GENETIC INFLUENCE ON SOME REPRODUCTIVE AND EGG QUALITY TRAITS OF VANARAJA AND ITS CROSSES WITH DESI CHICKEN OF BIHAR

THESIS

SUBMITTED TO THE

BIHAR AGRICULTURAL UNIVERSITY

(FACULTY OF VETERINARY SCIENCE)

SABOUR (BHAGALPUR) BIHAR

IN PARTIAL FULFILLMENT OF THE REQUIREMENT

FOR THE DEGREE OF

MASTER OF VETERINARY SCIENCE

(Animal Genetics and Breeding)

By

Dr. VINITA YASHVEER

Registration No. M/AGB /136/BVC/2013-14

Department of Animal Genetics and Breeding

BIHAR VETERINARY COLLEGE, PATNA-14

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(BIHAR)

2016

DEDICATED TO

My Husband, Dear Father

And

My Daughter "Suhani"

DEPARTMENT OF ANIMAL GENETICS AND BREEDING
BIHAR VETERINARY COLLEGE, PATNA - 14
Bihar Agricultural University, Sabour (Bhagalpur)

Dr. K.G. Mandal,
M.V.Sc., Ph. D.
Associate Professor cum - Sr. - Scientist,
Department of Animal Genetics and Breeding,
Bihar Veterinary College, Patna - 14

CERTIFICATE - I

This is to certify that the thesis entitled " **Genetic influence on some reproductive and egg quality traits of Vanaraja and its crosses with Desi chicken of Bihar**" submitted in partial fulfillment of the requirements for the Degree of Master of Veterinary Science (Animal Genetics and Breeding) of the faculty of post- graduate studies, Bihar Agricultural University, Sabour, Bhagalpur, Bihar is the record of bonafide research work carried out by **DR. VINITA YASHVEER, Registration** No. **M/AGB/136/BVC/2013-14,** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received during the course of this investigation and preparation of the thesis have fully acknowledged.

Endorsed:

05/4/2016

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Chairman / Head of Department

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CERTIFICATE - II

We, the undersigned members of the Advisory Committee of **DR. VINITA YASHVEER, Registration** No. **M/AGB/136/BVC/2013-14**, a candidate for the Degree of master of Veterinary Science with major in **Animal Genetics and Breeding** have gone though the manuscript of the thesis and agree that the thesis entitled " **Genetic influence on some reproductive and egg quality traits of Vanaraja and its crosses with Desi chicken of Bihar** " may be submitted by **DR. VINITA YASHVEER** in partial fulfillment of the requirements for the degree.

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CERTIFICATE – III

This is to certify that the thesis entitled " **Genetic influence on some reproductive and egg quality traits of Vanaraja and its crosses with Desi chicken of Bihar** " submitted by **DR. VINITA YASHVEER**, Registration No. **M/AGB/136/BVC/2013-14,** in partial fulfillment of the requirements for the Degree of Master of Veterinary Science (**Animal Genetics and Breeding**) of the faculty of post-graduate studies, Bihar Agricultural University, Sabour, Bhagalpur, Bihar was examined and approved on 22/6/2016

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Place; Patna

Date; 5.04.2016

Vinita Yashveer

(Vinita Yashveer)

ABBREVIATIONS

µg	:	microgram
ADG	:	Average daily gain
AOAC	:	Association of official analytical chemists
BAHS	:	Basic Animal Husbandry Statics
B.wt.	:	Body Weight
c.f.u	:	Colony forming units
CF	:	Crude fibre
CP	:	Crude protein
Cm	:	Centimetre
d	:	day
DFM	:	Direct fed microbial
dl	:	decilitre
DM	:	Dry matter
DMI	:	Dry matter intake
EE	:	Ether extract
FCE	:	Feed conversion efficiency
FCR	:	Feed conversion ratio
FDA	:	Food and Drug Administration
g	:	gram
GOI	:	Government of India
Hrs	:	Hour
kg	:	Kilogram
LYC	:	Live Yeast Culture
mg	:	Milligram
min	:	Minute
ml	:	Millilitre
mmol	:	Millimole
N	:	Nitrogen
NCDC	:	National collection of dairy culture
NH_3-N	:	Ammonia nitrogen
nm	:	nanometre
°C	:	Degree Celsius
OM	:	Organic matter
PRO	:	Probiotics
Rs	:	Rupees
SE	:	Standard error
SRL	:	Strained rumen liquor
TA	:	Total ash
TVFA	:	Total volatile fatty acid
Wt.	:	Weight
YC	:	Yeast culture

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INTRODCTION

Globally, Poultry meat has become a mass consumer product due to its cost of competitiveness, nutritional quality, universal availability and absence of religious taboos. It is a chief biological value added sources of protein that can be ploughed back into the human food chain by converting it into nutritionally balanced and delicious egg and chicken meat from “natural food base” (fallen grains, insects, earthworms, green grasses, household by-products and waste materials of agricultural products) produced in a backyard farming.

India is facing a great nutritional emergency due to mismatch of rising population and availability of quality food. Only plant sources cannot fulfil the requirement of quality protein in pace with its rising demand in our country. Poultry farming can meet the challenges of hungry population and will amplify the income generation, improvement in standards of living, employment to labourers and farmers.

In present scenario poultry farming is gaining strength with fast pace of development both in developed and developing countries, especially in India, where 67% of the population is dependent upon agriculture and its allied for their livelihood security.

India is rich repository of chicken genetic resources with 18 breeds of fowl along with various indigenous breed crosses. The breeds habituated in different agro-climatic zones of India have evolved more through natural selection than through deliberate intervention by man.

These breeds are important to rural backyard poultry keeping due to their better adaptability and better disease resistance (Sonaiya, 1996; Kitalyi, 1996; Sheldon, 1998). Poultry farming promises a great scope to mitigate the challenges of poverty alleviation, women empowerment, income generation, improvement in standard of living, employment to unskilled, illiterate women, small land holding farmers, landless farmers and labourers etc.

Although, India has achieved self sufficiency in grain production, but it has not been able to meet adequate quantities of pulses, meat and egg production. There has been observed a wide gap in energy protein intake.

According to Livestock census (2015), India ranks 5th in poultry production and 3rd in egg production. The eggs production in India during 2014-15 was 78.48 billion. The egg production has increased tremendously yet per capita availability of egg in India is 55 eggs/head/annum against the minimum nutritional requirement according to Nutritional Advisory Committee of India, which is only half egg/head/ day to maintain normal health. It contributes 100 billion rupees to the Gross National Product (GNP). India exports poultry products like table-eggs, meat, egg powder and frozen yolk. It provides employment to 1.6 million people.

According to Bihar Basic Animal Husbandry statistics 2015, poultry population estimated to be 14 million and ranked 6th among other states of India. In egg production its rank is 15th and in per capita availability of eggs it is 26th in position and only 8 eggs /head/annum is available whereas, Andhra Pradesh and Tamilnadu are leading in egg production. Therefore, the truncated Bihar is egg deficient state and there is a great need to increase egg production to cope up with its increasing demand with rapid growth in human population.

Thus, above relevant data seems to encourage research workers to do lots of work for egg production in the state. The number of eggs produced should not be only criteria, but due emphasis should also be given to the egg weight and other egg quality traits. For example a good internal quality egg can stand preservation better than the poor quality and good external quality egg ensures a good percentage of hatchability, its transportation to the wider area and thus, making poultry industry profitable and also the success of poultry farming in backyard largely depends upon egg quality. But, egg quality traits are greatly influenced by the factors like breed, strain, variety, temperature, relative humidity, rearing practices and season. (Sauter *et al.*, 1954; Washburn, 1990)

Therefore, for profitable marketing of eggs either for table purpose or for hatching purpose, it is desirable that a reasonable uniformity in shape, size and other egg quality traits should be maintained. For achieving the above said aim only those birds, which produce good quality eggs should be retained for future breeding purposes.

Though a lot of work has been carried out on performance of economic traits of chicken (Sethi *et al.*, 2003; Fayeye *et al.*, 2005; Bharadwaj *et al.*, 2006; Mondal *et al.*, 2007) the information on crosses/varieties developed for rural/free range farming are scanty.

Vanaraja is a improved dual purpose breed developed by crossing three different breeds at Project Directorate on Poultry, Hyderabad by Red Cornish and Desi for free range scavenging situation as well as backyard rearing at a very low inputs. It has multicoloured plumage, better immune-competence with liveability 95-98%, larger egg sizes, less brooding character, resistance to environmental changes and diseases with better growth rate at low plane of nutrient. It has egg production ranging from 110-120 per annum and body weight at 06 weeks recorded as 1.50-1.8 kg in seven weeks.

Thus, the present study is concerned with the improved varieties of chicken like Vanaraja and their crosses with Desi chicken of Bihar to observe the genetic influence of various genetic groups on egg quality and some of the reproductive traits. A great deal of interest is evidenced in exploring the possibility of utilizing hybrid vigour in poultry by adopting line, strain and breed crossing for egg production. Thus, an attempt would be made to study the genetic effect of Vanaraja and its crosses with Desi chicken of Bihar for various egg quality traits in agro-climatic condition of Bihar. If positive character is found to be significant then the cross breed would be encouraging among farmers.

Limited studies have been undertaken in our country in respect to different economic traits of these birds. Reproduction and production traits indicate its genetic constitution and adaptation with respect to specific environment (Ahmad and Singh, 2007). Therefore, an attempt is made to study some reproductive and productive performance of Vanaraja and its crosses with Desi chicken of Bihar.

Thus, keeping in view the above consideration the present study was undertaken with following objectives:

Objectives:-

- To estimate the mean, standard error and coefficient of variation percentage, percentage of fertility and hatchability, egg production, egg weight and egg quality traits.
- To study the effect of various genetic groups on fertility, hatchability, egg production, egg weight and egg quality traits.
- To study the effect of egg weight on egg quality traits.
- To estimate coefficient of phenotypic correlation among various egg quality traits and egg weight in different Genetic groups.

REVIEW OF

REVIEW OF LITRATURE

Egg weight

The number of eggs laid by a bird is not the only criterion to be considered in poultry breeding for egg production but emphasis must also be given to egg size since it adds equally well to the economics of production. Campos *et al.* (1964) reported that egg weight can be taken as a selection criterion for improving the internal egg quality as its genetic association can be established with the external egg quality traits.

The effect of breed and strain differences on egg weight in chicken has been reported by many workers.

Singh *et al.* (2000) studied the egg weight of indigenous breeds like Aseel and Naked Neck and compared with the exotic breeds like Dahlem Red and reported significant breed differences for this trait at the age of first egg laid, 40^{th} and 64^{th} weeks of age. The direct crosses of Dahlem Red with Aseel and Naked Neck were reported to have produced significantly heavier eggs than the reciprocal crosses at all the ages. They have reported positive and negative heterosis for egg weight at 40^{th} and 64^{th} weeks of age, whereas negative heterosis in all crosses except D x A at the age of first egg laid.

Devi *et al.* (2005) observed that egg weight in two pure lines of WLH strains and 2-way,3-way breed crosses at 28^{th} wk to be ranged from

49 to 53 g and at 40th wk to be ranged from 54.75 to 61 g. Egg weight of crosses was reported to be higher than the purebreds.

Parmer *et al.* (2006) and Singh *et al.* (2000) reported lower egg weights in Kadaknath to be ranged from 40.87 to 45.141 g and in Aseel 41 g from India under field condition.

Niranjan *et al.* (2008) reported that the average egg weight ranged from 50.94 g in Gramapriya to 52.97 g in Vanaraja. During the early production (24th wk), c_1 and c_2 recorded significantly ($P<0.01$) higher egg weight than Vanaraja and Gramapriya. The authors reported that rural crosses were as good as the exotic varieties/strain which might be due to utilization of exotic germplasm for the development of rural varieties (Sharma *et al.,* 2006).

Zita *et al.* (2009) reported that the egg weight increased with the advancement of age of layer's stain in all genetic groups.

Islam and Dutta (2010) revealed that the gross egg weight differed significantly ($P<0.001$) among the genetic groups of chicken where RIR had the highest egg weight and Fayomi did not differ statistically from Desi, exotic and crossbreds.

Mohanty *et al.* (2011) reported significantly lower average egg weight (30.79 g) of native fowl followed by Vanaraja, Aseel, Kadaknath, Dahlem Red, RIR, Red Cornish, V_2 chabro, Black rock at 25th week of age. Egg weights were not reported to be significantly different between the breeds except meat type chicken but significant ($P<0.01$) differences were reported among the varieties. However, the authors reported that the egg weights of all the genetic groups under this study gradually increased as age advances.

Padhi *et al.* (2013) studied the egg weight of Vanaraja birds at 28th wk, 40th wk, 52nd wk, 64th wk and 72nd wk of age and reported significant ($P<0.05$) difference between different age groups. The egg weight was reported to be increased as the age of measurement increases.

Jha and Prasad (2013) reported the average egg weight in improved varieties of chicken like Vanaraja and Gramapriya at 40th wk of age to be 53.98 and 54.23 g respectively which was higher than the eggs laid by Aseel birds (42.38 g).

Table -1 Estimates of average egg weight of chicken as reported in literature.

Breed/strain	No. of obs.	Mean	Reference
New Hampshire	92	55.66	Sapra & Aggarwal (1971)
White plymouth rock	85	57.39	,,
White Cornish	75	55.51	,,
Desi	85	40.78	,,
Aseel	25	52.80	,,
Kadaknath		40.87-45.41	Parmer *et al.*(2006)

Aseel		41	,,
C_1 cross(at 24th wk)	461	46.1	Niranjan *et al.*(2008)
C_2 cross	461	46.8	,,
Vanaraja	461	45.3	,,
Gramapriya	461	45.0	,,
Desi	50	40.04	Islam and Dutta (2010)
Exotic (fayomi ,RIR)	50	46.80	,,
RIR X Fayomi	50	56.5	,,
Local fowl	100	30.79	Mohanty *et al.*(2011)
Aseel	12	38.96	,,
Kadaknath	12	39.94	,,
Black rock	10	48.72	,,
Red Cornish	12	43.93	,,
RIR	15	43	,,
Dahlem	10	43	,,

Local germplasm Vanaraja	15	36.19	,,
Chabro	15	47.57	,,
Vanaraja	40	47.60	Padhi *et al.*(2013)
Egg weight at ASM			Jha and Prasad (2013)
Vanaraja		43.15	,,
Gramapriya		38.78	,,
Aseel		32.84	,,

Egg length and egg width

The average length and width of chicken eggs reported in the available literature is presented in table-2.

The average length of eggs reported to be ranged from 35.51 mm in Desi breed (Sapra and Aggrawal, 1971) to 57.8 mm in RIR (Islam and Dutta, 2010). The average width of the eggs reported to be ranged from 37.1 mm in Desi to 44.3 mm in RIR (Islam and Dutta, 2010).

Kumar and Kapri (1966) stated that egg quality is under genetic control and genetic improvement is possible by selection and breeding. They reported that the egg width is more constant in dimension than the egg length.

Singh *et al.* (1981) reported that bird's produce lesser number of eggs generally has wider and heavier eggs than those producing large number of eggs because of negative correlation between egg number and egg weight. They also reported the existence of significant difference between line crosses for egg width only but not for egg length. They stated that difference in egg weight between the groups was mainly due to egg width.

Niranjan *et al.* (2008) reported significant breed differences for egg length and egg width. The Vanaraja (53.0mm) birds were reported to have significantly higher egg length than the C_1, C_2 cross and Gramapriya, whereas Gramapriya (42.0mm) birds were reported to have significantly higher egg width than C_1, C_2 and Vanaraja.

Islam and Dutta (2010) also reported the significant breed differences for egg length and egg width. The RIR birds reported to have significantly ($P<0.05$) higher egg length and width than the indigenous, exotic and crosses.

Table – 2 Estimates of average egg length and egg width in chicken as reported in literature.

