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Analysis of fitness predominance for Gaoyou duck's double-yolk egg

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ABSTRACT

One pair of recessive major gene and several modifiers dominated the major gene of Gaoyou duck's double-yolk egg. The fitness of double-yolk egg trait was analyzed by population genetics one the basis of special environment and natural geography. The results showed that the double-yolk egg trait fitness was 8.23 under artificial selection during the year 2000 to 2002. The equilibrium of high intensive artificial selection and natural selection resulted in the trait of Gaoyou duck's double-yolk egg.

KEYWORDS

Gaoyou duck;
Double-yolk egg;
Fitness;
Gene.

INTRODUCTION

Domestication actually is the process of artificial selection. Like natural selection, artificial selection acts by allowing differential reproductive success to individuals with different genetically determined traits in order to increase the frequency of desirable traits in the population. However, unlike naturally selected traits, artificially selected traits do not necessarily convey greater fitness. Instead, artificially selected traits are based on what the person breeding animal's desires[4].

These traits, which can range from hornless goats[3,6] to a particular coat color in domestic animals[14], are selected for by allowing only individuals that possess the trait to reproduce, while those that lack the trait are prevented from reproducing. Because it lacks the control of fitness needing to increase fitness, artificial selection can cause problem traits to predominate in a species.

Fitness is a measure of reproductive success. Those individuals who leave the largest number of mature offspring are the fittest. The maintenance of reproductive fitness in lines subjected to artificial selection is one of the major problems in animal breeding. The decline in reproductive performance has neither been predictable from heritabilities and genetic correlations, nor have conventional selection indices been adequate to avoid the problem.

The Gaoyou Duck is one of the best duck strains in China. Gaoyou duck, distributed Lixiahe district, Jiangsu province and protected in preserve areas and in preserve farms (Gaoyou Breeder Duck Farm), is excellent in egg production. Gaoyou Duck can be used to make processed and salted duck, and is famous for producing double yolk eggs[1,13]. There were 100 000 ducks in 2002. Age at first laying is 120~160 days. Annual

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egg production is over 200 at 500 days. Average egg size is about 85g. Eggshell color is white and green[2]. Gaoyou duck is a breed of duck that has been bred for egg production, especially double-yolk egg. In the process of selecting for this appearance, a genetic defect has increased in frequency in the population. Usually, a double yolk egg will not even survive to hatch. If it does hatch, the poor ducks are severely deformed, connected to one another. Clearly, this condition does not increase the double-yolk egg's fitness and would be strongly selected against by natural selection. However, since these ducks have been subjected to artificial rather than natural selection for generations, the defect has spread in the population. The percentage of Gaoyou duck double-yolk egg reaches 2-10%, another high percentage's poultry breed of double-yolk egg is Shaver star cross 288 hens[7,11].

The trait of Gaoyou duck's double-yolk egg is a kind of fitness or embodiment of fitness. A double yolk egg can't be hatched and would be strongly eliminated through natural selection. But double-yolk egg line remains at the condition of artificial selection by the reason of human favor of double-yolk egg along the southern part of the Jianghuai Plain.

In this study, 4 closed populations, 19 lines egg laying performance from 2000 to 2002 are statistically and genetically analyzed in order to analyze of fitness predominance for Gaoyou duck's double-yolk egg.

MATERIALS AND METHODS

Basic investigation of Gaoyou duck population

Gaoyou Breeding Duck Farm was built in 1975. Since then, a series of breeding methods was carried out to establish basic breeding population. As a result of many year artificial selections, duck body and appearance are basically alike and production performance improves. Annual egg production is 170, 20 more than at the beginning of the Farm. The age at first egg is about 170-180d.

The breeding of Gaoyou duck has fast developed for individual selection since 1990's. By combining line selection with individual selection, egg production of the selection population is 220 to 240 at 500days and egg weight is about 84g by the end of year 2000. There were 39 lines more than 20 000 breeding ducks in 2002. The strain lay high quality and double-yolk egg, but a little plump and lower feed conversion.

Egg production data retrieval

There are 10 populations, 39 lines now. The data for this investigation were taken from egg production record of 4 closed populations,19 lines in Gaoyou Breeding Duck Farm during the period 2000 to 2002. Egg production records per year were all number and double-yolk number from 26th to37th week's age at first egg in early spring.

Statistical and genetic analysis

Statistical and genetic analysis are based on Falconer's method of quantitative genetics[4]

Estimation of double-yolk egg real production

Calculation of repeatability

The trait of double-yolk egg is affected by genetic and environmental factors. It shows different repeatability at different year. Estimation of possible production are needed by repeatability.

$$r_e = \frac{MSb - MSw}{MSb + (K-1)MSw} \qquad K = \frac{1}{D-1}\left(N - \frac{\sum n_i^2}{N}\right)$$

r_e : repeatability; MS_b: square between populations; MSw: square within population; D: number of determined years; N: sum of different population number

Significance testing is adopted by t-test.

