MINISTRY OF EDUCATION AND TRAINING

MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT

NATIONAL INSTITUTE OF ANIMAL SCIENCE

NGUYEN THI MUOI

SELECTION TO IMPROVE PRODUCTIVITY OF TWO LINES Ò LAC THUY CHICKEN AND THE MEAT-PRODUCING ABILIBITY OF THE CROSSBREEDS BETWEEN LAC THUY AND LUONG PHUONG CHICKENS

Speciality: Animal production

Code number: 9.62.01.05

EXECUTIVE SUMMARY OF THE DISSERTATION

HaNoi - 2021

The work was completed at National Institute of Animal Science

Supervisors:

1. PhD. Pham Cong Thieu

2. Assoc. Prof. PhD. Nguyen Huy Dat

Reviewer 1: Assoc. Prof. PhD. Nguyen Van Duc
Reviewer 2: Assoc. Prof. PhD. Tran Hue Vien
Reviewer 3: Assoc. Prof. PhD. Pham Kim Dang

The dissertation will be defended at the Inistitute – Level Doctoral Thesis Evaluation Council, at: National Institute of Animal Aciences, Thụy Phương, NorthTừ Liêm, Hanoi At: …h,..... 2021

The dissertation can be found at:
1. National Library
2. Library of NIAS

PUBLICCATIONS RELATED TO THE THESIS

1. Nguyen Thi Muoi, Nguyen Van Ba, Pham Thi Thanh Binh, Pham Cong Thieu, Nguyen Huy Dat and Pham Doan Lan, 2020. Analysis of genetic characteristics of Lac Thuy chickens using Microsatellite markers. Journal of Animal Husbandry Sciences and Technics (JAHST). Animal Husbandry Association of Vietnam, Vol. 257, June 2020, pp. 2-7.

2. Nguyen Thi Muoi, Pham Cong Thieu, Nguyen Huy Dat and Pham Thi Thanh Binh, 2020. Inheritance level and genetic predisposition of selected traits in LT1 and LT2 lines of Lac Thuy chickens. Journal of Animal Husbandry Sciences and Technics (JAHST). Animal Husbandry Association of Vietnam, Vol. 260, October 2020, pp.2-8.

3. Nguyen Thi Muoi, Pham Cong Thieu, Nguyen Huy Dat, Pham Thi Thanh Binh, Nguyen Trung Hieu, Nguyen Van Tam, Ngo Thi To Uyen, Tran Thi Thu Hang và Dao Doan Trang, 2020. Selection for improved performance of two lines LT1 and LT2 of Lac Thuy chicken breed after 3 generations. Journal of Animal Husbandry Sciences and Technics (JAHST). Animal Husbandry Association of Vietnam, Vol. 260, October 2020, pp. 8- 13.

4. Nguyen Thi Muoi, Pham Cong Thieu, Nguyen Huy Dat, Tran Quoc Hung, Le Thi Thuy Ha, Pham Thi Thanh Binh, Nguyen Trung Hieu, Nguyen Thi Thanh Van và Dao Doan Trang, 2021. Production ability and meat quality of the crossbreed between Lac Thuy and Luong Phuong chickens. Journal of Animal Husbandry Sciences and Technics (JAHST). Animal Husbandry Association of Vietnam, Vol. 264, April 2021, pp. 60 – 64.

INTRODUCTION

Research reasons

Lac Thuy chicken is an indigenous chicken breed that originates from Lac Thuy district, Hoa Binh province and My Duc district, former Ha Tay province a long time ago, and was discovered in 2012 during a survey of latent genetic resources in some Northern mountainous provinces by a research team of the National Institute of Animal Science. This breed has a beautiful conformation, uniform feather color: cocks have plum code color, hens have dry banana leaf color, meat and egg quality is delicious, and preferred by consumers. However, body weight (BW) is low, only 646g for cocks and 529,83g for hens at 8 weeks old; egg yield/hen/at the age of 40 weeks is only 36 - 39,36 eggs; egg yield /hen/at the age of 68 weeks is only 87,94 eggs; Feed consumption for 10 eggs is 4,4 - 4,7 kg (Vu Ngoc Son et al., 2015). Therefore, in order to efficiently conserve and exploit the Lac Thuy chicken gene pool, it is necessary to evaluate the genetic diversity as well as the impact of selection.

Luong Phuong chicken (LV) has been imported into Vietnam since 2000, many studies show that the ability to cross with native chicken breeds is very good, the feather color of Luong Phuong chicken is quite similar to that of Vietnamese native chickens. Moreover, this is the first imported chicken breed in Vietnam to be recognized as a grandparent flock (in 2004). In addition, Luong Phuong chicken has good disease resistance, high egg yield of 165 - 171 eggs/hen/year (Nguyen Huy Dat et al., 2001). Tran Cong Xuan et al. (2004) reported that body weight of LV1 chicken at 20 weeks of age is 2.658g (cock) and 2.106,04g (a hen); egg yield/hen/at the age of 68 weeks is 152,51 eggs; body weight of commercial LV12 chicken at 10 weeks is 1.902,79g; of LV13 is 1.915,50g. Thus, selection for performance improvement, line creation, and productive evaluation of commercial crossbreeds are necessary. Therefore, we carried out the project: "***Selection to improve the productivity of two lines of Lac Thuy chicken and the***

meat-producing ability of the crossbreeds between Lac Thuy and Luong Phuong chickens".

Objectives of thesis

Evaluation of genetic diversity and genetic differences of Lac Thuy chickens with some other native chicken breeds using Microsatellite molecular markers.

improvement of body weight of LT_1 Lac Thuy cock line and egg yield of LT_2 Lac Thuy hen line.

Evaluation of the productive ability of commercial LT_{12} crossbreed (LT_1 male x LT_2 female) and commercial LT_1LV_1 crossbreed (LT_1 male x LV_1 female) and LV_1LT_1 (LV_1 male x LT_1 female).