Breed/strain	No. of obs. (n)	Egg length (mm)	Egg width (mm)	Reference
Desi	85	35.51	39.46	Sapra & Aggarwal (1971)
Black Bengal	68	54.86	39.75	,,

Aseel	25	54.60	41.44	,,
Naked Neck	24	54.33	40.17	,,
New Hampshire	92	57.55	41.54	,,
White Plymouth Rock	85	57.56	42.28	,,
White Cornish	77	56.40	41.71	,,
C 1 cross	461	53.8	41.9	Niranjan *et al.* (2008)
C 2 cross	461	53.6	41.2	,,
Vanaraja	461	54.5	41.4	,,
Gramapriya	461	54.0	42.0	,,
Indigenous	50	48.3	37.1	Islam and Dutta (2010)
Broiler	50	56.9	42.2	,,
Fayomi	50	47.7	37.2	,,
RIR	50	57.8	44.3	,,
RIR X Fayomi	50	54.6	41.2	,,

Shape index

Shape is one of the most important characters of eggs, large deviations from the normal shape increase the tendency towards breakage and reduce hatchability. Egg shape is typically oval in shape. Elliptical, biconical, conical, round and other abnormal shapes occasionally occur. Experimentally, this trait is usually defined by an index which is expressed as 100 times the maximum width divided by maximum length.

It has been observed from the literature that shape of an egg is the characteristic of an individual hen. Curtis (1914) was probably the first to report individual variation in egg shape and found this trait to be more variable than the egg weight. In the inheritance of egg shape, neither the round eggs nor the long eggs appear to possess clear cut dominancy. If dam and sire's dam laid eggs of identical type the progeny also lay eggs of the same shape. However, when parents are derived from strains which produce the extremes of egg shape, the eggs of offspring are intermediate in shape (Benjamin, 1920). They were also of the opinion that the response to selection for the desirable ovoid shape of the eggs is rapid and marked progress can be achieved within two generations. Marbal (1943) established two strains characterized by round and long eggs. After three generations of selection the two strains were crossed to obtain two F_1 populations. These birds laid eggs of intermediate in shape. Back cross between the F_1 and each parental strain gave pullets which produced eggs of intermediate in shape between the F_1 and the strain concerned. Romanoff and Romanoff (1949) studied the shape index in White

Leghorn birds. They also reported that individual hen lays eggs with more or less uniform in colour and shape.

Chatterjee *et al.* (2006) observed higher shape index (80.76) for IWK and lower indices for IWI (73.77) and IWH (72.67) strains of White Leghorn.

Parmar *et al.* (2006) reported lower shape index (74.35) in Kadaknath.

Niranjan *et al.* (2008) reported the average shape index in Vanaraja birds to be ranged from 76.18 to 78.13 in C_1 cross. The shape index of C_1 cross was significantly ($P<0.01$) higher than the other three crosses at 24 weeks of age. At 40 weeks of age C_1 cross is reported to have significantly higher (78.88) shape index and Vanaraja had significantly lower (75.67) shape index. The authors did not find significant difference between C_1 cross and Gramapriya for shape index.

Zita *et al* .(2009) reported higher shape indices at early age of laying in all genotypes *i.e* ISA Brown (78.52), Hisex brown (78.94) and Moravia BSL (78.76) whereas lower shape indices in later weeks of laying that is 75.09, 75.34 and 76.59 in ISA Brown, Hisex brown and Moravia BSL respectively.

Islam and Dutta (2010) reported the breed differences for egg shape index of the five chicken breeds which was in the following order Fayoumi> Indigenous> RIR> Sonali> Cobb500.

Mohanty *et al* .(2011) studied the shape index and the highest shape index was recorded in eggs of Dahlem Red at 25 weeks of age and

Vanaraja at 74 weeks of age (77.80). They reported that shape index did not vary significantly among the genetic groups. However, in native variety it was reported to be significantly lower than the eggs of improved variety birds.

Jha and Prasad (2013) reported the mean shape index in Vanaraja and Gramapriya to be 74.24 and 74.17 respectively at 40 weeks of age. Shape index in Aseel birds reported to be 73.56 and result was comparable with the result of Parmer *et al.* (2006) who reported the average shape index of 73.95 in Kadaknath breed under free range conditions.

Padhi *et al.* (2013) reported no significant effect of age of measurements on shape indices in Vanaraja birds.

The estimates of shape index in different breeds of chicken, their strains and strain crosses as reported in the available literature have been presented in table-3.

Among the pure breeds the mean shape index in poultry is reported to be ranged from 59.15 in Local Fowl to 87.23 in Dahlem Red (Mohanty *et al.*, 2011). However, the value of shape index is reported to be ranged from 74.24 (Jha and Prasad, 2013) to 77.45 in Vanaraja birds (Padhi *et al.* 2013).

Table -3 Estimates of average shape index in chicken eggs as reported in literature.

Breed/strain	No. of obs.	Mean	Reference
Desi		77.64	Singh *et al.*(2000)
WLH		72.52	Reddy (2004)
WL Strain IWI	-	73.77	Chatterjee *et al.*(2006)
WL Strain IWH	-	72.67	,,
WL Strain IWk		80.76	,,
C1 cross	461	78.1	Niranjan *et al.*(2008)
C 2 cross	461	77.1	,,
Vanaraja	461	76.2	,,
Gramapriya	461	78.0	,,
ISA Brown		75.09 to 78.52	Zita *et al.* (2009)
Hisex Brown		75.34 to 78.94	,,

Moravia BSL		76.59 to 78.76	,,
Local fowl		59.15	Mohanty *et al* .(2011)
Aseel		78.84	,,
Kadaknath		76.33	,,
Black rock		80.05	,,
Red cornish		73.95	,,
RIR		78.23	,,
Dahlem red		87.23	,,
Chabro		79.75	
Vanaraja			Padhi *et al.*(2013)
28th wk		76.49	,,
40th wk		75.29	,,
52nd wk		75.57	,,
64th wk		76.00	,,
72nd wk		77.45	,,
At 40th wk			
Vanaraja		74.24	Jha and Prasad (2013)

Gramapriya		74.17	”
Aseel		73.56	”

Shell thickness:

Since shell thickness of the individual hen egg is the manifestation of her calcium metabolism, then the relative efficiency in assimilating and secreting calcium and other materials involves in shell formation apparently comes under hereditary control to some extent. Breed and family differences as well as lines difference in shell thickness may be established by selection (Taylor and Lerner, 1939; Quinn *et al.*, 1945).

In an experiment on egg quality traits of Gramapriya, Patel (2013) observed non-significant effect of genetic groups on the average value of shell thickness. However, it was reported to be thinner in backyard system (0.34) followed by semi intensive (0.35) and deep litter (0.36) system of management.

Devi *et al.* (2005) reported the shell thickness of two WLH strains and two bred crosses within the range of normal values that is 0.36, 0.36, 0.40 and 0.39 in IWD, IWF, 3-WAY and 2-WAY respectively.

Niranjan *et al.* (2008) reported that the shell thickness varies significantly ($p<0.01$) among different genetic groups. Gramapriya and C_2 reported to have similar shell thickness without any significant variation. The egg shell thickness was reported to be more in C_1(0.40mm) and less in Gramapriya (0.394mm).The egg shell of C_1 cross reported to be significantly ($p<0.01$) thicker than the other three crosses at 24^{th} weeks of age. Vanaraja birds reported to have better shell thickness at 32 weeks of age whereas C_1 and C_2 crosses were reported to have significantly thicker shell than the other two crosses.

Zita *et al.* (2009) reported significant difference between genetic groups in egg shell quality. Interaction between genotype and age of hens was also reported in all egg shell quality characteristics. The eggs of ISA Brown reported to have significantly ($p<0.001$) thicker egg shell than the other genotypes in all age groups.

Mohanty *et al.* (2011) reported that the average shell thickness did not vary significantly ($p<0.01$) between the genetic groups and native variety birds at all ages. However the higher shell thickness helps in preventing the damage during handling.

Jha and Prasad (2013) reported the mean shell thicknesses ranging from 0.31 to 0.38mm with an average of 0.35mm in Vanaraja, 0.32mm in Gramapriya and 0.36mm in Aseel eggs.

Padhi *et al.* (2013) reported that shell thickness differ significantly ($P<0.05$) between different age of measurement. The shell thickness was reported to be higher at 52 and 72 weeks of age as compared to other age of measurements indicating that the shell quality was better at the end of experiment. It was reported that egg shell thickness increases with the advancement of age.

Sreenivas *et al.* (2013) reported significant differences in egg shell thickness among different strains of White Leghorn and control. The shell thickness reported to be ranged from 0.336mm in IWH to 0.376mm in IWI strain.

The average shell thickness of different breeds of chicken as reported in the literature is presented in table -4.

Table -4 Estimates of average shell thickness (mm) in chicken egg as reported in literature.

Breed/strain	Mean	Reference
White Leghorn		Devi *et al.*(2005)
IWD	0.36	,,
IWF	0.36	,,
C1 cross	0.40	Niranjan et al(2008)
C2 cross	0.39	,,
Vanaraja	0.38	,,
Gramapriya	0.39	,,
Brown layer strain		Zita *et al.*(2009)
ISA	0.37	,,
Hisex	0.35	,,
Moravia	0.32	,,

Aseel	0.34	Mohanty *et al.* (2011)
Kadaknath	0.41	,,
Black rock	0.35	,,
Red cornish	0.39	,,
RIR	0.39	,,
Dahlem red	0.41	,,
Rural germ plasm Vanaraja	0.43	,,
Chabro	0.47	,,
IWH	0.336	Sreenivas *et al.* (2013)
IWI	0.376	,,
IWK	0.362	,,
WL control	0.365	,,
Vanaraja		Padhi *et al.*(2013)
28th wk	0.34	,,
40th wk	0.34	,,
52nd wk	0.37	,,
72nd wk	0.38	,,

The mean shell thickness is reported to be ranged from 0.336 to 0.376 mm in different strains of White Leghorn, (Sreeniwas *et al.* 2013) 0.33 to 0.39 mm in Rhode Island Red. The average shell thickness in Vanaraja is reported to be ranged from 0.34 to 0.38 mm (Padhi *et al.* 2013) and in Gramapriya 0.39mm (Niranjan *et al.* 2008).

Shell weight:

With eggs of same size, younger hens tend to lay eggs with a greater percentage of shell; however, the shell quality of individual hen tends to maintain its relative position with respect to shell quality of other hens throughout the laying period (Marion *et al.*, 1964).

Padhi *et al.* (1998) studied shell weight in different breeds of chicken like Nicobari, Necked neck and White Leghorn and reported that the breeds had no significant effect on shell weight.

Devi *et al.* (2005) observed 6, 5.6, 6 and 4.4 g shell weight in different strains of White Leghorn and breed crosses like IWD, IWF, 3-WAY AND 2-WAY respectively.

Chatterjee *et al.* (2007) also reported the non significant effect of breed on shell weight for six indigenous breeds from Andaman.

Niranjan *et al.* (2008) reported that shell weight was significantly affected by genetic groups at 24th, 32nd and 40th weeks of age. The shell weight was reported to be ranged from 5.24g in C_2 to 5.28g in Vanaraja. Shell weight was reported to be significantly higher in C_1 and C_2 crosses at 24 weeks of age whereas in C_1, C_2 and Vanaraja at 32 weeks and 40 weeks of age respectively.

Zita *et al.* (2009) observed highly significant interaction ($P < 0.0001$) in egg shell quality so as in shell weight. ISA Brown reported to have the highest shell weight in all the age groups and in all genotypes whereas Moravia BSL had the lowest shell weight.

Mohanty *et al.* (2011) reported that the shell weight varied significantly ($P<0.01$) between local fowl and other genetic varieties at 25th week of age. The lowest shell weight (5.02g) was reported in local native fowl. Significant variation ($P<0.01$) was also reported at 54 and 74 weeks of age between the genetic groups and local fowl. The average shell weight in non descriptive variety was reported to be significantly ($P<0.01$) lower than other established breeds at all ages.

Padhi *et al.* (2013) reported significant ($P<0.05$) effect of age on shell weight in Vanaraja. It was reported that as the age increases the shell weight also increases.

Sreenivas *et al.* (2013) reported significant differences in shell weight for different strain of White Leghorn and control. The highest shell weight was reported in IWK strain (5.12g) and lowest in IWH strain (4.32g).

The mean values of shell weight of different breeds of poultry available in the literature have been presented in table-5.

The average shell weight is reported to be ranged from 4.32 g in WIH to 9.10 g in RIR. The average shell weight in Vanaraja is reported to be ranged from 3.9 to 5.8 g and in Gramapriya it was reported to be 5.27 g.

Table -5 Estimates of average shell weight (g) and percent shell in chicken as reported in literature.

Breed/strain	Mean	Reference
Shell Weight (g)		
White Leghorn strain		Devi *et al.*(2005)
IWD	6±0.03	,,
IWF	5.6±0.01	,,
3-WAY	6±0.02	,,
2-WAY	4.4±0.01	,,
C_1 cross	5.26	Niranjan *et al.*(2008)
C_2 cross	5.24	,,
Vanaraja	5.28	,,
Gramapriya	5.27	,,
Brown egg layer strain		Zita *et al.* (2009)
ISA Brown	5.86 to 6.6	,,
Hisex Brown	5.5 to 6.3	,,
Moravia BSL	4.9 to 5.8	,,

Indigenous	6.41±1.97	Islam and Dutta (2010)
Broiler	6.80±1.23	,,
Fayuomi	6.14±2.02	,,
RIR	9.10±2.23	,,
Sonali	7.90±1.29	,,
25th week		Mohanty *et al.* (2011)
Aseel	7.44	,,
Kadaknath	6.87	,,
Black rock	7.87	,,
Red Cornish	7.24	,,
RIR	9.07	,,
Dahlem red	7.23	,,
Vanaraja	7.20	,,
V_2,Chabro	7.33	,,
Vanaraja		Padhi *et al.*(2013)
At 28th week	3.9±0.08	,,
At 40th week	4.4±0.07	,,
At 52nd week	5.4±0.10	,,

At 64th week	5.0±0.08	,,
At 72nd week	5.3±0.11	,,
White Leghorn strain		Sreenivas *et al.*(2013)
IWH	4.32	,,
IWK	5.12	,,
IWI	4.77	,,
Control	4.72	,,

Albumen quality:

The physical state of albumen is measured in a number of ways by the percent of thick White, by the height of albumen, by an albumen index, by an index of albumen height to egg size expressed as Hough unit and by scoring using the Van Wagenen Wilgus Chart.

Wesley and Stadelman (1960) measured the interior quality of fresh eggs and eggs stored for 24 hours for comparison of various measurable characters. They reported that yolk index and thin albumen diameter were most useful parameters for obtaining relatively complete quality description of a normal egg.

Various reports available in the literature have shown strong evidence for inherited differences between breeds and strains, lines and families within breeds for albumen qualities (Knox and Godfrey, 1940;

Farnsworth and Nordskog, 1955; Baker and Curtiss, 1958). Lorenz and Taylor (1910) found that it is possible to establish two lines characterized by different amounts of thick albumen.

Devi *et al.* (2005) reported no significant difference in albumen index for different White Leghorn strains and cross bred, it ranged from 6 to 7.

Parmer *et al.* (2006) reported the albumen weight as 20.74g in Kadaknath which was within the range.

Chatterjee *et al.* (2007) recorded 26.46g to 26.67g albumen weight in indigenous fowl of Andaman.

Niranjan *et al.* (2008) reported the albumen weight to be varied from 28.61±0.27g to 31.13±0.18g in rural crosses. The albumen weight was reported to be differed significantly ($P<0.01$) among the genetic groups except in C_2 cross and Vanaraja which were similar statistically. Albumen weight at 24 weeks of age was reported to be significantly ($P<0.01$) higher in C_1, C_2 and Vanaraja varieties. At 32 weeks, C_1 and C_2 crosses reported to have significantly higher albumen weight than Vanaraja and Gramapriya whereas at 40 weeks C_1 cross had significantly ($P<0.01$) higher albumen weight than other three crosses.

Zita *et al.* (2009) reported highly significant ($P <0.0001$) interaction among the albumen quality characteristics such as albumen weight, albumen percentage and albumen index in all the strains laying brown shelled eggs. Albumen weight tends to increase with the advancement of age but albumen index and percent albumen weight tends to decrease with age in all genotypes.