Estimation of double-yolk egg real production

$$P_x = (P_n - \bar{P})r_{e(n)} + \bar{P} = (P_n - \bar{P})\frac{nr_e}{1+(n-1)r_e} + \bar{P}$$

P_x: Double-yolk egg real production; $\bar{P}$: Mean value of all population double-yolk egg; P_n: Mean value of individual population n time

Mean value of all population real production and Estimation of sampling error

$$\bar{Y}_{cl} = \frac{\sum_{i=1}^{m} t_i}{\sum_{j=1}^{n} n_i} \qquad S_{\bar{Y}_{cl}} = \sqrt{\frac{M-m}{Mmn^{-2}} \cdot \frac{\sum^{m}(t_i - \bar{t})^2}{m-1}}$$

M: all families of all populations; m: families number of random sample; t_i: all number of within-families; $\bar{n} = \frac{\sum n_i}{m}$: mean value of different families; $\bar{t} = \frac{\sum_{1}^{n} t_i}{m}$ mean value of sample

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Calculation of double-yolk egg fitness under artificial selection

Supposing that trait of no double-yolk egg (H) via double-yolk egg (h) is complete dominant, the trait of double-yolk is recessive inheritance, all ducks laying double-yolk egg are with recessive gene(h), drake is heterozygote Hh, female duck is heterozygote Hh, all h'h' in filial generation shows "double yolk". h'h' is a theoretically sex in that double yolk egg can't be hatched.

q representation double-yolk egg gene frequency, x is double-yolk egg frequency. Because male and female duck theoretically have the trait of laying double-yolk egg, $x = q^2$

w denotes relative selection proportion of no double-yolk egg via double-yolk egg ($0<w<1$), namely, fitness predominance for no double-yolk egg under artificial selection.

Increment of double-yolk egg frequency over one generation

$$\Delta x = \{q^3(1-q)+q^2(1-q)^2\}/2(1-q^2)\{1-(1-q)^2(1-w)\} - q^2/2$$

Supposing double-yolk egg frequency is in equilibrium between adjacent two generation, when $\Delta x = 0$, the equation of which could be expressed: above turns to:

$$W = \frac{1-q}{(1+q)(1-q)^2} = 1 - \frac{\sqrt{x}}{(1-x)(1-\sqrt{x})}$$

$\frac{1}{w} - 1$ denotes fitness predominance for double-yolk egg under artificial selection in this period.

RESULTS

Early egg production record of 19 Gaoyou duck families

Egg production records of 4 Closed populations, 19 Gaoyou duck families shows in TABLE 1 during the year 2000 to 2002. The record was at the age from 26 to 37 week.

TABLE 1 : Early records (26-37 week-age) for egg production of 19 Gaoyou duck families during the year 2000 to 2002

C.P.	F.	2000y (tenth generation)				2001y (eleventh)				2002y (twelfth)			
		F.D.Nu.	E.Nu.	D.Nu	Perc.	F.D.Nu.	E.Nu.	D.Nu	Perc.	F.D.Nu.	E.Nu	D.Nu	Perc.
A	5	50	3161	47	1.49	50	3263	27	0.83	50	3837	61	1.59
B	4	40	2950	43	1.46	40	2516	25	0.99	40	2806	36	1.28
C	6	60	4076	45	1.10	60	3803	44	1.16	60	4510	35	0.78
D	4	40	2474	30	1.21	40	2754	23	0.84	40	3113	37	1.19

C.P.: Closed populations; F.: Families; F.D.N: Female duck number; E.N.: Egg number; D.N: double-yolk egg number; P: Percentage of double-yolk egg

r_e

$$r_e = \frac{MSb - MSw}{MSb + (K-1)MSw} = 0.26$$

$$V_{re} = \frac{2[1+(n-1)r_e]^2 \times (1-r_e)^2}{n(n-1)(D-1)} = 0.1444$$

$$\sigma_{re} = \sqrt{V_{re}} = \sqrt{0.1444} = 0.38$$

$$t = \frac{r_e}{\sigma_{re}} = \frac{0.26}{0.38} = 0.68 < 1.96$$ (=1%, value of t∞), no significant difference at 0. 01 level

Double-yolk egg of Gaoyou duck real production

$$P_X = (P_n - \bar{P})r_{e(n)} + \bar{P} = (P_n - \bar{P})\frac{nr_e}{1+(n-1)r_e} + \bar{P}$$

P_A=1.23; P_B=1.20 P_C=1.08 P_D=1.12

Populations mean real production of double-yolk trait and sample error

$$\bar{Y}_{cl} = \frac{\sum_{i=1}^{m} t_i}{\sum_{j=1}^{n} n_i} = 1.15 \qquad S_{\bar{x}} = 0.08$$

Fitness predominance of double-yolk egg trait under artificial selection

Fitness of no double-yolk egg under artificial selection:

$$W = 1 - \frac{\sqrt{x}}{(1-x)(1-\sqrt{x})} = 0.1215$$

Fitness predominance for Gaoyou duck's double-yolk egg under artificial selection

$$\frac{1}{0.1215} - 1 = 8.23$$

8.23 i.e. fitness of double-yolk is 8.23 time higher than that of no double-yolk egg