The scientific and practical value of the study

The scientific value of the study

The thesis is a systematic study from, application in conservation, exploitation to a genetic evaluation in order to select and improve the productivity of Lac Thuy chicken breed in two directions: improvement of body weight of LT_1 cock line, and improve egg yield of LT_2 hen line, and the final product is LT_{12}, LT_1LV_1, and LV_1LT_1 commercial crossbreeds. The research results of the thesis are valuable references for research, teaching, and animal production development.

The practical value of the study

Separately selecting and creating two lines of Lac Thuy chickens in two directions growth rate for LT_1 and egg yield for LT_2 as a basis for breeding, inbreeding management, and promoting the heterosis of commercial crossbreeds to contribute to biodiversity maintenance. increase animal production efficiency, meet the demand of the market for high-quality colored broiler chickens in the society.

New contributions of the thesis

Using the Microsatellite molecular marker, it is confirmed that Lac Thuy chickens are a source of an indigenous chicken gene in Vietnam, with genetic diversity and genetic differences distinct from

other indigenous chicken breeds, and at the same time, this is a precious source of animal genetic material for research and development of specialty chicken breeds in Vietnam.

Selection and improvement of meat and egg productivity of two LT_1 and LT_2 Lac Thuy chicken lines to serve the conservation and efficient exploitation of Lac Thuy chicken gene resources in the direction of specialty poultry development.

Determination of the crossbred formula between LT_1 cock and LV_1 hen for higher economic efficiency compared to the formula between LV_1 cock and LV_1 hen.

Chapter 1: LITERATURE REVIEW

1.1. *The scientific basis of the study*

1.1.1. Scientific basis of genetic diversity assessment using Microsatellite markers

The term microsatellite was introduced by Litt and Luty in 1989 to refer to tandemly repeated DNA sequences, with a length of only a few base pairs (2 - 6 bp), high polymorphism. and can be amplified by PCR reaction.

Microsatellites are used as genetic markers to study population genetics, evolutionary relationships, gene mapping, etc. However, Andrew, H. Paterson (1996) said there was a lot of evidence that the microsatellite sequence also served as a code carrier or regulator.

1.1.2. Scientific basis of selection

Breed selection is the individual selection of males and females to keep for breeding and breeding of livestock suitable for production and at the same time to eliminate the ones that cannot be used as breeding animals that are not suitable for production. Breed selection is a method of artificial selection. In terms of genetics, selection is the process of changing the gene frequencies of a livestock and poultry population. In order to conduct livestock selection to achieve results according to the objectives of the breeding operation, there are many selective methods of inbreeding. According to Lush (1945, citing Nguyen Van Thien, 1995), there are many selection methods for different traits:

a. Successive selection for each trait

b. Simultaneous selection and independent elimination

c. Selection by index

d. Selection by consanguinity.

+ Selection by family

+ Selection within the family

+ Combined selection by family and within the family.

1.1.3. Scientific basis of crossbreeding, heterosis, and influent factors

1.1.3.1. Scientific basis of crossing

Crossing two lines within a breed or crossing two breeds to create a commercial crossbreed, exploitation of high hybrid performance is to take advantage of the heterosis (UTL). The hybrid can carry the dominant traits of the parent breed or can also combine the characteristics of the two breeds.

According to Tran Dinh Mien and Nguyen Kim Duong (1992), based on the purpose of crossing, people often apply different crossing methods such as economic crossing, rotational crossing, improved crossbreeding, synthesis crossing. The economic crossing is the most common crossing method.

To achieve proper economic efficiency, pure lines must be well selected. In the population, heterozygous individuals should be decreased and homozygous individuals should be increased (Nguyen An et al., 1983). Crossing two populations together will produce two effects: Additive of genes and non-additive of genes.

1.1.3.2. Scientific basis of the heterosis

According to Lasley (1974), heterosis is a biological phenomenon that only increases the life expectancy of offspring over the parents in the case of mating between unrelated individuals. Heterosis not only includes high tolerance to unfavorable environments, but also includes mortality reduction, growth rate increase, and productivity and fertility increase. Therefore, the heterosis phenomenon is considered as the particularly beneficial life force of the organism.

According to Lasley (1974), heterosis is usually expressed in % value and calculated according to the following formula:

$$H\,(\%) = \frac{\bar{X}\ P1 - \bar{X}\ b.m}{\bar{X}\ b.m} \times 100$$

In which:

H is heterosis (%),

$\bar{X}$ P1 *is the average mean of phenotypic value for offspring trait*

$\bar{X}$ b.m *is the average mean of phenotypic value for parent trait*

1.1.3.3. Factors influencing the heterosis

a. Crossing formula

b. Trait

c. Difference between father and mother's genetic origin

d. Conditions of caring and feeding

Chapter 2: MATERIALS, CONTENTS AND RESEARCH METHODS

2.1. Research Materials

2.1.1. Research objects

- LT_1 Lac Thuy cock line chicken
- LT_2 Lac Thuy hen line chicken
- LV_1 Luong Phuong chicken
- LT_{12} commercial Lac Thuy crossing (LT_1 cock x LT_2 hen)
- LT_1LV_1 crossing (LT_1 cock x LV_1 hen) and LV_1LT_1 crossing (LV_1 cock x LT_1 hen).

2.1.2. Research location

The project was implemented in:

+ The Animal Experiments and Conservation Center

+ The Key Laboratory of Animal Cell Technology (National Institute of Animal Science)+ Department of Genetics - Animal Breeding, and Central Laboratory (Faculty of Livestock - VNUA).

2.1.3. Research duration

From 6/2016 – 12/2020

2.2. Research content

2.2.1. Determination of genetic diversity of Lac Thuy chickens

2.2.2. Selection for body weight improvement of LT_1 cock line and egg performance improvement of LT_2 hen line.

2.2.3. Evaluation of productivity of LT_{12}; LT_1LV_1 and LV_1LT_1 commercial crossbreeds.

2.3. Research methods

2.3.1. Determination of genetic diversity of Lac Thuy chickens

Method of DNA analyzing in genomes

a. Sampling method

40 blood samples of Lac Thuy chickens were collected at the Animal Experiments and Conservation Center. The chickens were selected randomly, minimizing the blood relationship between them. Each chicken was taken about 1ml of blood according to the given procedure and transferred to the laboratory and stored at -20^0C.

b. DNA extraction

Blood samples were collected and brought to the laboratory, and the samples after treated were extracted using Kit Qiagen.

c. Evaluation of DNA quality

Evaluation of DNA quality through testing on 1% agarose gel. One unit (1.0) of 260 nm absorbance value (A260) was equivalent to 50 μg/ml concentration of DNA.