Mohanty *et al.* (2011) reported statistically significant ($P<0.01$) variations in albumen index among the genetic groups. However, in native variety the albumen index values at 25, 54 and 74 weeks of age were reported to be 0.09, 0.08 and 0.09 respectively, showing significant ($P<0.01$) differences with that of albumen index of improved variety birds. However no significant differences were reported among the improved genetic varieties at all ages. The albumen weight did not vary significantly between the meat type and commercial broiler at 25 weeks. Except dual type and commercial broilers, no significant differences ($P<0.01$) were reported between the improved varieties at 54 weeks of age. However, at all ages non descript local fowl showed lowest albumen weight as compared to other improved varieties and suggested eggs with thicker albumen and higher total albumen weight are considered comparatively better eggs.

Jha and Prasad (2013) reported the average albumen index value in improved varieties was higher than the indigenous breed. In Vanaraja and Gramapriya albumin indices were 6.81 and 6.97, respectively and were significantly ($P<0.01$) higher than the Aseel having 6.25 albumen index.

Padhi *et al.* (2013) reported significant ($P<0.05$) difference in albumen index at different age of measurements. The highest albumen index (10.62) was reported at 52 weeks of age and lowest (6.17) at 72 weeks of age in Vanaraja birds. Albumen weight also showed significant

(P<0.05) difference at different age of measurements, the highest (37.84g) being at 52 weeks and lowest (30.56g) at 28 weeks. Significant (P<0.05) effect of age was reported for percent albumen weight, the highest (64.10) percentage was reported to be at 28 weeks and lowest (57.12) percentage at 72 weeks of age.

Sreenivas *et al.* (2013) reported significant (P<0.01) difference among White Leghorn strains. IWI (7.2) strain had the highest albumen index and IWK (5.6) had the lowest. The albumen weight was reported to be significantly (P<0.01) higher in IWK than IWH, IWI and control which is reported to be differed non-significantly among themselves. The percent albumen weight was reported to be significantly (P<0.01) higher in IWH strain (62.96) but did not differ significantly from IWI, IWK and control.

At any time, the albumen quality is primarily a function of age of bird. The decline in albumen quality is attributed by the physiological condition of the individual bird. The physiological characteristics such as intensity of lay and age at sexual maturity have influential effect on albumen quality.

The mean values of albumen index, albumen height and albumen weight reported in the available literature have been presented in table -6.

Table -6 Estimates of average albumen quality traits in chicken as reported in literature.

Breed/strain	**Mean**	**Reference**
Albumen Index		
Brown egg layer strain		Zita *et al.*(2009)
20-26th week		
ISA Brown	11.27	,,
Hisex Brown	11.33	,,
Moravia BSL	10.53	,,
36-42nd week		,,
ISA Brown	8.74	,,
Hisex Brown	9.03	,,
Moravia BSL	9.27	,,
54-60TH week		
ISA Brown	7.46	,,
Hisex Brown	7.11	,,
Moravia BSL	8.40	,,

25th week		Mohanty *et al.*(2011)
Local fowl	10	,,
Aseel	13	,,
Kadaknath	13	,,
Black rock	13	,,
Red Cornish	12	,,
RIR	15	,,
Dahlem Red	11	,,
Vanaraja	13	,,
V2,chabro	19	,,
Vanaraja	6.81	Jha and Prasad (2013)
Gramapriya	6.97	,,
Aseel	6.25	,,
Vanaraja		Padhi *et al.* (2013)
28th week	10.20	,,
40th week	9.36	,,
52nd week	10.62	,,
64th week	8.26	,,

72^{nd} week	6.17	,,
White Leghorn strain		Sreenivas *et al.*(2013)
IWH	7.2	,,
IWI	9	,,
IWK	5.6	,,
Control	8	,,
Albumen weight		
kadaknath	20.74	Parmer *et al.* (2006)
Indigenous fowl	26.46-26.67	Chatterjee *et al.* (2007)
C1 cross	31.1	Niranjan *et al.* (2008)
C2 cross	30.3	,,
Vanaraja	30.3	,,
Gramapriya	28.6	,,
Brown egg layer 20-26 week		Zita *et al.* (2009)
ISA Brown	34.36	,,
Hisex Brown	35.28	,,

Moravia BSL	32.78	,,
36-42 week		
ISA Brown	38.07	,,
Hisex Brown	37.87	,,
Moravia BSL	36.62	,,
54-60 week		
ISA Brown	37.57	,,
Hisex Brown	38.49	,,
Moravia BSL	38.25	,,
Indeginous	18.92	Islam and Dutta (2010)
Broiler	30.40	,,
Fayoumi	18.51	,,
RIR	36.10	,,
Sonali	19.50	,,
Local fowl	15.42	Mohanty *et al* .(2011)
Aseel	20.28	,,
Kadaknath	18.22	,,
Black rock	24.31	,,

Red cornish	24.56	,,
RIR	19.07	,,
Dahlem red	22.33	,,
Vanaraja	20.33	,,
V_2 , chabro	24.54	,,
Vanaraja		Padhi *et al.* (2013)
28th week	30.56	,,
40th week	33.53	,,
52nd week	37.84	,,
64th week	36.01	,,
72nd week	34.93	,,
White Leghorn		Sreenivas *et al.* (2013)
IWH	31.53	,,
IWI	31.19	,,
IWK	33.18	,,
Control	30.92	,,
Percent Albumen		
Brown egg layer		Zita *et al* .(2009)

20 – 26 weeks		
ISA Brown	63.85	,,
Hisex Brown	64.15	,,
Moravia BSL	64.57	,,
36 – 42 week		
ISA Brown	60.53	,,
Hisex Brown	60.92	,,
Moravia BSL	59.36	,,
54 – 60		
ISA Brown	59.19	,,
Hisex Brown	59.98	,,
Moravia BSL	58.50	,,
Vanaraja		Padhi *et al.* (2013)
28^{th} week	64.10	,,
40^{th} week	58.91	,,
52^{nd} week	61.18	,,
64^{th} week	59.47	,,
72^{nd} week	57.12	,,

White Leghorn		Sreenivas *et al.* (2013)
IWH	62.96	,,
IWI	61.31	,,
IWK	61.24	,,
Control	61.10	,,

YOLK QUALITY:

Yolk Index:

The physical State of yolk is measured by yolk index which is obtained by dividing the height of yolk by its average diameter.

Of all the structures of eggs, the yolk seems to be least influenced by hereditary factors. Breed differences for yolk index have been reported in the literature (Jeffrey, 1945) but for the most part the yolk quality is environmentally determined. Romanoff and Romanoff (1949) have stated that the value of yolk index was fairly constant in the eggs produced by a particular individual but it may vary considerably from the eggs of one bird to that of another.

Padhi *et al.* (1998) reported yolk indices ranging from 0.41 to 0.45 in Nicobari varieties of Andaman.

Parmer *et al.* (2006) also observed lower yolk index of (0.37) for Kadaknath breed.

Niranjan *et al.* (2008) reported that the yolk index values were significantly influenced by the genetic groups ($P<0.01$) at all ages .The yolk indices were reported to be ranged from 0.44 in C_2 cross to 0.46 in C_1 cross. The yolk indices among C_2 and Vanaraja were reported to be similar without any significant variation. The yolk indices were significantly higher in Vanaraja at 24 wks of age, C_1 and C_2 crosses at 32 wks of age and Gramapriya at 40 weeks of age respectively.

Zita *et al.* (2009) observed that yolk indices differed significantly ($P<0.0001$) with age and genotype. Yolk indices were reported to be decreased with the advancement of age. The highest yolk index was of Moravia BSL and lowest was of Hisex Brown.

Islam and Dutta (2010) reported significant ($P<0.001$) difference between breeds. Yolk weight was reported to be the highest in Sonali (14.88) and the lowest (11.20) in RIR.

Mohanty *et al.* (2011) reported that the yolk index did not vary significantly at all ages between six varieties of birds namely Aseel, Kadaknath, Black rock, Red Cornish, Rhode Island Red, Dahlam Red, Vanaraja, V_2 Chabro while the yolk index values reported to be differed significantly ($P<0.01$) between genetic groups and native local fowl at 25 weeks indicated spherical nature of yolk.

Jha and Prasad (2013) reported yolk indices of Vanaraja, Gramapriya and Aseel differed significantly ($P<0.01$). Yolk indices of Gramapriya (36.68) were reported to be higher than Vanaraja (36.12), and Aseel had the lowest (35.84).

Padhi *et al.* (2013) experimented on eggs at different weeks of age on Vanaraja birds and found that yolk indices showed significant ($P<0.05$) difference between different age of measurements. However, no specific trend was reported and the yolk indices were not significantly different between 40 and 72 weeks of age.

Sreenivas *et al.* (2013) reported significantly ($P<0.01$) higher yolk indices in IWI strain of White Leghorn than other strains and control groups whereas IWH, IWK and control did not differ significantly.

Yolk height and yolk diameter:

McNally and Brant (1952) considered that yolk height alone should be used instead of yolk index because it provided a more accurate and simple measure of yolk shape. But they used eggs which were within narrow weight ranging from 50 to 60g whereas using eggs of greater variation Bornstein and Lipstein (1962) showed that determination of yolk height alone is unacceptable as an assessment of yolk shape due to significant correlation with egg weight.

Potentially yolk width could be the easiest and most convenient criterion of internal quality, since it involves only one direct measurement, with a simple but accurate tool, the Vernier Calipers. Bornstein and Lipstein, (1962) obtained the existence of very high and negative correlation between yolk index and yolk width, since the horizontal yolk diameter increases with decreasing yolk quality. They also reported that eggs from older chicken had consistently a greater yolk height than those of younger layer, in contrast to the lower interior quality of eggs from older hens on the basis of Haugh unit scores and yolk index values. The effect of age of layer and size of egg on yolk height is reported to be highly significant.

Niranjan *et al.* (2008) reported the yolk height to be varied from 16.2 in C_2 cross to 16.9 in C_1 and Vanaraja birds. Yolk height of C_2 cross was reported to be significantly ($P<0.01$) lower than other breeds whereas yolk height of C_1, Vanaraja and Gramapriya did not differ significantly.

Yolk width as reported by Niranjan *et al.* (2008) differed significantly ($P<0.01$) among all the breeds. Highest width was reported in Vanaraja (39.4mm) and lowest in C_1 cross (31.2mm).

Yolk weight:

Parmer *et al.* (2006) reported the average yolk weight in Kadaknath to be 15.18g.

Niranjan *et al.* (2008) reported that yolk weight in the crosses varied from 16.17g in C_2 cross to 17.42 in Vanaraja which differed significantly ($p<0.01$) in all the varieties studied at different ages. Yolk weight at 24 weeks of age were reported to be significantly ($P<0.01$) higher in Gramapriya but at 32 weeks of age C_1 cross had significantly higher yolk weight and at 40 weeks of age C_1, C_2 and Vanaraja had significantly higher yolk weight than Gramapriya .

Zita *et al.* (2009) reported highly significant ($P<0.001$) effect of age and genotype on yolk weight of brown egg layer hens. Yolk weight reported to be increased with the advancement of age, the highest yolk weight was found to be in Moravia BSL (19.64g) at 54 -60 weeks age group and lowest in ISA Brown (12.46g) at 20-26 weeks age groups.

Islam and Dutta (2010) reported that yolk weight exhibited highly significant ($P<0.001$) difference between the breeds.

Mohanty *et al.* (2011) reported significant effect of genetic groups on yolk weight. At 25 weeks of age significant differences were reported between the native local fowl and the improved varieties. Highest yolk weight was recorded by the author in meat type birds as 16.45g and lowest in rural germplasm of Vanaraja as 8.7g, whereas the native local fowl showed a comparatively higher yolk weight as 10.36g. Yolk weight at both 54th and 74th weeks was reported to be the highest in meat type birds (20.51g and 23.32g) and lowest in native local fowl (14.03g and 16.01g).

Padhi *et al.* (2013) reported highly significant ($P<0.05$) effect of age on yolk weight at different ages of laying in Vanaraja birds. Yolk weight reported to be increased with the advancement of age of laying. The highest yolk weight (20.81-0.44g) and the lowest yolk weight (13.05-0.19g) were reported at 72 and 28 weeks of laying respectively.

Sreenivas *et al.* (2013) experimented on three strains of White Leghorn and control group , reported that yolk weight of IWH, IWK and control differed significantly whereas IWI and control did not differ significantly. IWK strain had the highest (15.58-0.12g) yolk weight and IWH had the lowest (14.16-0.13g).

The mean values of yolk index, yolk width, yolk height, yolk weight and yolk percentage reported in the available literature are presented in table 7.

Table -7 Estimates of average yolk quality traits in chicken as reported in literature.

Breed/strain	**Mean**	**Reference**
Yolk Index		
C_1 cross	46	Niranjan *et al* .(2008)
C_2 cross	44	,,
Vanaraja	44	,,
Grampriya	45	,,
Brown egg layer strain		Zita *et al* .(2009)
ISA Brown(20-26wk)	48.12	,,
Hisex Brown	47.22	,,
Moravia BSL	48.19	,,
ISA Brown(36-42)	44.36	,,
Hisex Brown	43.93	,,
Moravia BSL	46.56	,,

ISA Brown(54-60)	43.63	,,
Hisex Brown	42.91	,,
Moravia BSL	45.12	,,
Native fowl	20	Mohanty *et al.* (2011)
Aseel	38	,,
Kadaknath	45	,,
Black rock	41	,,
Red Cornish	34	,,
RIR	40	,,
Dahlem Red	29	,,
Vanaraja	23	,,
V_2, Chabro		
Vanaraja		Padhi *et al.* (2013)
28th week	41	,,
40th week	37	,,
52nd week	43	,,
64th week	39	,,
72nd week	35	,,

White Leghorn		Sreenivas *et al* .(2013)
IWH	34.3	,,
IWI	35	,,
IWK	34.1	,,
Control	37.0	,,
Yolk weight		
Kadaknath	15.18	Parmer *et al* .(2006)
C_1 cross	11.5	Niranjan *et al.* (2008)
C_2 cross	11.9	,,
Vanaraja	12	,,
Gramapriya	13.5	,,
Native variety	10.36	Mohanty *et al.* (2011)
Aseel	10.92	,,
Kadaknath	14.90	,,
Black rock	16.61	,,
Red Cornish	16.21	,,
RIR	15.23	,,
Dahlem red	14.52	,,

Vanaraja	8.7	,,
V_2,Chabro	16.28	,,
Indigenous	14.65	Islam and Dutta (2010)
Broiler	9.6	,,
Fayoumi	14.88	,,
RIR	11.2	,,
Sonali	16.4	,,
Vanaraja		Padhi *et al.*(2013)
28th week	13.05	,,
40th week	17.18	,,
52nd week	18.48	,,
64th week	19.40	,,
72nd week	20.81	,,
White Leghorn		Sreenivas *et al.* (2013)
IWH	14.16	,,
IWI	14.70	,,
IWK	15.58	,,
Control	14.84	,,

Percent yolk weight		
Brown egg layer strain		Zita *et al.*(2009)
ISA Brown(20-26)	23.12	,,
Hisex Brown	23.53	,,
Moravia BSL	23.42	,,
ISA Brown(36-42)	26.94	,,
Hisex Brown	26.93	,,
Moravia BSL	29.23	,,
ISA Brown(54-60)	28.12	,,
Hisex Brown	27.76	,,
Moravia BSL	30.13	,,
Vanaraja		Padhi *et al.* (2013)
28th week	27.50	,,
40th week	31.17	,,
52nd week	30.01	,,
64th week	32.21	,,
72nd week	34.13	,,

White Leghorn		Sreenivas *et al.*(2013)
IWH	28.28	,,
IWI	29.17	,,
IWK	29.15	,,

Age and body weight at the age of sexual maturity (ASM)

Age and body weight of chicken at the age of sexual maturity affect the size and weight of egg. Heavy breeds, in general, produce larger eggs as compared to light breeds. Differences also exist among strains/lines of the same breed and even between families and individuals with respect to egg weight. The birds which mature early produce smaller size eggs because of low body weight.(ICAR, Hand book)

Table-8 the estimates of average age and body weight at the ASM as reported in the literature.