DISCUSSIONS

Gaoyou is located at 32°47'N, 119°25'E in the southern part of the Jianghuai Plain, on the north bank of Yangtze River. The climate of Gaoyou belongs to the subtropical monsoon marine climate. It is temperate and moist and the four seasons are quit distinct. Gaoyou is relatively flat with an elevation of 2 to 3 meters. This area is situated in a transit belt from the subtropical region to a warm temperate zone with humid changeable wind and the average temperature is close 15°C with the hottest 27.6°C in July and the coldest 1.7°C in January. The raining season is from the middle of June to July and the annual average rainfall is around 1,000 mm. The average relative humility is 67% and over 200 days free of frost. Numerous rivers and lakes crisscross Gaoyou and the Grand Canal runs northward. The third largest freshwater lake of Jiangsu, Lake Gaoyou, is to its west, providing this area the most important water resource. This environment furnishes Gaoyou duck with the abundance of aquatic produce. So the environment of this area is markedly different from vicinity.

Gaoyou was founded in 223 BC, but archaeological finds in Gaoyou has found evidence of rice growing dating back 5,500-7,000 years[5]. Agriculture has played a large part in the overall economy of the region. The history of domesticating duck is at least more than 1000 years[8]. The well-known feature product this area is double-yolk duck egg and "egg culture" come into being therefore. So Gaoyou duck is the production of long selection and breeding to duck.

At present, most of domesticated chicken and ducks are lower frequency lines of double-yolk egg in the world. Only starcross 288, which has degenerated since it was introduced into China, and Gaoyou duck can be considered as high yield lines of double-yolk egg.

Production traits of Gaoyou duck now depend on breeding system, history of population, selection pressure and so on. At first, a serious of different habitats in different community can lead to domestic duck trait and genetic space differentiation. Secondly, the genetic diversity of Gaoyou duck is the results of long-term evolution accumulation just as other organisms. Production traits of Gaoyou duck now come down to the breeding methods over thousands in the regions of Gaoyou lake. People are especially keen on some traits and fix the trait through some breeding methods in the areas of Yangtze River. For example, people in Lixiahe Region, which attribute to parts of areas of Yangtze River, breed Gaoyou duck by selection of big eggs or double-yolk eggs as hatching egg, which can be approved by long-term egg culture in the regions of Gaoyou lake. The bigger the egg, the more likely chance of a double yolk.

The form causes of double-yolk egg consist of at least genetic factor, only high percentage of Gaoyou duck can be inherited to next generation, and physiological factor, it shows high activities of ovaries from the point of view of physiology and frequently appears in youth female fowls. In additions, other factors, such as environment and pathology, can also affect the trait. Genes control domestic animal economical traits, which is the embodiment of gene expression. The gene expression is affected by organism in- and out-environment. These varieties regulate gene expression by nervous and humoral system. The high ovary activities of youth female fowls are the results of nervous and humoral regulation. So double-yolk egg trait is the result of genetic and environmental correlations.

Season variety, as a kind of predicted and permanent, is proved to involve in the trait of double-yolk egg. The trait is sensitive to environment variety, which cause generally some un-inherited differentiations and increase the difficulties of genetic analysis. The history of Gaoyou duck breeding shows that the Gaoyou ducks laying egg at early spring have upper double-yolk percentage. So we choice the records from 26th to 37th week's age at first egg in early spring of each year.

The trait of double-yolk egg can steadily be inherited and be affected by environment at same time, which shows that the trait is controlled by major genes and affected by modifying genes. Inherit make the Gaoyou duck possess the trait's physiological basis. Whether Gaoyou duck lays double-yolk egg depends on other environment factors. The male and female duck are naturally normal, or they can't reproduce. That is to say, normal duck lays double-yolk egg, which can't al-

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most be hatched. Normal duck carry double-yolk egg gene, which by all means is a recessive mutation according to common genetics. So major genes of double-yolk egg trait attribute to dominant-recessive relationship and are controlled by a couple of recessive major genes and some modifying genes.

Because of special natural-, anthro-geography and culture in the region of Lixiahe river, the endearment of big egg, especially double-yolk egg, make the fitness of double-yolk egg gene reach 8.23 time via undouble-yolk egg under artificial selection and shows high strength artificial selection. Through long-term this selection precession, a high percentage double-yolk egg line appear. High double-yolk percentage egg of Gaoyou duck is the result of artificial long-term selection. Other domesticated duck breeds can also lay double-yolk egg, there are not high percentage of double-yolk egg and special line just as Gaoyou duck because absence of long-term artificial painstaking selection. The balances between artificial and natural selection could been seen in the process of domestication for other animals. Intersexual goats haven't reproductive ability, but the incidence of intersexuality in goat is constant in that selection possibility for hornless goats, whose intersexual genes are supposed to link with polledness gene, is much higher than the horn ones[9,10,12].

Gaoyou duck is one of excellent duck breeds in China. Double yolk egg of Gaoyou is famous around the World. It is first time to study the fitness of Gaoyou duck double-yolk egg trait by population genetics. The fitness analysis are carried through under special background, that is, the condition of local natural- and anthropo-geography.

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