2.3.2. Selection method for 02 LT_1 and LT_2 chicken lines

2.3.2.1. Selection method

a. For LT_1 chickens (cock line)

Selection for body weight at the age of 8 weeks: weighing some sampled chicken every week, and the whole flock at the age of 8 weeks. Samling based on the weight mean, the selection from high to lower values, for the cock is $\geq$ Mean+2σ and for the hen is $\geq$ Mean.

The stabilizing selection was applied for other traits.

b. For LT_2 chickens (hen line)

Selection for egg productivity: monitoring egg productivity of individual hens in cages (01 cages each) up to 38 weeks of age, then selecting individuals with high to low egg yield for the value $\geq$ Mean to combine into 25 families to collect eggs for breeding for next generation.

The stabilizing selection was applied for other traits.

2.3.2.2. Line multiply method

Used a closed line multiply method, rotated the male over generations to avoid inbreeding. LT_1 chicken was included 20 families; LT_2 chicken was included in 25 families. Each family was included 3 males (01 male for breeding and 1 - 2 male for backup).

2.3.2.3. Feeding method, nutritional value applying to LT_1 and LT_2 chicken lines

LT_1 chickens were raised underfloor and completely captive according to Lac Thuy chicken raising process of the Animal Experiments and Conservation Center. egg yield was monitored by using nests with an automatic closing door.

LT_2 chickens were cared, raised, and veterinary and hygiene cared from 01 day - 16 weeks old according to Lac Thuy chicken raising process of the Animal Experiments and Conservation Center. From week 17^{th}, chickens were put into cages (closed cages) to monitor l egg performance individually.

LT_1, LT_2 chickens in the period from 01day – 6 weeks old were fed freely all day and night, from 7 - 8 weeks old were fed freely during the day to 6 pm daily; period of 9 - 20 weeks old was limited feeding; at a reproductive period, the chickens were fed according to laying rate.

2.3.3. Methods to evaluate production ability of commercial crossbreeds

2.3.3.1. Experimental arrangement method

The experiment was arranged in a completely randomized design with one factor, each batch of 50 one-day-old chicks (50% cocks and 50% hens), between the lots, there was a similarity in procedures of rearing, and animal health care …, the only difference in experimental factor was the hybrid formula. Chickens were raised on the ground, sharing cocks and hens, free-feeding regime, and naturally ventilated cages. Experimental chickens were arranged in the 3rd generation.

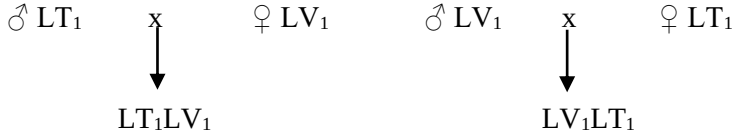
LT_{12} commercial chicken crossing diagram

♂ LT_1 x ♀ LT_2

↓

LT_{12}

LT_1LV_1 and LV_1LT_1 commercial chicken crossing diagram



2.3.3.2. Methods of monitoring, data collection, and research indicator determination

The experimental chickens were recorded in detail in the daily diary, including: the health status of each flock, the number of chickens lost, and the amount of daily feed. All experimental chickens were weighed before fed in the morning on a fixed day of the week, used an electronic balance with an accuracy of ±0,5g and a uniform balance with an accuracy of ±10g. The method of determining the research indicators was evaluated and calculated according to the method described by Bui Huu Doan et al. (2011).

The indicators on chemical components of chicken meat (breast meat and thigh meat) were analyzed by TCVN standard methods at the Central Laboratory of the Faculty of Livestock Production, VNUA (ISO/IEC 17025: 2017, VILAS). 1223).

2.3.3.3. Monitoring indicators: Conformation, survival rate (%) body weight (KLCT) at different weeks of age (g), feed consumption/kg body weight gain (TTTA/kg body weight gain) (kg), heterosis (%), chicken meat performance and chemical composition.

2.4. Data analysis methods

Population statistical parameters (F-statistics-Weir and Cockerham 1984) such as alleles number (Na), mean allele number per locus, polymorphic information (PIC) and theoretical heterozygosity coefficient(He), heterozygosity observation coefficient (Ho), inbreeding coefficient (Fis) were estimated by FSTAT 2.9.3.2 software (Goudet, 2002).

Genpop 3.3 software was used to test the Hardy-Weinberg (HW) genetic balance of each locus (Raymond & Rousset, 1995).

The genetic distance was calculated according to the method of Nei (1972) and tested for genetic differences according to the standard "Chi-square distribution" using the Genetix software version (3.0).

Comparative statistical analysis of production traits between generations of LT_1 cock lines; LT_2 hen lines and production traits of commercial chickens between purebred and crossbred chickens by

the general linear model (GLM) on SAS software. Pair comparisons among means were performed using Duncan's method.

Chapter 3: RESULTS AND DISCUSSION

3.1. Determination of genetic diversity for Lac Thuy chickens

The genetic diversity of Lac Thuy chicken population is relatively high. The inbreeding coefficient of Lac Thuy chicken is very low, which shows that the current operations of conservation and development of this breed is good.

Lac Thuy chickens have a long genetic distance from Dong Tao, Mia, and Ri chickens and have a separate and homogeneous genetic structure. This result is the scientific basis for using Lac Thuy chickens to cross with other breeds for hybrid heterosis.