Breed	Age at ASM (in days)	Body weight at ASM(g)	Reference
WLH strain			Devi *et al.*(2005)
IWD	150	1348	,,
IWF	153	1271	,,

3-WAY	145	1596	,,
2-WAY	152	1448	,,
Vanaraja	164.79	-	Niranjan *et al.(*2008*)*
Gramapriya	160.89	-	
Gramapriya	179.50	-	Haunshi *et al.*(2009)
Vanaraja	197.70	-	
DBxDB	140	1350	Ojo and Ayorinde (2011)
DBxFE	145	1388	,,
FExDB	148	1408	,,
FExFE	158	1405	,,
Gramapriya	138		Giri and Sahoo(2012)
Vanaraja	142		,,

MM	168.31	1459.33	Taha *et al.*(2013)
SS	173.50	1519.86	,,
MS	166.65	1492.50	,,
SM	163.14	1524.25	,,
Vanaraja	161.58	-	Jha and Prasad (2013)
Gramapriya	155.32	-	,,
Aseel	192.83	-	,,

MM – Mandarah , MS – Mandarah X El-Salam, SS – El – Salam SM–El-SalamX Mandarah, DB – Dominant Black, FE – Fulani Ecotype

Devi *et al.*(2005) reported that the average age at first egg lay among the crosses was significantly different and average age at first egg was reported to be 145 days in 3- way cross which is 5-8 days earlier to 2-way cross and pure strains.

Panda and Pasupalak (2007) observed that age at first egg of Gramapriya at Orissa state's climatic condition was 5 months and egg weight was 55-56g.

Niranjan *et al.* (2008) reported that the age at sexual maturity was 164.79 days for Vanaraja and 160.89 days for Gramapriya birds

Haunshi *et al.* (2009) reported 179.50 and 197.70 days of age at sexual maturity in Gramapriya and Vanaraja respectively.

Giri and Sahoo (2012) reported that age at first egg in Grampriya chicken was 138days and 142 days respectively under intensive and extensive condition of rearing.

Ojo and Ayorinde (2011) reported that age at sexual maturity was influenced by genotypes. Dominant black pure line reached to the sexual maturity earlier than the other groups. They also reported that Dominant black started laying at an early age and at lighter body weight than other genotypes. He showed that FExDB had the highest body weight at first egg laid followed by FExFE, DBxFE and DBxDB and reported significant breed differences in the weight at the onset of laying.

Jha and Prasad (2013) reported that the average age at sexual maturity was lower in Vanaraja and Gramapriya as compared to Aseel.

Taha *et al.* (2013) reported that the cross of El-Salam x Mandarah recorded to have significantly the highest averages for egg weight at sexual maturity, reaching sexual maturity at earlier ages than other lines.

Phenotypic correlation

A brief review on phenotypic correlation between various egg quality traits in pure and crossbred chickens as reported in the available literature is presented in Table 8.

Table -9 The Phenotypic correlation coefficients between various egg quality traits in pure and crossbred chicken as reported in the available literature.

Traits	r_p	Reference
Egg weight x Egg shape/shape index		
Indigenous	-0.17	Islam and Dutta (2010)
Broiler	-0.21	,,
Fayoumi	-0.21	,,
RIR	-0.49	,,
Sonali	-0.05	,,
Egg Weight x Albumen weight		
Indigenous	0.45	Islam and Dutta (2010)
Broiler	0.82	,,
Fayomi	0.13	,,

RIR	0.96	,,
Sonali	0.70	
Kazak layers	0.90	Alipanah *et al.*(2013)
IWH strain	0.964	Sreenivas *et al.*(2013)
IWI Strain	0.892	,,
IWK Strain	0.965	,,
Control Strain	0.953	,,
Egg weight x Shell weight		
Indeginous	0.10	Islam and Dutta (2010)
Broiler	0.37	,,
Fayoumi	0.2	,,
RIR	0.47	,,
Sonali	0.24	,,

Vanaraja at 28th wk	0.20	Padhi *et al* .(2013)
Vanaraja at 40th wk	0.44	,,
Vanaraja at 52nd wk	0.38	,,
Vanaraja at 64th wk	0.23	,,
Vanaraja at 72nd wk	0.55	,,
IWH Strain	0.531	Sreenivas *et al.*(2013)
IWI Strain	0.294	,,
IWK Strain	0.054	,,
Control Strain	0.546	,,
Egg weight x Shell thickness		
Brown egg layer strain(pooled)	-0.152	Zita *et al.*(2009)
Vanaraja at 28th week	0.02	Padhi *et al.*(2013)

At 40th week	0.25	”
At 52nd week	0.27	”
At 64th week	0.27	”
At 72nd week	0.43	”
IWH Strain	-0.229	Sreenivas *et al.*(2013)
IWI Strain	0.580	”
IWK Strain	0.111	”
Control Strain	0.137	”
Egg weight x Egg length		
Cobb500 broiler	0.468	Amankwah (2013)
Yolk weight x Albumen weight		
Indigenous	-0.31	Islam and Dutta (2010)
Broiler	0.20	”

Fayoumi	-0.51	”
RIR	0.65	”
Sonali	-0.39	
Cobb500 broiler	-0.114	Amankwah (2013
Egg weight x Albumen weight		
Exotic ISA Brown	0.91	Olawumi and Ogunlade (2008)
Cobb500 broiler	0.712	Amankwah (2013)
Egg weight x Albumen height		
Exotic ISA Brown	0.51	Olawumi and Ogunlade (2008)
Kazak layers	-0.03	Alipanah *et al.* (2013)
Cobb500 broiler	0.435	Amankwah (2013)

Egg weight x percent albumen		
Brown egg layer strain(pooled)	-0.039	Zita *et al* .(2009)
Egg weight x Yolk weight		
Exotic ISA Brown	0.55	Olawumi and Ogunlade (2008)
Indigenous	-0.59	Islam and Dutta (2010)
Broiler	-0.28	,,
Fayoumi	0.66	,,
RIR	0.72	,,
Sonali	0.12	,,
Kazak layers	0.59	Alipanah *et al*.(2013)

Cobb500 broiler	0.271	Amankwah (2013)
IWH Strain	0.768	Sreenivas *et al.*(2013)
IWI Strain	0.611	
IWK Strain	0.023	
Control Strain	0.578	
Egg weight x Yolk Height		
Exotic ISA Brown	0.45	Olawumi and Ogunlade (2008)
Cobb500 broiler	0.385	Amankwah (2013)
Egg weight x Yolk width		
Exotic ISA Brown	0.42	Olawumi and Ogunlade (2008)
Cobb500 broiler	0.299	Amankwah (2013)

Egg length x Albumen height		
Cobb500 broiler	0.364	Amankwah (2013)
Egg width x Albumen height		
Cobb500 broiler	0.196	Amankwah (2013)
Egg length x Shape Index		
Cobb500 broiler	-0.788	Amankwah (2013)
Egg length x Shell thickness		
Cobb500 broiler	0.028	Amankwah (2013)
Egg length x Shell weight		
Cobb500 broiler	-0.185	Amankwah (2013)
Egg width x Egg length		
Cobb500 broiler	0.407	Amankwah (2013)

Egg width x Shape index		
Cobb500 broiler	0.218	Amankwah (2013)
Egg width x Shell thickness		
Cobb500 broiler	-0.008	Amankwah (2013)
Egg width x Shell weight		
Cobb500 broiler	-0.135	Amankwah (2013)
Shape index x Shell thickness		
Cobb500 broiler	0.040	Amankwah (2013)
Shape index x Shell weight		
Cobb500 broiler	0.132	Amankwah (2013)
Shape index x Albumen height		
Exotic ISA Brown	-0.14	Olawumi and Ogunlade (2008)

Kazak layers	0.05	Alipanah *et al.*(2013)
Cobb500 broiler	-0.264	Amankwah (2013)
Shape index x Albumen weight		
Indigenous	0.27	Islam and Dutta (2010)
Broiler	0.10	,,
Fayoumi	-0.15	,,
RIR	-0.44	,,
Sonali	-0.13	,,
Shape index x Yolk weight		
Exotic ISA Brown	-0.03	Olawumi and Ogunlade (2008)
Kazak layer	-0.20	Alipanah *et al.*(2013)
Cobb500 broiler	0.009	Amankwah (2013)

Shape index x Yolk index		
Cobb500 broiler	-0.226	Amankwah (2013)
Shellthickness x Albumen height		
Exotic ISA Brown	-0.23	Olawumi and Ogunlade (2008)
Cobb500 broiler	0.030	Amankwah (2013)
Shellthicknes x Albumen weight		
Exotic ISA Brown	-0.03	Olawumi and Ogunlade (2008)
Cobb500 broiler	-0.028	Amankwah (2013)
IWH Strain	-0.301	Sreenivas *et al.*(2013)
IWI Strain	0.312	,,
IWK Strain	0.053	,,

Control Strain	0.116	,,
Shell thickness x Yolk weight		
Exotic ISA Brown	-0.09	Olawumi and Ogunlade (2008)
Cobb500 broiler	0.003	Amankwah (2013)
IWH Strain	-0.035	Sreenivas *et al.*(2013)
IWI Strain	0.648	,,
IWK Strain	0.016	,,
Control Strain	0.096	,,
Shell thickness x Yolk index		
Cobb500 broiler	0.066	Amankwah (2013)
IWH Strain	-0.097	Sreenivas *et al.*(2013)
IWI Strain	0.037	,,

IWK Strain	-0.183	,,
Control Strain	-0.018	,,
Shell thickness x Shell weight		
Cobb500 broiler	0.038	Amankwah (2013)
IWH Strain	0.354	Sreenivas *et al.*(2013)
IWI Strain	0.336	,,
IWK Strain	0.318	,,
Control Strain	0.352	,,
Albumen Height x Albumen weight		
Cobb500 broiler	0.578	Amankwah (2013)
Albumen Height x Yolk Height		
Cobb500 broiler	0.684	Amankwah (2013)

Shell weight x Yolk index		
Cobb500 broiler	-0.178	Amankwah (2013)
Shell weight x Yolk weight		
Kazak layers	0.32	Alipanah *et al.*(2013)
Cobb500 broiler	-0.069	Amankwah (2013)
Shell weight x Albumen height		
Kazak layer	-0.11	Alipanah *et al.* (2013)
Cobb500 broiler	-0.236	Amankwah (2013)

Phenotypic Correlation between the External Egg Quality Traits

The weight of egg is the most important external quality trait of the egg influencing the weight of newly hatched chicks and hatching performance (Farooq *et al.*, 2001). The existence of significant positive correlation between egg weight, shell weight and shell thickness has been reported by Farooq *et al.* (2001). This provides an indication for better prediction of egg shell weight and thickness from other quality traits (Khurshid *et al.*, 2003).

Zita *et al.*(2009) found that there was significant ($P<0.05$) and positive correlation between egg weight and egg shell thickness, yolk percentage. However, they reported significant ($P<0.05$) negative correlation of egg weight with albumen percentage and egg shell percentage. The authors have also reported positive and significant correlation between egg shell percentage and egg shell thickness.

Phenotypic correlation between external egg quality traits from five breeds of chicken reported by Islam and Dutta (2010) to be significant ($P<0.05$) and positive between shell weight and shell ratio for all breeds. They also found a significant ($P<0.05$) and positive phenotypic correlation between egg weight and egg volume (egg length and egg width) for the Sonali breed.

Amankawah (2013) reported significant ($P<0.01$), ($P<0.05$) and positive correlation among different external egg quality traits except shape index and shell weight which were negatively correlated to egg length . Shell thickness and shell weight also reported to be negatively correlated with egg width.

Padhi *et al.* (2013) reported negative correlation between egg shape index and egg weight upto 52^{nd} week of age in Vanaraja and thereafter positively correlated. However, shell weight and shell thickness were reported to be positively correlated at all ages of measurement. Shell percent was reported to be negatively correlated at all ages of measurement except at 40^{th} week of age.

Phenotypic Correlations between Internal Egg Quality Traits

Kul and Seker (2004) reported significant negative correlation between the albumen height and the yolk ratio. They found statistically significant and positive correlations of albumen index with albumen height, albumen weight, haugh unit and yolk height. These indicate that an improvement of the albumen index will result the improvement in albumen weight and the albumen ratio (Ozcelik, 2002).

Olawumi and Ogunlade (2008) observed highly significant ($P<0.01$) and positive correlation between yolk weight, yolk width, albumen weight and yolk height. However, negative correlation between yolk height, albumen height and albumen width was reported by the authors.

Islam and Dutta (2010) reported that phenotypic correlation between yolk weight and albumen weight was direction less and non-significant between different breeds.

Amankawah (2013) found that all internal egg quality traits were significantly ($P<0.01$) and positively correlated between themselves except albumen weight which was negatively correlated with yolk width and yolk weight, and yolk index which was reported to be negatively correlated with yolk weight and yolk diameter.

Phenotypic correlation between external and Internal egg quality traits

In laying flock of poultry it is very important to obtain a large number of eggs with normal structure, normal morphological composition and good interior quality. These elements have very significant influence on biological value of the egg which determines normal development of the embryo. Weight of the egg albumen was predicted with accuracy from the egg weight, egg width and length due to significant correlation between them (Khurshid *et al.*, 2003). They were also able to predict with accuracy the weight of the yolk from the egg weight, length and width due to significant and positive correlation between them. However, a negative correlation value was obtained between shell weight and albumen ratio. There were no significant correlations between the shape index and internal quality traits with the exception of the albumen weight and yolk weight (Olawumi and Ogunlade, 2008). These findings were supported by Ozcelik (2002) and Kul and Seker (2004). Oluwami and Ogunlade (2008) also found that there was negative but non -significant correlation between shell thickness and almost all the internal quality traits of the egg. They also found that all the internal quality traits of the egg such as albumen height, albumen weight, yolk diameter, yolk height and yolk weight were significantly and positively correlated with egg weight, in general.

Olawumi and Ogunlade (2008) reported highly significant ($P<0.01$) and positive correlation between egg weight, egg length, egg width, shell weight and yolk weight, yolk height, yolk width whereas non-significant negative correlation with shell thickness and shape index. Similarly albumen weight reported to have highly significant ($P<0.01$) and positive correlation with egg weight, egg length, egg width and shell weight whereas non-significant correlation with shell thickness and shape index. Albumen height is reported to be positively correlated with egg weight, egg length and egg width whereas negatively correlated with shell weight, shell thickness and shape index. However, these correlations were statistically non-significant. Albumen width had highly significant ($P<0.01$) and positive correlation with egg weight and shell weight.

Islam and Dutta (2010) reported significant and positive phenotypic correlations between egg weight and yolk weight, and between egg weight and albumen weight. They also reported negative but non-significant phenotypic correlation between egg weight and both albumen ratio and yolk ratio. Yolk weight and albumen weight were reported to be negatively correlated with the egg weight but it was statistically non-significant.

Padhi *et al.*(2013) reported that in Vanaraja birds at different weeks of measurement there was positive correlation between egg weight and yolk index whereas albumen index showed positive correlation up to 52^{nd} weeks of age. Yolk weight, albumen weight and shell weight reported to have positive correlation with egg weight. The correlation of egg weight with albumen percent was reported to be higher than that with yolk and shell weight.

Alipanah *et al.* (2013) reported positive correlation between egg weight, egg shell weight, egg width, egg length and yolk weight, albumen weight whereas negative correlation between shape index and yolk weight, albumen weight.

Amankawah (2013) reported significant ($P<0.05$) phenotypic correlation between internal and external egg quality traits in Cobb500.

However, there were significant ($P<0.05$) positive correlations between egg weight and albumen weight, albumen height, albumen ratio, haugh unit, yolk diameter, yolk height, yolk weight, and yolk index. Almost all internal quality traits of the egg were reported to be correlated positively and significant ($P<0.05$). They also reported negative phenotypic correlation between the shell weight and albumen height, albumen weight and yolk ratio. Highly significant ($p<0.01$) but negative phenotypic correlation were reported between shape index and all the internal quality traits except yolk width and yolk diameter.

Fertility:

Fertility has been reported to be influenced by various factors such as time of mating (Parker, 1950), Sex ratio (Trehen *et al.*, 1983), Social dominance (Guhl and Warren, 1946), Season and environmental temperature (Hays and Sanborn, 1939; Parker and Mespadden, 1942), age of breeds (Singh, 1961), laying capacity of strains (Bernier *et al.*, 1951), Stage of laying cycle (Tomohave, 1958) etc.

