 0.22	2.50 ± 0.35	2.39 ± 0.22
Breast muscle weight (g)	258.00 ± 19.89	286.00 ± 35.90	290.00 ± 43.40
Thigh muscle weight (g)	322.00 ± 22.63	337.00 ± 53.10	350.00 ± 47.32
Slaughter rate (%)	86.49 ± 2.13	84.34 ± 3.90	87.86 ± 2.21
Half-eviscerated rate (%)	76.93 ± 3.34	78.28 ± 4.12	70.86 ± 3.51
Eviscerated rate (%)	66.67 ± 2.36	63.13 ± 2.77	64.06 ± 3.12
Breast muscle rate (%)	11.12 ± 0.37	11.14 ± 0.52	12.10 ± 0.64
Thigh muscle rate (%)	13.88 ± 1.21	13.48 ± 0.78	14.61 ± 1.02

Note. All the data in the table were shown as mean ± SEM (standard error of the mean). No superscript indicated no significant difference was observed among these three groups ($p > 0.05$). Group I was Carlos♂ × Zi♀ (routine), Group II was Carlos♂ × F1♀ (upgrading), and Group III was F1♂ × F1♀ (intersecting).

Table 8. Comparison of down feather quality among different cross-breeding strategies.

Index	Weight of thousand down feathers (g)		Length of down feathers (mm)	
	70d	120d	70d	120d
Group I	1.17 ± 0.13	1.92 ± 0.15	21.04 ± 1.80	25.32 ± 2.76
Group II	1.11 ± 0.16	1.96 ± 0.18	20.43 ± 1.98	27.86 ± 3.12
Group III	1.06 ± 0.11	1.98 ± 0.16	19.56 ± 2.12	28.08 ± 2.47

Note. All the data in the table were shown as mean ± SEM (standard error of the mean). No superscript indicated no significant difference was observed among these three groups ($p > 0.05$). Group I was Carlos♂ × Zi♀ (routine), Group II was Carlos♂ × F1♀ (upgrading), and Group III was F1♂ × F1♀ (intersecting).

4.3. Down feather production capability

The feathers grow from the feather follicles, contour feathers are from primary feather follicles, and down feathers are from secondary feather follicles [18,19]. For duck and goose, down feathers are the unique type of feathers with the highest economic value compared with egg and meat. But the genetic and developmental knowledge of down feathers is largely unknown which hinders the progress of goose cross-breeding for this economic trait. Our results showed no significant difference among the three groups on the down feather trait suggesting that genomic selection and other breeding methods should be taken into consideration to improve the down feather trait [20,21].

In conclusion, our results demonstrated that upgrading and intersecting cross-breeding strategies were better methods to improve growth performance, meat production capability, and egg quality of goose, though these two methods had no superiority on fertility and hatchability. Our results suggested that cross-breeding strategies could not improve every economic trait of the goose, the optimal strategy we choose depends on the total economic value of these changed traits or the specific breeding aims we plan.

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