3.2. Selection for improved productivity of 2 LT_1 and LT_2 Lac Thuy lines

3.2.1. Confirmation of LT_1 and LT_2

Selection results over 4 generations: LT_1 and LT_2 chicken have similar conformation. On the first day of age, chickens are mostly yellow-white (98 - 100%), beak, and legs are light pinks. At maturity, chickens have a red comb, standing, bright red, red crest, yellow skin, and legs, cocks have plum color, hens have mainly dried banana leaves color. The results of this study are consistent with the publication of Vu Ngoc Son et al. (2015).

3.2.2. Selection for an improved body weight of LT_1 chicken

3.2.2.1. Selection for body weight of LT_1 chicken at the age of 8 weeks

The results in Table 3.1 show that the selection intensity at 8 weeks age of cocks is 2,18 - 2,54 and hens is 0,67 - 0,87 in generations, the selection differential is 174,41 - 225,10g/chicken for cocks and 50,68 - 67,73 g/chicken for hens. Thus, after 3 generations of selection, the body weight of LT_1 chickens in the 3rd generation is 855,03g for cocks and 704,06g for hens, increasing at 148,75g and 94,62g respectively, 21,06 and 15,53% compared to the parental generation ($P<0,05$).

The results of this study are also consistent with the results of research on a selection of Ri Ninh Hoa chickens by Dong Sy Hung et al. (2019). The author reported that after 3 generations of selection, the body weight of Ri Ninh Hoa chickens in the 3rd generation at 8

weeks old was increased by 15,78% compared to the parental generation.

Table 3.1. Body weight of LT_1 chicken at the age of 8 weeks over generations

Flock	indicator	Unit	Parental Gn	Gn1	Gn2	Gn3
Cock						
Populatipon	Number	chicken	653	630	664	667
	Mean	g	706,28^{d}	788,90^{c}	831,61^{b}	855,03^{a}
	SD	g	80,11	97,26	91,35	83,08
Selection	Number	chicken	72	64	67	67
	Mean	g	880,69	1.002,66	1.056,72	1.065,67
	Selection differential	g	174,41	213,76	225,10	210,64
	Selection rate	%	11,03	10,14	10,09	10,03
	Selection intensity		2,18	2,20	2,46	2,54
Hen						
Populatipon	Number	chicken	658	752	742	759
	Mean	g	609,44^{d}	660,08^{c}	695,66^{b}	704,06^{a}
	SD	g	77,78	75,19	77,96	75,15
Selection	Number	chicken	286	334	426	418
	Mean	g	677,17	725,49	752,05	754,74
	Selection differential	g	67,73	65,41	56,39	50,68
	Selection rate	%	43,47	44,41	57,41	55,07
	Selection intensity		0,87	0,87	0,72	0,67

Note: the mean values in the same column with different superscripts are statistically different (P<0,05).

3.2.2.2. Survival rate, feed consumption in the young age stage (poussin) of LT_1 chicken

The survival rate of LT_1 chickens at the age from 0 - 8 weeks over generations is 92,75% - 96,90%, similar to the research results of Do Thi Kim Dung (2014) on Lac Thuy chickens that is 92,86%; but in 9 - 20 weeks old, the survival rate of LT_1 cocks is 94,44 -

95,52%, of LT_1 hens is 95,45 - 96,89%, higher than the research results of Do Thi Kim Dung. (2014) of 80% for cocks and 90,93% for hens at 9 - 19 weeks of age.

Feed consumption per chicken in the period of 01day - 8 weeks of age in generations is 1,70 - 1,82kg, consistent with the research results of Tran Duc Hoan et al. (2018), the author announced that the feed consumption per chicken in general for cock and hen in the period of 01 day - 8 weeks of age of Lac Thuy chickens is 1,81kg

3.2.2.3. Laying age, body weight, and egg weight at the stage of laying 5%; 30%; 50% and the age of 38 weeks

The mature age of LT_1 chickens is earlier than many other native chicken breeds, 5% laying age at 138 - 142 days, earlier than To chicken in the study of Pham Cong Thieu et al. (2018) with 5% laying age at the day of 145 - 157, a study of Ngo Thi Kim Cuc et al. (2017) showed that the 4th generation Mong chickens having 5% laying age at 161 days.

Body weight at the stages: 5%; 30%, 50% laying rate and at 38 weeks of age are increased gradually over time in each generation and also gradually increased over generations, this is consistent with the rule of poultry development and also confirms the selection results in increased body weight of LT_1 chickens.

3.2.2.4. Egg performance, feed consumption/10 eggs of LT_1 *chickens*

Egg performance at 38 weeks of age of LT_1 chickens in the parental generation is 44,82 eggs; the first generation is 44,93 eggs; the second generation is 44,92 eggs and the 3rd generation is 45,02 eggs, at 68 weeks of age, egg performance over generations is: 94,15; 94,26; 93,52; 93,83 eggs. This result is also similar to the study result of Do Thi Kim Dung (2014) with egg performance at 38 weeks of age of 45,56 eggs.

3.2.2.5. Embryo rate and hatchability of LT_1 *chickens over 4 generations*

Eggs were collected and incubated from week 27^{th} to week 38^{th}, the results are presented in Table 3.2.

Table 3.2. Embryo rate and hatchability of LT_1 chickens over 4 generations

Indicator	Unit	Parental Gn	Gn 1	Gn2	Gn3
Total hatching eggs	eggs	6.667	7.030	10.142	7.547
Embryonic rate	%	90,18	90,67	91,35	91,22
Incubated rate/total hatching eggs	%	79,74	80,79	81,08	81,16
Incubated rate/embryonic egg	%	88,42	89,11	90,66	90,43

Table 3.2 shows that the embryonic rate of LT_1 chickens in 4 generations is relatively stable at 90,18 - 91,35%; incubated rate/total hatching eggs is 79,74 - 81,16%.

According to Le Thi Thu Hien et al. (2015), the embryonic egg of Dong Tao chickens is 85,24 - 86,03%, type 1 chickens rate/total hatching eggs is 67,88 - 68,83%, our research results are higher than that.