The breeding system is also reported to have a significant effect on fertility. The difference in fertility between various types of mating system is either a function of the strain of male and females used for crossing or is due to preferential mating or the tendency of male and female to mate more frequently with certain birds of opposite sex in a flock as demonstrated by Lamoreux (1940) and Funk and Irwin (1955).

The fertility depends on various factors such as breed, season, pre – incubation holding period, lighting, level of nutrition, mating and time of mating (Sliversides and Scott, 2001). It has been reported that temperature is the major factor for the production of fertile eggs. It has been reported that fertility is affected badly during both hot and cold weather (Crawford, 1984).

Islam *et al.* (2002) reported highest fertility percentage in WLH (94.78%) and lowest in RIR (88.29%)

Bhardwaj *et al.*(2006) reported fertility percentage ranging from 62.65 to 76.39. The fertility percentage was reported to be the highest in RIR and Aseel crosses and lowest in Kadaknath and Brown Cornish.

Ojo and Ayorinde (2011) reported that fertility percentage was highest in Dominant Black and Fulani Ecotype crosses and lowest in pure Fulani ecotype. They also reported significant breed effect on this trait.

Miazi *et al.*(2012) reported that fertility of crossbred Sonali (RIR x Fayoumi) ranged from 83 to 94.4%. The fertility rate of Fayoumi and Sonali did not vary much between two breeds. This was reported to be due to the nutritional facilities as well as management procedure, although the weather condition was same for all eggs from where the eggs were collected.

The average fertility percentage of various pure and crossbred chickens reported in available literature is presented in table -9.

Table -10 Fertility percentages in various pure and crossbred chicken reported in the available literature.

Breed	Fertility percentages	Reference
PURE BREED		
Barred Plymouth rock	95.10	Islam *et al.* (2002)
White leghorn	96.70	,,
Rhode island red	94.03	,,
White rock	94.94	,,
Kadaknath	70.44	Bhardwaj *et al* .(2006)
Aseel	73.22	,,
RIR	75.21	,,
Brown Cornish	71.92	,,
DB x DB	73.00	Ojo and Ayorinde (2011)
FE x FE	54.12	,,
Fayoumi	88.6	Miazi *et al* .(2012)
CROSS BRED		
Kadaknath x Brown Cornish	62.61	Bhardwaj *et al* .(2006)

Brown Cornish x Kadaknath	71.35	,,
Aseel x RIR	74.43	,,
RIR x Aseel	76.39	,,
DB x FE	76.24	Ojo and Ayorinde (2011)
FE x DB	62.88	,,
WLH x NN	90.6	Ahmed *et al.* (2012)
WLH x Fayoumi	84.6	,,
WLH x RIR	87	,,
WLH x Aseel	55	,,
WLH x Desi	82.6	,,
Sonali	89.8	Miazi et al (2012)

NN – Naked Neck , FE – Fulani ecotype, RIR – Rhode Island Red DB – Dominant black

The average fertility percentage in various pure breeds of chicken reported to be ranged from 54.12 in Fulani ecotype to 96.70 in White Leghorn. Among the crossbreds the fertility percentages reported to be ranged from 62.61 in Kadaknath x Brown Cornish crosses to 90.6 in WLH x NN crosses.

Hatchability:

Generally, the term hatchability is used to mean the number of chicks hatched out per 100 eggs incubated, but from the research points of view the term hatchability means the number of chicks hatched out of 100 fertile eggs incubated.

Hatchability of fertile eggs depends upon several factors starting from frequency of collection of eggs, seasons, methods and length of storing eggs prior to incubation, temperature, humidity and condition of the incubator during incubation, egg size and shape, shell thickness and its porosity, time of laying, age of breeds, genetic background of the breeding stock etc. (Arora, 1970).

It is well accepted that heritability for the hatchability ranges from 0.10 to 0.15 indicated that the trait is mainly affected by the environment (Rahman, 1995).

The average sized eggs give better hatchability than that of large sized eggs as reported by many workers (Godfrey, 1936 and Skoglund *et al.*, 1948). They also found the lower hatchability in extremely large and small sized eggs. Obenko and Antakov (1956) in White Russian birds found that eggs weighing 48-50 g had only 75% hatchability. Olsen and Haynes (1949) found the highest hatchability in eggs of White Leghorn weighing from 46-64 g and concluded that normal shaped eggs had 87% hatchability against 49% of unshaped eggs. Czarnecka (1954) observed good hatchability percentage (74.8%) from the large sized eggs weighing over 65 g although medium sized eggs weighing between 60-65 g had the better hatchability (81.1%).

Skoglund *et al.* (1951) classified the chicken eggs into three categories, long and narrow (Shape index below 69), normal (Shape index between 69-77) and short and round eggs (Shape index above 77) and showed that normal eggs had 2% higher hatchability than the extremes.

Ahmed *et al.*(2012) found that hatchability from fertile eggs was higher for Naked neck (90.6%) than the RIR (87%), Fayumi (84.6%), Desi (82.6%) and in Aseel (55%)

Breed effect

The existence of breed differences and different breeding systems on hatchability has been reported by many authors in the available literatures.

Islam *et al.* (2002) reported that different hatchability traits are influenced by different breeds. The percentage of normal chicks hatched was slightly higher in RIR (98.56%) followed by those of WLH (97.70%), BPR (97.73%) and WR (96.49%).

The percent hatchability on fertile egg set basis ranged from 49.49 to 84.93. Bhardwaj *et al.* (2006) reported the highest hatchability on fertile eggs in RIR and Aseel crosses and lowest in Brown Cornish.

Ojo and Ayorinde (2011) reported that hatchability percentage was highest for Dominant Black and Fulani ecotype cross (78.30) whereas lowest for Fulani ecotype pure (70.10).

Miazi *et al.* (2012) reported that the overall fertility rate was 86.0% in Fayoumi, which was lower than Sonali (87.5%) but didn't vary significantly.

Jha and Prasad (2013) reported 87.58% hatchability on fertile egg set basis in Vanaraja birds and a lower value of 79.42%, 68.97% in Gramapriya and Aseel respectively.

Table – 11 Hatchability percentages of pure and crossbred chicken as reported in the available literature.

Breed	Hatchability percentages	Reference
PURE BREEDS		
Barred Plymouth rock	88.59	Islam *et al* .(2002)
White leghorn	90.15	,,
Rhode island red	88.37	,,
White rock	91.93	,,
Kadaknath	57.75	Bhardwaj *et al* .(2006)
Aseel	58.00	,,
RIR	50.39	,,
Brown Cornish	49.49	,,
DB x DB	73.90	Ojo and Ayorinde(2011)
FE x FE	70.10	,,
Fayoumi	86.0	Miazi *et al.* (2012)
Vanaraja	87.58	Jha and Prasad (2013)

Gramapriya	79.42	,,
Aseel	68.97	,,
CROSS BRED		
Kadaknath x Brown Cornish	78.82	Bhardwaj *et al*. (2006)
Brown Cornish x Kadaknath	79.13	,,
Aseel x RIR	78.33	,,
RIR x Aseel	84.93	,,
DB x FE	78.30	Ojo and Ayorinde(2011)
FE x DB	70.47	,,
WLH x NN	85.3	Ahmed *et al*. (2012)
WLH x Fayoumi	84.6	,,
WLH x RIR	83.9	,,
WLH x Aseel	57.5	,,
WLH x Desi	76.2	,,
Sonali	87.5	Miazi *et al*. (2012)

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MATERIALS AND METHODS

MATERIALS AND METHODS

Vanaraja breed of Poultry developed at Directorate of Poultry Research, Hyderabad and Desi chicken native to Muzaffarpur and Gaya districts of Bihar were constituted the genetic material for the present study.

The male line and female line of Vanaraja were maintained at Instructional Livestock Farm Complex (ILFC), Bihar Veterinary College, Patna for production and supply of commercial chicks to the farmers for backyard Poultry keeping. Desi chicken native to Muzaffarpur and Gaya districts of Bihar maintained in the farm were utilized for crossing with Vanaraja females. Thus, Vanaraja and its crosses with Desi chicken native to Muzaffarpur and Gaya districts of Bihar had been constituted the genetic material for the study.

The three genetic groups, constituted for the present study are as follows:

- Vanaraja ♂ x Vanaraja ♀
- Desi (Muzaffarpur) x ♂ Vanaraja ♀
- Desi (Gaya) ♂ x Vanaraja ♀

Various parameters like Egg weight, Egg production (Up to 40 wks of age), Fertility & Hatchability percentage and Egg quality traits of the three genetic groups of chicken were recorded. External egg quality traits like Egg length(mm), Egg width(mm), Egg shape index, Egg shell thickness(mm) and internal egg quality traits like Albumen diameter (mm), Albumen height(mm), Albumen weight(g), Albumen index, Yolk diameter (mm), Yolk height (mm), Yolk weight (g) and Yolk index were recorded. Measurement of above traits was done through vernier calipers, tripod, screw gauge and spherometer. Then comparative studies were done among the eggs of different genotypes to assess its influence on egg quality traits and some of the reproductive traits, in same environmental and climatic condition at same age group.

Twenty males and 100 females of 16 weeks of age were taken from each genetic group and maintained separately under deep litter system in a flock with a mating ratio of 1 Male: 5 Females during the experimental period. To study the genetic effect on egg weight and egg quality traits a total of 150 eggs were collected at random considering at the rate of 50 eggs from each genetic group at 40 weeks of age. Daily Egg production was recorded to study the hen day egg production.

To examine the effect of egg weight on egg quality traits all these eggs were divided into 4 different groups according to the egg weight with the difference of 5 g from each. These groups were designated as:

Group I (30-36 g), Group II (36-42 g),

Group III (42-48 g) and Group IV (48g and above).

The eggs were weighed with the help of electronic balance to the nearest of 0.01 g. Eggs from each genetic group were collected at 40 weeks of age to record the egg weight. The eggs were stored in the cold storage for a period of 7 days at 15^0C prior to the incubation. The eggs were set in the incubation trays and incubated for 18 days at 100^0F temperature with relative humidity of 60-70%. The eggs were candled on 7^{th} day of incubation and removed the unfertile eggs. On 18^{th} day of incubation the eggs were transferred to the hatchery maintained at the temperature of 98^0F with relative humidity of 80-90% until the chicks hatched out. As such six hatches were taken to study the fertility and hatchability percentage.

During the entire period of experiment, the chicks were kept under uniform managemental conditions and standard Poultry ration. Feed and water was provided *ad lib* throughout the experimental period.

The following traits were recorded:

- Age of sexual maturity.
- Egg weight at the age of sexual maturity
- Egg production upto 40 weeks of age
- Egg quality traits :

(i) External egg quality traits:

(a) Egg length (mm)

(b) Egg width (mm)

(c) Shape index

(d) Egg shell thickness (mm)

(e) Shell weight

(f) Percent shell weight

(ii) Internal egg quality traits

(a) Albumen height (mm)

(b) Albumen diameter (mm)

(c) Albumen weight (g)

(d) Albumen index

(e) Percent albumen weight

(f) Yolk height (mm)

(g) Yolk weight (g)

(h) Yolk index

(i) Yolk width (mm)

(j) Percent yolk weight

MEASUREMENTS OF TRAITS

Egg Weight: The weight of eggs were taken with the help of electronic balance to the nearest of 0.01 g accuracy at the age of sexual maturity and at different weeks of age.

Egg Length and Egg Width: The length and width of the egg were measured with the help of Vernier Callipers to the nearest of 0.01 cm.

Shape Index: The shape index was calculated as the ratio of egg width to the egg length.

$$\text{Shape index} = \frac{\text{Egg width}}{\text{Egg length}} \times 100$$

Age at sexual maturity (ASM): It is the age at which 3% of the pullets of the flock laid the eggs.

Egg Shell Thickness: Egg shell was separated from the vitelline membrane and thickness was measured by Screw Gauge. The shell thickness was measured at three places, first at the broaden end, second at narrow end and third at the middle part of the body of the egg shell. The mean of these three measurements was considered as shell thickness of the egg.

Shell Weight and Percent Shell: For taking shell weight the vitelline membrane was separated from the egg shell and then it was washed in running tap water and kept for a period of 24 hrs, after that weight of egg shell was taken with the help of electronic balance with accuracy of 0.01 g. The percent egg shell was calculated as the ratio of shell weight to the total egg weight and expressed as percentage.

Albumen Height: The eggs were broken on a perfectly leveled glass plate. The height of thick albumen was measured by Spherometer at the highest and lowest points of the albumen. The average of two measurements was taken as mean height.

Albumen Diameter: The diameter of albumin was measured with the help of vernier callipers taking average of the minimum and maximum length of spread of albumin.

Albumen Index: Albumen index was calculated by the following formula, given by Oluyemi and Ogunlade (2008).

$$\text{Albumen index} = \frac{\text{Height of albumen}}{\text{Width of albumen}} \times 100$$

Albumen and Yolk Weight and Percentage: The egg albumen and yolk were separated with the help of spatula and poured in two clean beakers after cleaning the residual albumen from the shell and weighted by Top pan Sartorius balance with accuracy of 0.01g. The percent albumen was calculated as the ratio of albumen weight to the total egg weight and percent yolk was calculated as the ratio of yolk weight to the total egg weight and expressed as percentage.

Yolk Height: The yolk height was measured using the Spherometer. The height was taken at the highest point of egg yolk.

Yolk Diameter: The diameter of Yolk was measured with the help of vernier calipers with the nearest accuracy of 0.01 cm.

Yolk Index: Yolk index was calculated as per the formula given by Oluyemi and Ogunlade (2008).

$$\text{Yolk index} = \frac{\text{Height of the yolk}}{\text{Width of yolk}} \times 100$$

Height was determined by Spherometer and width (diameter) of egg yolk was measured with the Vernier Callipers. The width was multiplied by 10 to convert it into millimetre and the average of three measurements was taken for each observation.

Fertility: The fertility of eggs was estimated as the ratio of number of fertile eggs to the total number eggs set and expressed as percentage.

$$\text{Fertility \%} = \frac{\text{Total number of fertile eggs}}{\text{Total number of eggs set}} \times 100$$

Hatchability: The hatchability was calculated on the basis of total number of eggs set as well as on the basis of total number of fertile eggs set.

(i) On the basis of total number of eggs set, the hatchability is the number of chicks hatched out of the total number of eggs set and expressed as percentage.

$$\text{Hatchability \%} = \frac{\text{No. of chicks hatched}}{\text{Total no. of eggs set}} \times 100$$

(ii) On the basis of fertile eggs the hatchability is the ratio of number of chicks hatched to the total number of fertile eggs set and expressed as percentage.

$$\text{Hatchability \%} = \frac{\text{No. of chicks hatched}}{\text{Total no. of fertile eggs set}} \times 100$$

STATISTICAL ANALYSIS:

Data were analyzed by MIXED MODEL LEAST-SQUARES AND MAXIMUM LIKELIHOOD COMPUTER PROGRAM PC-2 in the Department of Animal Genetics and Breeding, Bihar Veterinary College, Patna-14. The least squares means, standard error and coefficient of correlation were calculated through least squares models (Harvey, 1990) and some of the minor calculations were carried out by a programmable scientific calculator $\text{CASIO}_{\text{fx-100s}}$ as per standard statistical method (Snedecor and Cochran, 1994).

Significant differences between means were tested by Duncan multiple ranges test modified by Kramer, 1957. The coefficient of phenotypic correlation between the traits was estimated as per standard statistical methods (Snedecor and Cochran, 1994).

Effect of genetic group on the egg quality traits:

- Coefficient of variation percentage of egg weight and egg quality traits in all the genetic groups were computed using the formula given by Snedecor and Cochran (1998)

$$\overline{X} = \frac{\sum_{i=1}^{n} x_i}{n}$$

$$S.E = \frac{S}{\sqrt{n}}$$

$$C.V.\% = \frac{S}{\overline{X}} \times 100$$

$$S = \sqrt{\frac{\Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n}}{n-1}}$$

$\overline{X}$ = Mean

X_i = Measurement of a trait on i^{th} bird

n = number of Observations

Effect of egg weight on various egg quality traits

The following linear statistical model was used to study the effect of genetic groups on various egg quality traits

$$Y_{ij} = \mu + G_i + e_{ij}$$

Where,

Y_{ij} is the measurement of a trait on the j^{th} bird of i^{th} genetic group

μ is the overall population mean

G_i is the effect of i^{th} genetic group

e_{ij} is the random error assumed to be normally and independently distributed with mean 0 and variance $\sigma^2 e$ *i.e NID* $(0, \sigma^n_e)$

Correlation Co-efficient:-

The simple correlation coefficient on the basis of the phenotypic values among different characters was computed by using the formula given by Snedecor and Cochran (1998):

$$r_{xy} = \frac{Covariance\ xy}{sd_x \cdot sd_y}$$

Where,

χ = represents one trait.