3.2.3. Selection to improve egg performance of LT_2 chicken line

3.2.3.1. Selection to improve egg performance at 38 weeks age of LT_2 chicken over 4 generations

Table 3.3 shows that the egg performance at the age of 38 weeks of LT_2 chickens is increased gradually from the parental generation to the 3rd generation, is 53,83; 58,56; 61,70, and 63,34 eggs, respectively. After 3 generations of selection, the egg performance at 38 weeks of age of LT_2 chickens in the 3rd generation is increased by 9,51 eggs compared to the parental generation, corresponding to an increase of 17,67%, an increase of 18,32 eggs compared to LT_1 chickens, equivalent to 40,66%. Dong Sy Hung et al. (2019) announced the results of selection for egg performance of Ri Ninh Hoa chicken eggs in the 3rd generation with an increase of 9,2 eggs, equivalent to 23,3% compared to the parental generation. Thus, the results of our study are consistent.

Table 3.3. Selection to improve egg performance at 38 weeks of age over 4 generations

Flock	Parameter	Parental Gn	Gn 1	Gn2	Gn3
Population	n (chicken)	425	540	520	540
	Mean (egg)	53,83[c]	58,56[b]	61,70[a]	63,34[a]
	SD (egg)	17,55	17,26	16,61	15,08
Selection	n (chicken)	252	305	305	300
	Mean (egg)	65,44	71,61	73,64	75,15
	Selection differential (egg)	11,61	13,04	11,94	11,81
	Selection intensity	0,66	0,76	0,72	0,78

Note: the mean values in the same column with different superscripts were statistically different (P<0,05).

3.2.3.2. Body weight of LT_2 chicken over generations

LT_2 chickens were selected to improve egg performance, but body weight traits at 8 weeks and 20 weeks of age remained stable. The body weight of the LT_2 cocks of the pairs: for the parental generation and the 1st generation are 632,44 and 640,10g; for the second generation and the third generation are 665,25 and 670,39g, with P>0,05, but the parental generation and the 1st generation compared to the 2nd, and 3rd generations are lower, but only 25,15 - 30,29g, equivalent to 3,9 - 4,7%. For hen at the age of 8 weeks, the body weight of the 1st, 2nd and 3rd generations are similar, reached 544,41; 546,80 and 550,83g, respectively (P>0,05). Particularly, the parental generation is lower, only 538,85g.

Vu Ngoc Son et al. (2015) researched on Lac Thuy chickens, confirmed that the body weight of Lac Thuy cocks is 646,27g at 8 weeks of age and 1.852,15g at 20 weeks of age. At 20 weeks of age, our research results are similar.

3.2.3.3. Survival rate, feed consumption at the young age (poussin) of LT_2chicken

The survival rate of LT_2 chickens at 0 - 8 weeks of age is 92,75 - 95,96% (in general for hen and cock); the period of 9 - 20 weeks of age is 94,29 - 96,15% for cocks and 94,11 - 96,15% for hens, similar to the results of Do Thi Kim Dung (2014) researched Lac Thuy chicken breeds at 0 - 8 weeks of age with the result of 92,86%, but higher than those of Do Thi Kim Dung at 9 - 19 weeks of age, only 80% for cocks and 90,93% for hens…

The feed consumption/chicken/in the stage of 01day - 8 weeks of age for generations is 1,63 - 1,64kg (calculated for both cock and hen); At 9 - 20 weeks of age, the male is 5,83 - 5,86 kg, and female is 4,97 - 5,65 kg.

3.2.3.4. *Laying age, body weight, and egg weight at the stage of 5%; 30%; 50% laying and 38 weeks of age*

The 5% laying age of LT_2 chickens at 138 - 141 days is similar to that of LT_1 chickens, but the time at 50% laying of LT_2 chickens is 9 - 10 days earlier than LT_1 chickens. According to Do Thi Kim Dung (2014), the age of sexual maturity of Lac Thuy chickens at the time of 5% laying is 142 - 144 days; 50% laying is 191 - 194 days, the laying rate of LT_2 chickens at these laying levels is earlier.

3.2.3.5. Egg performance, feed consumption/10 eggs of LT_2 chickens

Egg performance at 68 weeks of age of LT_2 chickens in the parental generation is 123,80 eggs; of the 1st generation is 129,48 eggs, of the 2nd generation is 133,51 eggs and of the 3rd generation is 135,73 eggs, which are higher than the parental generation 11,93 eggs, equivalent to 9,6%, leading to feeding consumption/10 breeding eggs is also improved, reducing from 2,74 kg in the parental generation to 2,52 kg in the 3rd generation. This confirms an important role in the selection work to improve performance.

Egg performance at 68 weeks of age of LT_2 chickens in this study in the 3rd generation is 135,73 eggs, higher than the results reported by Vu Ngoc Son et al. (2015) in the study on selection and

conservation of Lac Thuy chicken gene resources, with only 87,94 eggs.

3.2.3.6. Some hatching parameters of LT_2 chickens over 4 generations

Table 3.4. Embryonic rate and hatchability of LT_2 chickens over generations

Parameter	Unit	Parental Gn	Gn1	Gn2	Unit
Total hatching eggs	eggs	11.865	15.420	15.343	17.000
Embryonic rate	%	91.00	90.76	92.55	91.21
Incubated rate/total hatching eggs	%	81.37	79.97	83.91	82.48
Incubated rate/embryonic egg	%	89.42	88.11	90.66	90.43

Embryonic rate and incubated rate/embryonic egg at 27 - 38 weeks of age of LT_2 chickens show that there is no great variation between generations: 90,76 - 92,55% and 88,11 - 90,66%. This result is lower than the published result of Vu Ngoc Son et al. (2015) with the embryonic rate of 93.3%, but higher in incubated rate/total hatching eggs (81,6%).

3.2.4. Heritability and genetic correlation

Table 3.5. Components of variance and heritability for body weight at 8 and 20 weeks of age of LT_1 chickens over generation 3

Content	Body weight at 8 weeks of age	Body weight at 20 weeks of age
Cumulative genetic variance (V_A)	2.516.8	14.376.9
External variance (V_E)	4.720.9	46.855.7
Phenotypic variance (V_P)	7.237.7	61.232.6
Heredity coefficient (h^2±SE)	0.348±0.046	0,235±0,048
External coefficient (e^2±SE)	0.652±0.046	0,765±0,048

The absolute value of heritability for the body weight trait at 8 weeks of age is higher than that of body weight at 20 weeks of age, but is still at medium level, 0,348 and 0,235, respectively. This result

is consistent with the value of 0,31 - 0,35 in the Vietnamese Golden Tau chicken (Nguyen Huu Tinh et al., 2016).

Table 3.6. The components of variance and heritability for the egg performance trait at 38 weeks of age of the 3rd generation LT_2 chickens

Content	Egg performance trait at 38 weeks of age
Cumulative genetic variance (V_A)	99,194
External variance (V_E)	232,787
Phenotypic variance (V_P)	331,981
Heredity coefficient (h^2±SE)	0,299±0,069
External coefficient (e^2±SE)	0,701±0,069

For egg performance trait at 38 weeks of age of LT_2 line (table 3.6), the heritability of this trait is at the medium level (0,299). This result is also consistent with the research results on the Tau Vang chicken breed in Vietnam, which is 0,25 - 0,29 (Nguyen Huu Tinh et al., 2016).

Table 3.7. Genetic, external and phenotypic correlations between body weight at 8- weeks of age and 20- weeks of age in the 3rd generation of LT_1 chicken lines

Correlations	Correlation coefficients
Genetic correlation (r_A ± SE)	0,959 ± 0,023
External correlation (r_E ± SE)	0,871 ± 0,048
Phenotype correlation (r_P)	0,889

Table 3.7 shows that genetic, external, and phenotypic correlations between two traits for body weight at 8 weeks and at 20 weeks of ages of LT_1 line are positively correlated and very tight, 0,959; 0,871 and 0,889, respectively. This result is consistent with the study on the Vietnamese Tau Vang chicken breed (Nguyen Huu Tinh et al., 2016).

3.2.5. Genetic predisposition

In this study, the mean breed values of each generation (parental, 1, 2, 3) for the body weight traits at 8 weeks, 20 weeks of age of the LT_1 line, and the egg performance at 38 weeks of age of the LT_2 line are expressed in very positive improvement trend by a positive linear regression line with the corresponding probability

level P = 0,009; 0,08 and 0,1 and the almost absolute coefficient of determination is 98,3%; 98,5%; 98,1%, respectively. The genetic progress of the body weight trait at 8 weeks of age is 23,3 g/generation, at 20 weeks age was 57,2 g/gn for the LT_1 line and the egg performance trait in the genetic progress for the LT_2 line is 1 egg/generation.

3.3. Production ability of commercial crossbreds

3.3.1. LT_{12} crossbred

3.3.1.1. Conformation characteristics of LT_{12} chicken

The LT_{12} crossbred has style, feather color, crest similarly to that of LT_1 and LT_2 chicken breeds.

3.3.1.2. Survival rate

The survival rate of LT_1, LT_2, and LT_{12} chickens are quite high (94,00 - 95,33%) and there are no differences among the plots (P>0,05).

Compared to the research results on 01 day - 16 weeks of age of chin feather chicken raised in Luc Ngan - Bac Giang reported by Nguyen Ba Mui et al. (2012) of 80%; or Lac Thuy chicken raised in Bac Giang reported by Tran Duc Hoan et al. (2018) that the survival rate until 16 weeks age is only 89%, the survival rate of LT_1, LT_2 and LT_{12} chickens is higher.

3.3.1.3. Body weight of experimental chickens

Table 3.8. Body weight of LT_1, LT_2 chickens and LT_{12} crossbred

n = 150; Unit: g

Week age	LT_1		LT_2		LT_{12}	
	n	Mean±SD	N	Mean±SD	n	Mean±SD
6	144	$551,94^{a}$±62,61	146	$415,48^{c}$±41,27	146	$459,66^{b}$±46,98
8	143	$896,29^{a}$±86,37	146	$686,95^{c}$±64,51	145	$760,97^{b}$±87,88
12	142	$1.436,48^{a}$±154.02	142	$1.212,18^{c}$±126.5	144	$1.324,55^{b}$±173.96
14	141	$1.616,24^{a}$±178.37	142	$1.338,87^{c}$±149.52	144	$1.514,17^{b}$±193.79
16	141	$1.790,99^{a}$±219.34	142	$1.455,63^{c}$±181.68	143	$1.690,14^{b}$±229.22
Heterosis (%)						4,12

Note: the mean values in the same column with different superscripts were statistically different (P<0.05).

At age of 16 weeks, the body weight of LT_1 chicken is highest, is 1.790,99g, followed by LT_{12} crossbred, is 1.690,14g and the lowest is LT_2 chicken of 1.455,63g, this is statistically significant. P<0,05). According to Tran Ngoc Tien et al. (2011), the body weight at the age of 16 weeks of Lac Thuy chickens raised in farm-scale farming in Hoa Binh province is 1.656,33g; Pham Thanh Dinh et al. (2017) studied on meat production of Lac Thuy chickens raised in Dong Nai province found that the body weight at 16 weeks of age of with mixed feed in experiments 1 and 2 is 1.446,1 - 1.455,7g, while fed with industrial feed-in experiments 1 and 2 is 1.556,9 - 1.608,6g, our research results are completely appropriate.

In addition, the heterosis of LT_{12} crossbred for body weight is 4,12% compared to the average parent which confirmed the selective orientation to create two lines in two different directions, the LT_1 cock line for improved body weight and the LT_2 hen line for improved egg performance that is appropriate and effective.