γ = represents another trait.

$r_{\chi\gamma}$ = Coefficient of correlation between χ and γ traits.

sd_χ = Standard deviation of the trait χ

sd_y = Standard deviation of the trait γ

n = paired number of observations.

$$r_{xy} = \frac{\Sigma xy - \dfrac{(\Sigma x)(\Sigma y)}{n}}{\sqrt{\left[\Sigma x^2 - \dfrac{(\Sigma x)^2}{n}\right]\left[\Sigma y^2 - \dfrac{(\Sigma y)^2}{n}\right]}}$$

Significance of coefficient of correlation was done through't' test at N-2 d.f.

RESULTS

AND

DISCUSSION

RESULTS & DISCUSSION

Age at Sexual Maturity

The age at sexual maturity of Vanaraja and its crosses with Desi chicken native to Bihar has been presented in table- 12

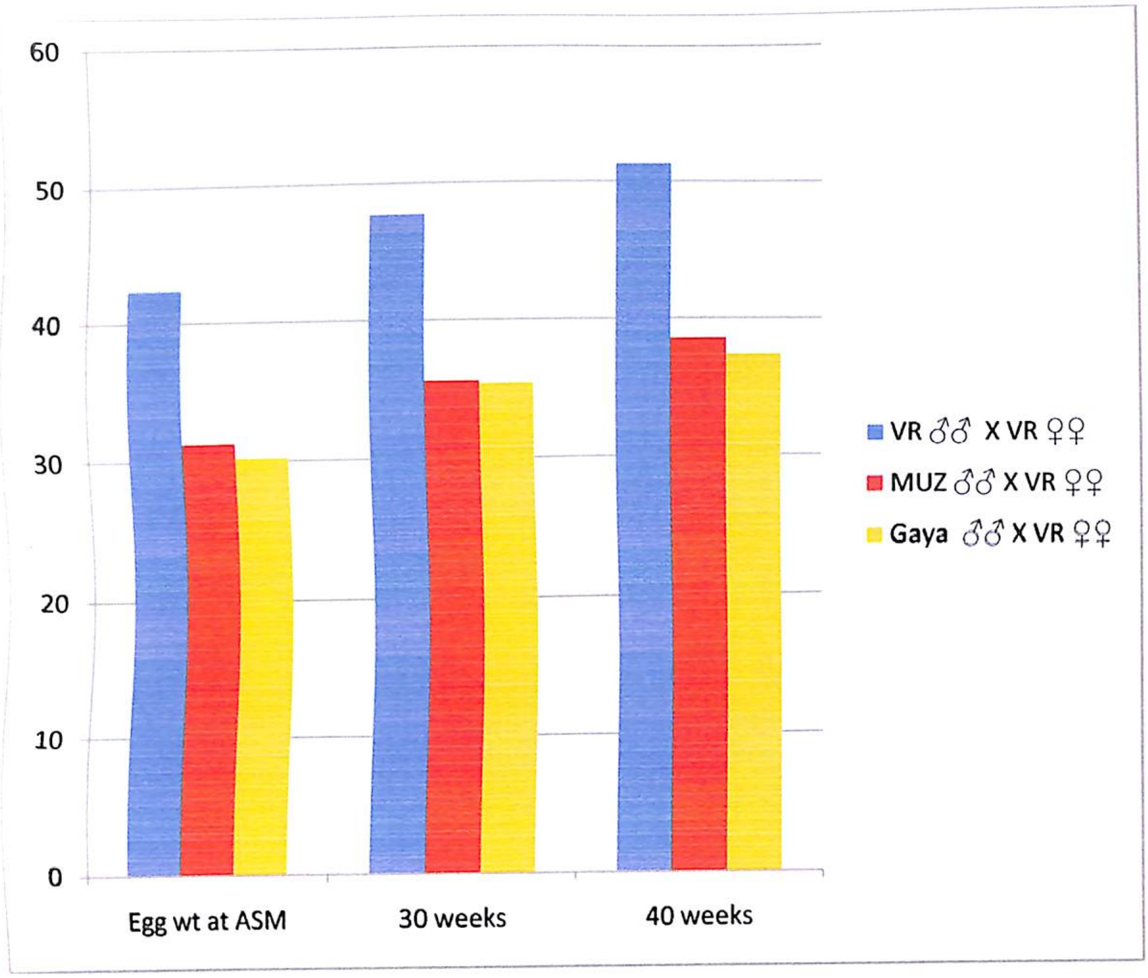
The average age at sexual maturity was determined when 3% of total flock size started to lay the eggs. The average age at sexual maturity of VR♂♂ x VR♀♀ was found to be 165 days which was higher as compared to Gaya Desi ♂♂ x Vanaraja♀♀ by 7 days.

The hens of MUZ Desi ♂♂ x VR♀♀ attained the sexual maturity at 152 days which was found to be shorter by 13 and 6 days as compared to VR x VR and Gaya Desi x VR respectively.

The information of age at sexual maturity of VR and its crosses with Desi chicken native to Bihar was very scanty in the literature, however, Sharma (2014) reported the age at sexual maturity of VR x GAYA and VR x MUZ to be 128.33 and 128.00 days respectively. The findings of the present study were not in accordance with the findings of Sharma (2014).

Table-12 Age at sexual maturity of Vanaraja and its crosses with Desi chicken native to Bihar.

Genetic groups	Age of sexual Maturity (days)
VR♂♂ x VR♀♀	165
MUZ Desi ♂♂ x VR♀♀	152
GAYA Desi ♂♂ x VR♀♀	158



Graph showing: Age at sexual maturity of Vanaraja and its crosses with Desi chicken native to Bihar.

Egg weight : The least squares means along with standard error (SE) and coefficient of variation percentage (CV%) of egg weight at the age of sexual maturity and at 30 and 40 weeks of age of Vanaraja and its crosses with Desi chicken native to Muzaffarpur (MUZ) and Gaya (Bihar) have been presented in table -13.

The average estimates of egg weight at sexual maturity of VR x VR, MUZ x VR and GAYA x VR were found to be 42.36±0.29, 31.24±0.25 and 30.18±0.14 g, respectively. The egg weight of Vanaraja at the age of sexual maturity reported by Jha and Prasad (2013) was in close agreement with the findings of the present study.

The average egg weight of VR x VR observed in the present study was found to be higher than the findings of Sinha (2014).

The average egg weight of MUZ x VR and GAYA x VR obtained in the present study are in agreement with the findings of Sharma (2014) who have reported the average egg weight of MUZ x VR and GAYA x VR at 50% genetic inheritance to be 33.47 and 29.71 g respectively.

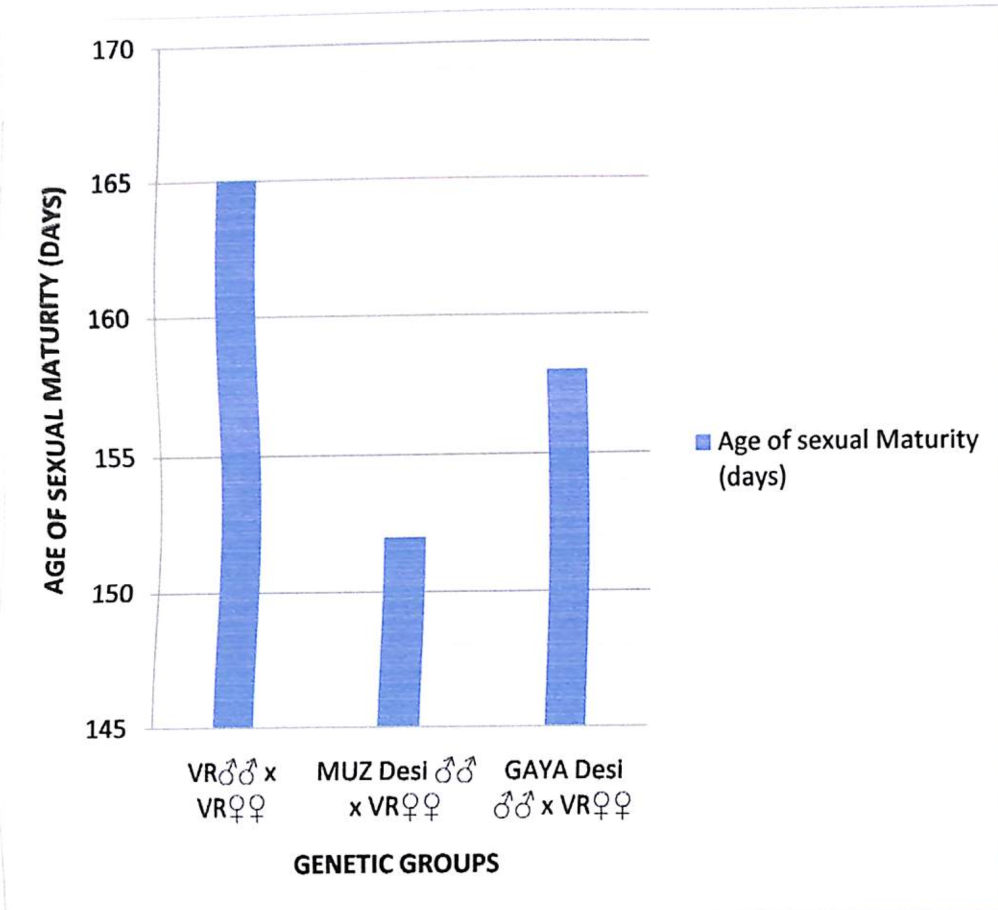
The average egg weight of VR x VR, MUZ x VR and GAYA x VR at 30 weeks of age were observed to be 47.68±0.46, 35.58±0.39 and 35.38±0.37 g respectively.

The average egg weight of VR x VR, MUZ x VR and GAYA x VR at 30 weeks of age were observed to be increased by 12.56, 13.89 and 17.23 percent respectively over their corresponding values at sexual maturity. The average egg weight of Vanaraja obtained in the present study was in agreement with the findings of Niranjan *et al.* (2008) and Padhi *et al.* (2013).

Table -13. Least squares means, SE and CV% of egg weight at different weeks of age in different genetic groups of chicken.

Genetic Groups	Egg weight (g)							
	No. of obs.	Egg wt at ASM		No. of obs.	30 weeks		40 weeks	
		Mean ±S.E.	C.V.%		Mean ±S.E.	C.V.%	Mean ±S.E.	C.V.%
VR ♂♂ X VR ♀♀	15	42.36^{b}±0.29	4.84	50	47.68^{b}±0.46	6.82	51.30^{b}±0.14	1.92
MUZ ♂♂ X VR ♀♀	15	31.24^{a}±0.25	5.65	50	35.58^{a}±0.39	7.75	38.56^{a}±0.45	8.25
Gaya ♂♂ X VR ♀♀	15	30.18^{a}±0.14	3.28	50	35.38^{a}±0.37	7.39	37.38^{a}±0.29	6.04

NB : Means with similar superscripts (column wise –abc) did not differ significantly.



Graph showing: Average egg weight at different weeks of age in different genetic groups of chicken

In table 13, the average estimates of egg weight of VR x VR, MUZ x VR and GAYA x VR at 40 weeks of age were recorded to be 51.30±0.14, 38.56±0.45 and 37.38±0.29 g respectively. The average egg weight of Vanaraja at 40 weeks of age observed in the present study was in close proximity with the findings of Sapra and Aggarwal (1971) for egg weight of meat type birds such as New Hampshire, White Plymouth Rock and White Cornish.

Islam and Dutta (2010) reported the average egg weight of RIR x Fayomi to be 56.5 g which was in close proximity with the findings of the present study. The average egg weight of MUZ x VR and GAYA x VR could not be compared as the information in the available literature could not be observed.

The average egg weight of VR x VR, MUZ x VR and GAYA x VR were found to be increased by 21.10, 23.43 and 23.86 percent, respectively as compared to the egg weight at sexual maturity.

Effect of Genetic group on Egg weight:

The least squares analysis of variance for the effect of genetic group on egg weight at different weeks of age has been presented in table -14.

The least squares analysis of variance revealed significant effect ($P<0.01$) of genetic groups on egg weight of VR and its crosses with Desi chicken.

Table 14. Least squares analysis of variance showing the genetic effect on egg weight at different weeks of age in chicken.

Traits	Source of variation	D.F.	M.S.	F.
Egg weight at ASM	Between groups	2	42.0352	16.42**
	Error	42	2.56	
Egg weight at 30 weeks	Between groups	2	183.4250	28.75**
	Error	147	6.38	
Egg weight at 40 weeks	Between groups	2	184.6019	12.67**
	Error	147	14.57	

** Significant at P<0.01

The VR x VR genetic group was found to have laid heaviest egg at sexual maturity as well as at 30 and 40 weeks of ages. At the age of sexual maturity VR x VR laid significantly (P<0.05) heavier eggs than the MUZ x VR and GAYA x VR by 11.12 and 12.18 g respectively. However there was no significant difference in egg weight between MUZ x VR and GAYA x VR. At 30 weeks of age, the average egg weight of VR x VR was found to be the largest, which was significantly (P<0.05) heavier than the eggs laid by MUZ x VR and GAYA x VR by 12.10 and 12.30 g respectively.

At 40 weeks of age VR x VR genetic group also laid significantly (P<0.05) heavier eggs than the MUZ x VR and GAYA x VR by 12.74 and 13.92 g , respectively. GAYA x VR genetic group laid the smaller eggs as compared to the eggs laid by MUZ x VR by 1.06, 0.20 and 1.16 g at ASM as well as at 30 and 40 weeks of age respectively but did not differ significantly among themselves. The effect of genetic group on egg weight at different weeks of age has also been reported by Sinha (2014), Alam (2015) which is in agreement with the findings of the present study.

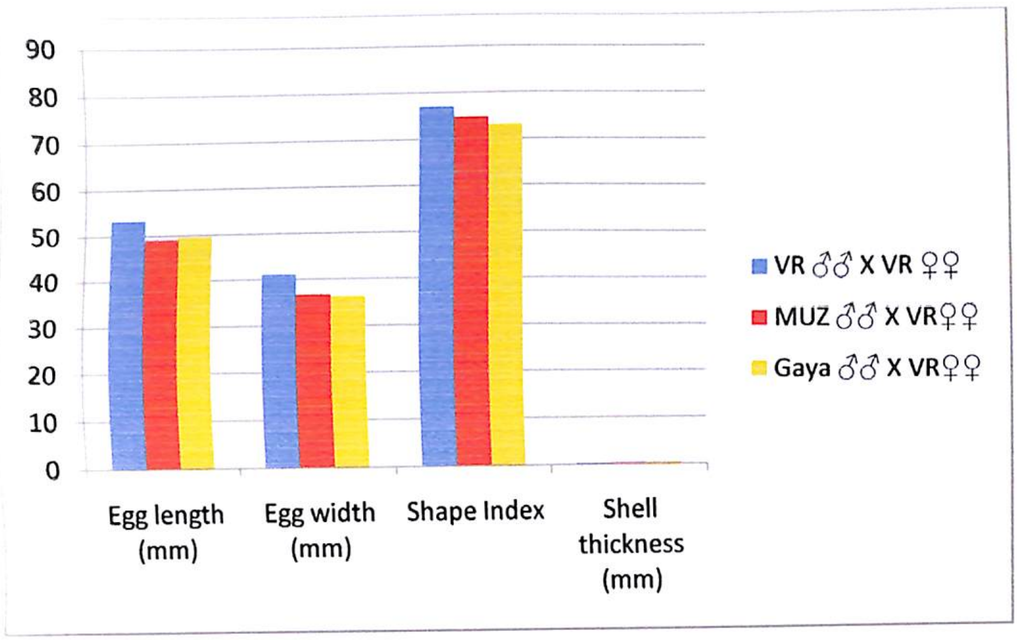
External Egg Quality Traits

Least square means along with their standard error and coefficient of variation percentage (CV %) of various external egg quality traits like egg length, egg width, shape index and shell thickness have been presented in table -15.