3.3.1.4. Feed consumption/kg body weight gain of commercial LT_1, LT_2 chickens and LT_{12} crossbred.

Table 3.9. Feed consumption/kg body weight gain of commercial LT1, LT2 chickens and LT12 crossbred

n = 3; Unit: kg

Weeks of age	LT_1	LT_2	LT_{12}
	Mean±SD	**Mean±SD**	**Mean±SD**
6	$1,99^{b}$±0.06	$2,21^{a}$±0,04	$2,13^{a}$±0,01
8	$2,11^{c}$±0.03	$2,35^{a}$±0,02	$2,21^{b}$±0,04
10	$2,31^{b}$±0.01	244^{a}±0,03	$2,32^{b}$±0,04
12	$2,75^{b}$±0.00	$2,86^{a}$±0,03	$2,77^{b}$±0,03
14	$3,19^{b}$±0.01	$3,37^{a}$±0,02	$3,20^{b}$±0,03
16	$3,58^{b}$±0.01	$3,87^{a}$±0,06	$3,61^{b}$±0,03
Heterosis (%)			**- 3.09**

Note: the mean values in the same column with different superscripts were statistically different (P<0.05).

Feed consumption/kg body weight gain of LT_1 chickens at the age of 16 weeks is the lowest of 3,58kg, followed by LT_{12} of 3,61kg

and the highest is LT_2 of 3,87kg. Thus, feed consumption/kg body weight gain of LT_{12} crossbreed is equivalent to that of LT_1 chicken but lower than LT_2 with $P<0.05$ and with heterosis of -3,09%, it is shown that the crossbreed produced high economic efficiency for farmers (high growth rate, low feed consumption).

Tran Duc Hoan et al. (2018) studying on Lac Thuy chickens showed that feed consumption/kg body weight gain at 16-week age of Lac Thuy chickens raised in Bac Giang is 3,87kg for cocks and 3,98kg for hens, feed consumption in our results is lower.

*3.3.2. **Production ability of commercial LT_1LV_1 and LV_1LT_1 crossbred***

3.3.2.1. Conformation characteristics of LT_1LV_1 and LV_1LT_1 crossbreeds

At 01 day old, the conformation of LT_1LV_1 and LV_1LT_1 crossbred is the same such as: Light pink beak and legs, light yellow-brown feathers, dark brown melon stripes on the back. At slaughter (14 weeks of age) both the LT_1LV_1 and LV_1LT_1 crossbreeds had red comb, standing, magenta, red crests, and yellow skin and legs.

The LT_1LV_1 and LV_1LT_1 crossbreeds have differences in feather color: The LT_1LV_1 cock has a purple-red or yellow-purple color, a yellow or brown beaded neck, a blackish-blue tail, and a yellow-apricot-colored. while the LV_1LT_1 cock is completely purplish-plum, with a yellow beaded neck, a bluish-black tail, brown or brown. Hens had yellow beads, a dark brown beaded neck similar to Lac Thuy feather color.

3.3.2.2. Survival rate of LT_1, LV_1 chickens and LT_1LV_1 and LV1LT1 crossbreeds

The survival rate of LV_1 chickens at 14 weeks of age is the lowest, only 91,33%, the reason is at the age of 10 - 11 weeks, the weather was hot and strong sunlight (May 2020) and poor heat tolerance, therefore, the diminished rate of LV_1 chickens is higher than other chickens. The survival rate of LV_1LT_1 crossbreed is the highest (97,33%), followed by LT_1LV_1 crossbreed of LT_1 chicken of 95,33 and 94%, respectively. This result is equivalent to the research

results on commercial LT chicken reported by Tran Ngoc Tien et al. (2021) of 94,6%.

3.3.2.3. Body weight of LT_1, LV_1 chicken and LT_1LV_1 and LV_1LT_1 crossbreeds.

At the age of 14 weeks, the body weight of LV_1 chicken is the highest (2.427,37g), of LT_1 chicken is the lowest, only 1.605,32g, but cross between LV_1 chicken and LT_1 chicken, the body weight of LT_1LV_1 and LV_1LT_1 crossbreeds is significantly improved in comparison with LT_1 chicken, that is 1.807,41 and 1.757,33g, respectively, this is statistically significant (P<0,05).

Body weight of crossbreed between Ri chickens with TP1 (RiTP1) chickens at 14 weeks of age is 2.070,47g, (Dao Thi Bich Loan et al. (2019)), this result is lower than our result.

3.3.2.4. Feed consumption of LT_1, LV_1 chicken, LT_1LV_1 and LV_1LT_1 crossbreeds

Feed consumption/kg body weight gain of chickens in all experimental plots is increased gradually over weeks of age. Feed consumption/kg body weight gain of LT_1LV_1 chickens at 14 weeks of age is the lowest (3,29kg), LT_1, LV_1 and LV_1LT_1 crossbred chickens are similar, is 3,37; 3,44; 3,44kg, respectively. This is statistically significant (P<0.05).

The feed consumption/kg body weight gain of LT_1LV_1 and LV_1LT_1 crossbreeds is similar to the research results of Phung Duc Tien et al. (2015) on F1 crossbred chickens (Choi x LV) at 14 weeks of age, 3,46 kg.

3.3.2.5. Meat performance

The investigated slaughter results showed that the carcass ratio of LT_1, LV_1, LT_1LV_1 and LV_1LT_1 chickens is not different (P>0,05) ranged from 75,48 - 77,05%. This result is higher than the research results of Le Xuan Son (2013) on Mia chickens and the crossbreeding with TP chickens of 72,39 and 74,46% respectively; the thigh meat rate of LV_1LT_1 and LT_1LV_1 crossbred chickens is 22,05 and 21,71%, respectively, similar to LV_1 chicken (22,61%) and higher than LT_1 chicken (19,80%). The fat rate of LV_1LT_1 and

LT_1LV_1 crossbreed is 1,94% and 1,60%, respectively, lower than the fat rate of LV_1 chickens (2,65%), this is also one of the reasons why LV1 chickens died from hot weather during the experiment.

3.3.2.6. Meat quality

The results in Table 3.10 show that the crude protein ratio of thigh meat and the breast meat is different in 4 lots. Breast protein is higher than thigh protein and both are ranged within the limitation of chicken quality. Thigh meat is 19,21 - 20,47%, and the breast meat is 22,93 - 24,17%. The protein percentage in thigh meat of LV_1LT_1 chicken is 19,21%, lower than that of the other 3 plots.