Table -15. Least squares means, SE and CV% of egg length, egg width, shape index and shell thickness in different genetic groups of chicken.

Genetic group	No. of obs.	Egg length (mm)		Egg width (mm)		Shape Index		Shell thickness (mm)	
		Mean ±S.E.	C.V.%	Mean ±S.E.	C.V.%	Mean ±S.E.	C.V.%	Mean ±S.E.	C.V.%
VR ♂♂ X VR ♀♀	50	53.28^{b}±0.26	3.45	40.99^{b}±0.40	6.90	76.96^{b}±0.74	6.79	0.330^{b}±0.74	4.22
MUZ ♂♂ X VR♀♀	50	49.07^{a}±0.18	2.59	36.70^{a}±0.14	2.59	74.82^{a}±0.34	3.21	0.295^{a}±0.34	9.58
Gaya ♂♂ X VR♀♀	50	49.61^{a}±0.48	6.84	36.23^{a}±0.15	2.92	73.03^{a}±0.69	6.65	0.459^{c}±0.69	9.24

NB : Means with similar superscripts (column wise –abc) did not differ significantly.



Graph showing: Average egg length, egg width, shape index and shell thickness in different genetic groups of chicken.

Egg length (mm)

The average estimates of egg length in VR x VR, MUZ x VR and GAYA x VR were found to be 52.28±0.26, 49.07±0.188 and 49.61±0.48 mm, respectively.

The average egg length of VR x VR obtained in the present study was found to be in close proximity with the findings of Sapra and Aggarwal (1971) and Islam and Dutta (2010). Sapra and Aggarwal (1971) reported the average egg length for Black Bengal, Aseel and Necked Neck to be 54.86, 54.60 and 54.33 mm, respectively. However, they have reported the higher estimates of egg length for New *Hampshire*, White Plymouth Rock and White Cornish as compared to the findings of the present study. The average egg length of Vanaraja reported by Niranjan *et al.* (2008) was 54.5 mm, which is in close proximity with the findings of the present study.

The average egg length of Vanaraja in crosses with Desi chicken of Muzaffarpur and GAYA observed in the present study are is in close proximity with the findings of Islam and Dutta (2010), who have reported the average egg length of indigenous chicken to be 48.30 mm. However, Sapra and Aggarwal (1971) reported the average length of Desi chicken to be 35.51 mm, which is much lower than the findings of the present study for MUZ Desi x Vanaraja and Gaya Desi x Vanaraja crosses. The average estimates of egg length observed in the findings of the present study were higher than the average egg length of VR x MUZ Desi and VR x GAYA Desi reported by Sharma (2014) at different levels of genetic inheritance of the Desi chicken.

The least squares analysis of variance for the effect of genetic group on egg length is presented in table -16 which revealed significant (P<0.01) effect of genetic group on egg length. The VR x VR genetic group was found to have the longest egg length which was significantly (P<0.05) lengthier than the eggs laid by MUZ x VR and GAYA x VR genetic groups by 4.21 and 3.67 mm, respectively. Significant (P<0.05) effect of genetic group on egg length observed in the findings of the present study has also been reported by Sapra and Aggarwal (1971), Niranjan *et al.* (2008), Islam and Dutta (2010), Sharma (2014), Sinha (2014) and Alam (2015).

Table 16. Least squares analysis of variance showing the genetic effect on egg length, egg width, shape index and shell thickness in chicken.

Traits	Source of variation	D.F.	M.S.	F.
Egg length (mm)	Between groups	2	262.476	48.39**
	Error	147	5.4237	
Egg width (mm)	Between groups	2	343.0705	103.80**
	Error	147	3.3050	
Shape index	Between groups	2	166.6786	8.69**
	Error	147	19.2649	
Shell thickness (mm)	Between groups	2	0.3674	370.26**
	Error	147	0.0001	

** Significant at P<0.01

Egg Width (mm)

The least squares means along with SE and CV % of egg width have been presented in table -15.

The average estimates of egg width of VR x VR, MUZ x VR and GAYA x VR were observed to be 49.99±0.40, 36.70±0.14 and 36.23±0.15 mm, respectively. The average estimate of egg width of Vanaraja obtained in the present study was in close proximity with the findings of Niranjan *et al.* (2008), who have observed the average egg width of Vanaraja to be 41.4 mm. The average estimate of egg width for VR x VR genetic group observed in the present study was in agreement with the findings of Beena (2014), who reported the average egg width to be 40.29±0.16 mm. However, Sapra and Aggarwal (1971) reported the higher estimates of egg width for New Hampshire, White Plymouth Rock and White Cornish as compared to the average egg width observed in the present study for VR x VR genetic group. Islam and Dutta also reported higher estimates of average egg width for RIR and Broiler chicken. The average estimates of egg width for Vanaraja and its crosses with Desi chicken native to Muzaffarpur and GAYA observed in the present study were higher than the average egg width reported by Sharma (2014) for MUZ x VR and GAYA Desi x VR at 50% of level of genetic inheritance to be 32.0 mm. However, Sapra and Aggarwal (1971) reported the higher estimates of egg width for indigenous breeds of chicken like Black Bengal, Aseel and Necked Neck to be 39.75, 41.44 and 40.17 mm, respectively. Islam and Dutta (2010) also reported the higher estimates of average egg width for RIR x Fayomi as compared to the values obtained in the present study. However, the average egg width for indigenous chicken reported by Islam and Dutta (2010) to be 37.10 mm, which is in close proximity with the findings of the present study for crossbred chicken.

Effect of Genetic group on egg width

The least squares analysis of variance for the effect of genetic group on egg width has been depicted in table -16, which revealed highly significant ($P<0.01$) effect of genetic group on egg width. The VR x VR genetic group laid the widest egg which was significantly ($P<0.05$) wider than the eggs laid by MUZ x VR and GAYA x VR by 4.29 and 4.76 mm, respectively. However MUZ x VR genetic group though laid wider eggs than the GAYA x VR by 0.47 mm but did not differ significantly. The significant effect of genetic group on egg width as observed in the present study has also been reported by Sapra and Aggarwal (1971), Niranjan *et al.* (2008), Islam and Dutta (2010), Sinha (2014), Sharma (2014) and Alam (2015).

Shape Index

The least squares means, SE and CV% of shape index have been shown in table -15. The average shape indices of VR x VR, MUZ x VR and GAYA x VR Genetic groups were estimated to be 76.96±0.74, 74.82±0.34 and 73.03±0.69 percent, respectively.

The average shape index of Vanaraja fowl reported by Niranjan *et al.* (2008), Padhi *et al.* (2013) and Sinha (2014) were in accordance with the findings of the present study. However, Jha and Prasad (2013) found lower magnitude for shape index in Vanaraja than the findings of the present study. Niranjan *et al.* (2008) also reported the higher estimates of shape index in different breeds of chicken and their crosses ranging from 76.2 to 78.10 which was in close proximity with the findings of the present study for Vanaraja. Zita *et al.* (2009) and Mohanty *et al.* (2011) also reported the higher magnitudes for shape index of different exotic breeds of chicken.

The average shape indices of Vanaraja in crosses with Desi chicken native to Muzaffarpur (MUZ x VR) and GAYA (GAYA x VR) found in the present study were in close proximity with the findings of Jha and Prasad (2013) who have reported the average shape index of Aseel (indigenous breed of chicken) to be 73.56. Chatterjee *et al.* (2006) reported the average shape index of White Leghorn ranging from 72.52 to 73.77% which is in close proximity with the findings of the present study. However, Sharma (2014) reported the lower estimates of shape index for Vanaraja in crosses with Desi chicken native to Muzaffarpur and Gaya in comparison to the findings of the present study. The author reported the average shape index for Vanaraja x MUZ and Vanaraja x GAYA genetic groups to be 68.37 and 70.58%, respectively.

Effect of genetic group on shape index

The least squares analysis of variance (Table-16) revealed highly significant ($P<0.01$) affect of genetic group on shape index VR x VR genetic group had the highest percentage of shape index which was significantly ($P<0.05$) higher than the shape index of MUZ x VR and GAYA x VR genetic groups by 2.14 and 3.93 % , respectively.

The average estimates of shape index of MUZ x VR was found to be higher than the GAYA x VR genetic group by 1.79, but did not differ significantly. The significant effect of genetic group on shape index observed in the present study have also been reported in the literature by Niranjan *et al.* (2008), Zita *et al.* (2009), and Mohanty *et al.* (2011), Alewi *et al.* (2012), Sinha *et al.* (2014) and Alam (2015). Significant effect of genetic group on shape index as observed in the present study has also been reported by Sarica *et al.* (2012) in five genetic groups of chicken. However, Sharma (2014) did not observe significant effect of genetic group on egg shape index in chicken.

Shell Thickness

The least squares mean ±SE and CV% of shell thickness for different genetic groups of chicken have been presented in table -15. The average diameter of shell thickness of VR x VR, MUZ x VR and GAYA x VR genetic groups were found to be 0.330±0.002, 0.295±0.004 and 0.459±0.006 mm, respectively. The average estimates of shell thickness for Vanaraja observed in the present study are in close agreement with the findings of Niranjan *et al.* (2008), Padhi *et al.* (2013) and Sinha (2014). However, Padhi *et al.* (2013) reported the shell thickness of Vanaraja to be ranging from 0.34 mm at 28 weeks of age to 0.38 mm at 72 weeks of age which was reported to be increased with the advancement of age. Mohanty *et al.* (2011) reported the shell thickness of Vanaraja to be 0.43 mm under rural management condition. Mohanty *et al.* (2011) reported the higher estimates of shell thickness for indigenous and exotic breeds of chicken as compared to the finding of present study for VR x VR.

Sharma (2014) reported the lower estimates of shell thickness for Vanaraja x MUZ and Vanaraja x GAYA genetic groups of chicken as compared to the findings of present study.

The effect of genetic group on shell thickness

The least squares analysis of variance for the effect genetic group on egg shell thickness has been presented in table -16 and it was revealed that genetic group had highly significant ($P<0.01$) influence on shell thickness. GAYA x VR genetic group was found to have the highest shell thickness (0.459 mm) which was significantly ($P<0.05$) thicker than the egg shell thickness of VR x VR and MUZ x VR genetic groups by 0.129 and 0.164 mm, respectively. MUZ x VR genetic group had the lowest shell thickness which was significantly ($P<0.05$) thinner than the egg shell thickness of VR x VR by 0.035 mm.

The effect of genetic group on egg shell thickness as observed in the present study has also been reported in the literature by Niranjan *et al.* (2008), Zita *et al.* (2009), Mohanty *et al.* (2011), Jha and Prasad (2013); Sarica *et al.* (2012); Sinha (2014); Sharma (2014) and Alam (2015).

Internal Egg Quality traits

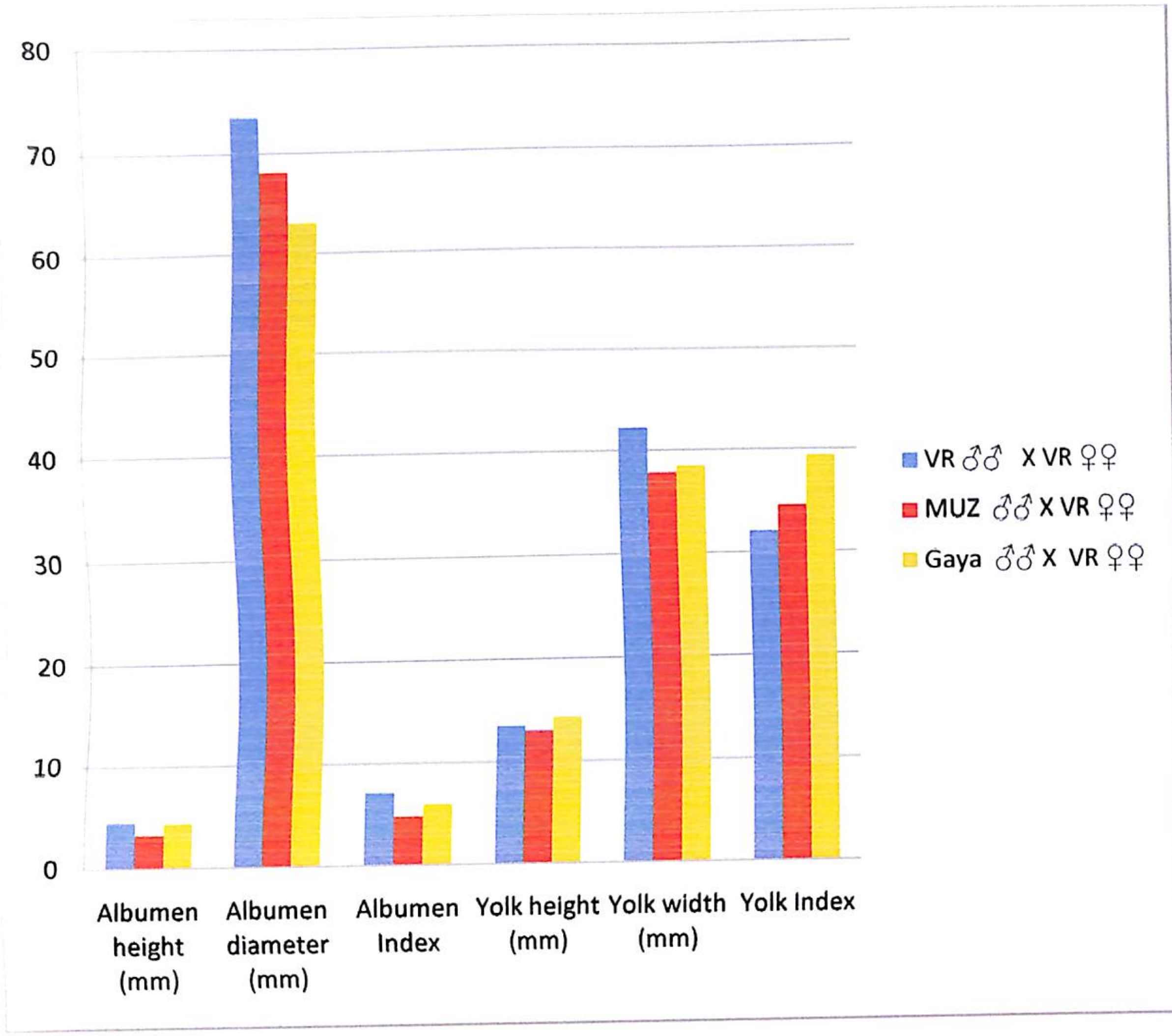
Albumen height

Least squares means along with SE and CV% of albumen height have been presented in table -17.

Table -17. Least squares means, SE and CV% of albumen height, albumen diameter, albumen index, yolk height, yolk width and yolk index in different genetic groups of chicken.

Genetic group	No. of obs.	Albumen height (mm)		Albumen diameter (mm)		Albumen Index		Yolk height (mm)		Yolk width (mm)		Yolk Index	
		Mean ±S.E.	C.V. %	Mean ±S.E.	C.V. %	Mean ±S.E.	C.V. %	Mean ±S.E.	C.V. %	Mean ±S.E.	C.V. %	Mean ±S.E.	C.V. %
VR ♂♂ X VR ♀♀	50	4.479^{b} ±0.08	12.31	73.46^{a} ±0.59	16.51	7.097^{c} ±0.14	14.47	13.448^{b} ±0.25	13.09	42.236^{a} ±0.32	5.37	31.998^{b} ±0.70	15.49
MUZ ♂♂ X VR ♀♀	50	3.268^{a} ±0.02	3.24	68.09^{c} ±0.69	7.16	4.784^{a} ±0.22	32.97	13.038^{a} ±0.29	15.72	37.846^{b} ±0.31	5.79	34.538^{a} ±0.80	16.37
Gaya ♂♂ X VR ♀♀	50	4.379^{b} ±0.11	12.19	63.01^{b} ±0.67	6.46	5.99^{b} ±0.19	15.46	14.418^{c} ±0.08	3.97	38.50^{b} ±0.36	7.53	39.45^{c} ±0.52	46.26

NB : Means with similar superscripts (column wise –abc) did not differ significantly.