Table 3.10. Chemical composition of commercial chicken meat

n = 6 (3 cocks + 3hens)

Indexs	LT_1 chickens		LV_1 chickens		LT_1LV_1 chickens		LV_1LT_1 chickens	
	Thigh	**Breast**	**Thigh**	**Breast**	**Thigh**	**Breast**	**Thigh**	**Breast**
DM (%)	26,86	28,22	26,73	28,01	27,56	27,44	27,34	28,63
CP (%)	20,34	23,52	20,33	22,93	20,47	24,17	19,21	23,89
Minerals (%)	1,13	1,31	1,17	1,44	1,19	1,42	1,16	1,22
Lipid (%)	1,91	1,92	4,42	2,69	5,34	1,16	5,99	2,62

3.3.2.7. Economic efficiency of LT_1, LV_1 commercial chicken, LT_1LV_1 and LV_1LT_1 crossbreeds

Experimental chickens were arranged from March 8, 2020, to June 14, 2020 at the Animal Experiments and Conservation Center with a total of 150 chickens/plot (3 replicates). With the price of raw materials and price of selling at that time, the results showed that the efficiency of LT_1LV_1 crossbred is the highest, the difference between revenue and expenditure is 4.599.000 VND, of LV_1 chicken is the lowest of 3.297.500 VND. Compared the LT_1LV_1 with the LV_1LT_1 crossbreed, the efficiency is similar. However, if compare the amount of kg of carcass/mother, the formula of crossbreed between

LT_1 cock x LV_1 hen would be higher, so this formula would be better.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The genetic diversity of Lac Thuy chickens

Genetic diversity of Lac Thuy chicken population is relatively high. Lac Thuy chicken has a very low inbreeding coefficient, the genetic distance is quite far from Dong Tao, Mia, and Ri breeds and has a separate and homogeneous genetic structure.

Two of Lac Thuy chicken lines have been selected: LT_1 cock line and LT_2 hen line

Both LT_1 and LT_2 lines have stabilized in the typical conformation of Lac Thuy chickens: At 1 day old, feather color is ivory white color; at natural stage, the cock has a ripe plum color, the hen has mainly dried banana leaf color; red comb, yellow skin and legs.

The body weight of the LT_1 cock line at 8 weeks of age in the 3rd generation is 855,03g for cocks and 704,06g for hens, equivalent to increasing of 21,06 and 15,53% compared to the parental generation. The egg performance of the LT_2 hen line at 38 weeks of age in the 3rd generation is 63,34 eggs, an increasing of 9,51 eggs, equivalent to 17,67% compared to the parental generation.

Other indicators such as: survival rate, feed consumption, body weight of LT_2 chickens, egg performance of LT_1 chickens and hatching are all stable, ensuring the typical characteristics of the breed.

The heritability for body weight at 8 weeks and 20 weeks of age of the LT_1 line, as well as egg performance at 38 weeks of age of LT_2 line is at a medium level of 0,348; 0,235 and 0,299, respectively. The genetic correlation between the body weight at 8 weeks and 20 weeks of age in the LT_1 line are both positive and very close, of 0,959; 0,871 and 0,889, respectively. All three traits showed genetic

predisposition of selection is positive over three generations, with an average growth rate of 23,3g; 57,2g and 1,0 eggs/generation. The method of creating the selection of LT_1 cock line and LT_2 hen line for different production orientations is initially achieved in the research objective.

Productivity of commercial crossbreeds

The conformation characteristics of LT_{12} crossbreed are the same as LT_1 and LT_2 chickens. At 1 day old, the coat color is ivory white color, at a mature age, plum color for male, dried banana leaves color for female.

LT_1LV_1 and LV_1LT_1 crossbreeds have similar conformation: Light pink beak and legs, light yellow-brown feathers, dark brown melon stripes on the back. At slaughtering age (14 weeks of age) both LT_1LV_1 and LV_1LT_1 chickens have red comb, standing, magentad crests, yellow skin and legs; LT_1LV_1 cocks are purplish-red or purplish yellow, the neck is yellow or brown, the tail is black with blue light, hens are apricot yellow color like of the LV_1 cock, while the LT_1LV_1 cocks are completely plum purple, the neck has yellow beads, black tail with blue light, hens have the brown color or with yellow pots, dark brown poted necks like Lac Thuy chicken feathers.

The survival rate at 16 weeks of age of LT_{12} crossbreed is high, of 95,33%; body weight at 16 weeks of age is 1.690,14g; the heterosis for body weight compared to the average of parents is 4,12%; feed consumption/kg body weight gain is 3,61kg; the heterosis is -3,09%.

The survival rate at 14 weeks of age of LT_1LV_1 and LV_1LT_1 crossbreeds is high, 97,33% for LV_1LT_1 and 95,33% for LT_1LV_1 chickens; Body weight at 14 weeks of age is 1.757,33g and 1.807,41g, respectively; Feed consumption/kg body weight gain of LT_1LV_1 chicken is 3,29kg, and LV_1LT_1 chicken is 3,44kg.

Carcass rate of LV_1LT_1 and LT_1LV_1 chickens is 76,31 - 76,52%; thigh meat rate is 22,05 - 21,71%; breast meat rate of LV_1LT_1 is 16,63 - 17,86%, respectively.

Commercial raising of the LT_1LV_1 crossbreed is as efficient as the LV_1LT_1 crossbreed. However, if compared to the number of kg of carcass/hen, the LT_1 cock x LV_1 hen formula of crossbreeding will be higher than the LV_1 cock x LT_1 hen formula of crossbreed, therefore, the selection of LT_1LV_1 crossbreed will be better.

Recommendations

Need to have a plan to develop LT_1, LT_2 chicken lines to create commercial chickens and LT_1LV_1 crossbred for production.

Research on appropriate nutrition and breeding methods to develop LT_1 cock lines, LT_2 female lines, and LT_{12} commercial crossbreed according to different ecological regions.