Graph showing: average estimates of albumen height, albumen diameter, albumen index, yolk height, yolk width and yolk index in different genetic groups of chicken.

The average estimates of albumen height were observed to be 4.479±0.08, 3.268±0.02 and 4.379±0.11mm in VR x VR, MUZ x VR and GAYA x VR, respectively. The average height of thick albumen for VR x VR obtained in the present study was found to be lesser as compared to the findings reported by Sinha (2014). However, the average height of albumen obtained in the present study for MUZ x VR and GAYA x VR was higher as compared to the findings reported by Sharma (2014). The average height of albumen for Gramapriya x Vanaraja and Vanaraja x Gramapriya reported to be varied from 5.69 to 6.75 mm which is much higher than the findings of the present study Sinha (2014) and Alam (2015) also reported the higher estimate of average albumen height for Gramapriya in crosses with Desi chicken of Muzaffarpur and Gaya as compared to the average albumen height obtained for MUZ x VR and GAYA x VR genetic groups in the present study.

Effect of Genetic Group on Albumen Height

The least squares analysis of variance for the effect of genetic group on albumen height has been depicted in table-18, which revealed highly significant (P<0.01) effect of genetic group on albumen height. The average height of albumen of VR x VR was found to be significantly (P<0.05) higher than the average height of albumen for MUZ x VR by 1.211 mm but did not differ significantly from GAYA x VR genetic group. GAYA x VR genetic group was found to have significantly (P<0.05) higher albumen height than the MUZ x VR genetic group. The results obtained in the present study are in agreement with the findings of Niranjan *et al.* (2008), Alam *et al.* (2012), Sarica *et al.* (2012) and Kumar *et al.* (2014), who have reported the significant effect of breed and strain on albumen height. Sharma (2014) did not observe significant difference for albumen height between VN x GAYA and VN x MUZ genetic groups but reported to be differed significantly from Gramapriya x GAYA and Gramapriya x MUZ genetic groups.

Albumen Diameter

The average estimates of albumen diameter for VR x VR, MUZ x VR and GAYA x VR genetic groups were calculated to 63.46±0.59, 68.09±0.69 and 73.01±0.67 mm, respectively. The mean albumen diameter could not be compared from the available literature due to lack of information.

Effect of Genetic Group on Albumen Diameter

The least squares analysis of variance for the effect of genetic group on albumen diameter has been shown in table -18 which revealed highly significant ($P<0.01$) effect of genetic group on albumen diameter.

Table 18. Analysis of variance showing the genetic effect on albumen height, albumen diameter, albumen index, yolk height, yolk width and yolk index in chicken.

Traits	Source of variation	D.F.	M.S.	F.
Albumen height (mm)	Between groups	2	12.2944	176.31**
	Error	147	0.06973	
Albumen diameter (mm)	Between groups	2	1140.6228	54.12**
	Error	147	21.0779	
Albumen index	Between groups	2	20361.7132	113.49**
	Error	147	179.4224	
Yolk height (mm)	Between groups	2	25.1195	9.89**
	Error	147	2.5390	
Yolk width (mm)	Between groups	2	953.9793	175.63**
	Error	147	5.4317	
Yolk Index	Between groups	2	1751.8480	74.77**
	Error	147	23.4286	

** Significant at $P<0.01$

VR x VR genetic group was found to have the largest albumen diameter which was significantly ($P<0.05$) larger by 5.37 and 10.47 mm from GAYA x VR and MUZ x VR genetic groups. Among the crosses, GAYA x VR genetic group had significantly ($P<0.05$) shorter albumen diameter than the MUZ x VR by 5.08 mm.

Albumen Index

Least squares means ±SE x CV% of albumen index were calculated to be 7.09±0.14, 4.78±0.22 and 5.97±0.19 in VR x VR, MUZ x

VR and GAYA x VR genetic groups, respectively. The average albumen index observed for Vanaraja (VR x VR) in the present study was in close proximity with the findings of Sinha (2014).

The average estimates of albumen index obtained for MUZ x VR and GAYA x VR genetic groups were found to be lower as compared to the findings reported by Sharma (2014) who reported the average albumen index for VN x MUZ and VN x GAYA to be 8.32 and 7.88 percent , respectively. The average estimates of albumen index obtained in the present study for Vanaraja were much lower than the findings of Mohanty *et al.* (2011) and Padhi *et al.*(2013) but the albumen index obtained by Jha and Prasad (2013) was as in close agreement with the findings of the present study.

Effect of Genetic Group on Albumen Index

The least squares analysis of variance (Table -18) revealed highly significant (P<0.01) effect of genetic group on this trait. The average albumen index of VR x VR genetic group was found to be significantly (P<0.01) higher than the cross breeds. The average albumen index of VR x VR was significantly (P<0.05) higher than the MUZ x VR and GAYA x VR genetic groups by 2.31 and 1.10, respectively. The average albumen index of Gramapriya x VR genetic group was also found to be significantly (P<0.05) higher than the index value of MUZ x VR genetic group. It was indicated that the pure bred had better albumen quality than the crossbreds. The evidence on significant effect of breed and strain on Albumen index has been reported in the literature by many scientist [(Zita *et al.* (2009), Mohanty *et al.* 2011), Sarica *et al.* (2012), Sreenivas *et* *al.* (2013), Sinha (2014) and Alam (2015)].

Yolk Height

The least squares means along with SE and CV% of yolk height have been depicted in table -17. The average estimates of yolk height of VR x VR, MUZ x VR and GAYA x VR genetic groups were found to be 13.448±0.25, 13.038±0.29 and 14.418±0.08 mm, respectively. The information on yolk height is very scanty in the literature, however, the average estimates of yolk height for Vanaraja and its crosses with Desi chicken of Muzaffarpur and Gaya districts in Bihar were lower than the findings of Sharma (2014) and Sinha (2014). Alam (2015) also reported higher estimates of Yolk height for Gramapriya and its Crosses with Desi chicken of Bihar. The average estimates of yolk height for Vanaraja x GAYA and Vanaraja x MUZ is reported to be 21.40 and 9.80 mm, respectively (Sharma, 2014).

Effect of Genetic Group on Yolk Height

The least squares analysis of variance for the affect of genetic group on Yolk height (Table-18) revealed highly significant (P<0.01) effect of genetic group on yolk height. The magnitude of yolk height was the highest (14.418 mm) in GAYA x VR genetic group which was significantly (P<0.05) higher than the VR x VR and MUZ x VR genetic groups by 0.97 mm and 1.38 mm, respectively. Significant effect of genetic group on yolk height has also been reported in the literature by Sinha (2014), Sharma (2014) and Alam (2015).

Yolk width

The least squares means, SE and CV% of yolk width has been shown in table -18. The average estimates of yolk width were observed to be 42.236±0.32, 37.846±0.31 and 38.50±0.36 mm in VR x VR, MUZ x VR and GAYA x VR genetic groups, respectively. The average estimates of yolk width for Vanaraja (VR), Gramapriya (GP) and their reciprocal crosses reported to be varied from 35.513 to 40.220 mm which is in close proximity with the findings of the present study (Sinha 2014 and Alam 2015). However, Sharma (2014) reported the yolk diameter in Vanaraja x MUZ Desi and Vanaraja x GAYA Desi chicken of Bihar to be 30.70 and 31.00 mm, respectively which was lesser than the findings of the present study.

The effect of Genetic Group on Yolk width

The least squares analysis of variance for the effect of genetic group on yolk width has been shown in table -18. The analysis of variance revealed highly significant (P<0.01) effect of genetic group on yolk width. VR x VR genetic group was found to have the largest yolk width which was significantly (P<0.05) larger than the MUZ x VR and GAYA x VR genetic groups by 4.39 and 3.736 mm, respectively. However, the crossbreds did not differ significantly among themselves for this trait.

The reports on the effect of genetic group on yolk width are very scanty in the literature. However, Niranjan *et al.* (2008), Alewi *et al.* (2012), Sharma (2014), Sinha (2014) and Alam (2015) reported the significant effect of genetic group on yolk width which is in agreement with the findings of the present study.

Yolk Index

The least squares means, SE and CV% of yolk index have been presented table -17. The average estimates of yolk indices were calculated to be 31.998±0.70, 34.538±0.80 and 37.45±0.52 in VR x VR, MUZ x VR and GAYA x VR genetic groups, respectively. The average estimates of yolk index obtained in the present study were found to be lower than the findings of Niranjan *et al.* (2008), who reported the average index of Vanaraja, Gramapriya and their crosses to be varied from 44 to 46, Zita *et al.* (2009) also reported the higher percent of yolk index of different breeds of chicken to be varied from 42-48. However, Mohanty *et al.* (2011) reported the average yolk index for Vanaraja and native fowls to be 23 and 20, respectively which is much lower than the findings of the present study. However, the average estimates of yolk index for indigenous breeds and Red Cornish reported by Mohanty *et al.* (2011) was in close proximity with the findings of present study. Padhi *et al.* (2013) reported the average yolk index of Vanaraja at 28 weeks of age to be 41 which is gradually declined with the advancement of age and the magnitude was lowest at 72 weeks of age. The findings of the present study is corroborated with the findings of Sreenivas *et al.* (2013) who reported the average yolk index of different strains of White Leghorn to be varied from 34-35.

Effect of Genetic group on yolk Index

The least squares analysis of variance (Table-18) revealed highly significant (P<0.01) effect of genetic group of yolk index. GAYA x VR genetic group was found to have the highest estimate of yolk index which was found to be significantly (P<0.05) higher than the VR x VR and MUZ x VR genetic groups by 5.45 and 2.91, respectively. Significant effect of genetic group on yolk index have also been reported in the literature by Niranjan *et al.* (2008), Zita *et al.*(2009), Mohanty *et al.* (2011), Sinha (2014), and Alam (2015). However, the non-significant effect of genetic groups on yolk index has been reported in the literature by Sharma (2014).

Albumen Weight and Percentage of Albumen

Least squares means, SE and Coefficient of Variation percentage of albumen weight have been presented in table -19. The average estimates of albumen weight were recorded to be 28.842±0.482, 8.770±0.346 and 19.376±0.411g of VR x VR, MUZ x VR and GAYA x VR genetic groups, respectively.

Table -19. Least squares means, SE and CV% of albumen weight, yolk weight and shell weight in different genetic groups of chicken.

Genetic group	No. of obs.	Albumen weight (g)		Yolk weight (g)		Shell weight (g)		Yolk albumen ratio
		Mean ±S.E.	C.V.%	Mean ±S.E.	C.V.%	Mean ±S.E.	C.V.%	
VR ♂♂ X VR ♀♀	50	28.842^{b}±0.482	11.81	14.050^{b}±0.276	13.89	4.783^{b}±0.114	16.85	0.49
MUZ ♂♂ X VR ♀♀	50	18.770^{a}±0.346	13.04	12.830^{a}±0.233	12.84	3.980^{ab}±0.020	3.55	0.68
GAYA ♂♂ X VR ♀♀	50	19.376^{a}±0.411	14.99	12.908^{a}±0.272	14.90	3.096^{a}±0.147	33.57	0.66

NB : Means with similar superscripts (column wise –abc) did not differ significantly.

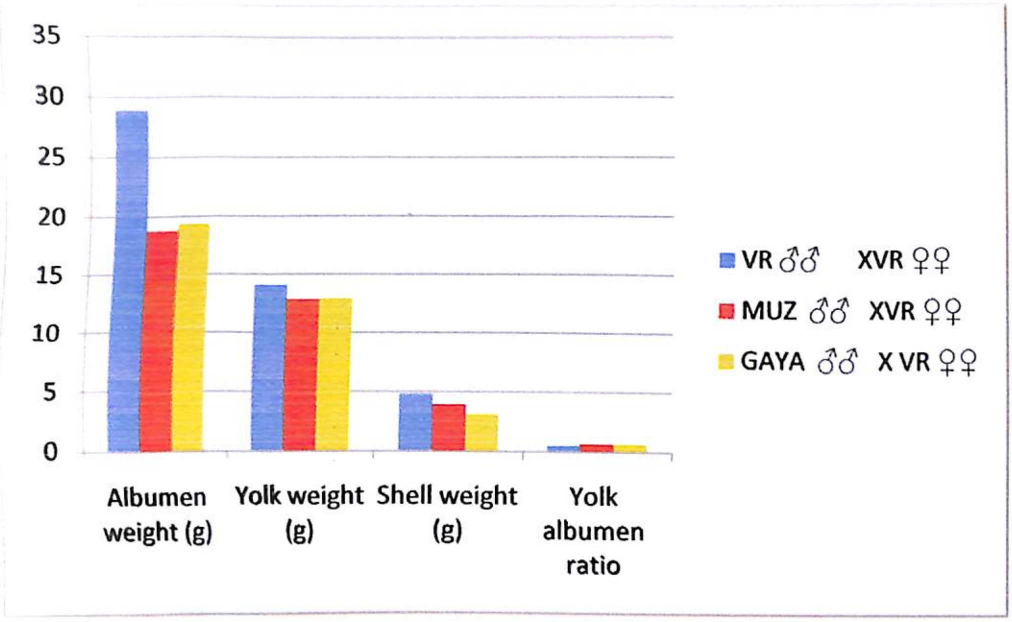


Table showing: Average estimates of Albumen weight, yolk weight and shell weight in different genetic groups of chicken.

In table- 19, The average albumen weight of Vanaraja reported by Niranjan *et al.* (2008) and Sinha (2014) to be 30.3g and 30.01g, respectively which close proximity with the findings of the present study. Padhi *et al.* (2013) reported the average albumen weight of Vanaraja at 28 weeks of age to be 30.56 g, which is also in close proximity with the findings of the present study, However, they have reported higher estimates of average albumen weight of Vanaraja than the findings of the present study at the later age groups and it was maximum (37.84g) at 52 weeks of age and there after average albumen weight declined gradually. However, Mohanty *et al.* (2011) reported the average albumen weight of Vanaraja to be 20.33g which is lesser than the findings of present study. Chatterjee *et al.* (2007) reported the average albumen weight of indigenous fowl to be ranged from 26.46 to 26.67 g which is higher than the findings of the present study. However, Islam and Dutta (2010) reported the average albumen weight of indigenous fowl to be 18.92 g which is in close proximity with the findings of the present study for Vanaraja in Crosses with Desi fowl of Bihar. The average albumen weight of indigenous breeds like Aseel and Kadaknath reported by Mohanty *et al.* (2011) to be 20.28 and 18.22 g, respectively which is also in close proximity with the findings of the present study for Vanaraja x Desi genetic groups of chicken. However, the authors have reported the average albumen weight of local fowl to be 15.42 g which is lower than the findings of the present study.

The least squares analysis of variance showing the genetic effect on albumen weight has been depicted in table -20 which revealed the existence of highly significant ($P<0.01$) difference for albumen weight between the genetic groups. The VR x VR genetic group was found to have the highest average albumen weight (28.842g) which was significantly (P<0.05) higher than the MUZ x VR and GAYA x VR genetic groups by 10.072 and 9.446 g, respectively. The MUZ x VR genetic group was found to have the lowest average albumen weight which is observed to be lower than the GAYA x VR genetic group by 0.606 g but did not differ significantly. Effect of genotype in different breeds have been reported in the literature by many scientist (Sreenivas *et al.* 2013, Niranjan *et al.* 2008, Zita *et al.* 2009, Islam and Dutta 2010, Mohanty *et al.* 2011, and Sinha 2014).

Table 20. Analysis of variance showing the genetic effect on albumen weight, yolk weight and shell weight in chicken.

Traits	Source of variation	D.F.	M.S.	F.
Albumen weight (g)	Between groups	2	1595.1565	182.66**
	Error	147	8.7328	
Yolk weight (g)	Between groups	2	23.3220	6.82**
	Error	147	3.4222	
Shell weight (g)	Between groups	2	22.857	43.45**
	Error	147	0.526	

** Significant at P<0.01

The least squares means, SE and coefficient of variation percentage of angles corresponding to the percentage of albumen weight have been presented in table-21 and the analysis of variance showing the genetic effect on the angles corresponding to the percentage of albumen weight has been presented in table-22. The analysis of variance (Table - 22) revealed highly significant (P<0.01) effect of genetic group on percentage of albumen weight. The VR x VR genetic group was found to have 60.49 percent of albumen which was found to be significantly (P<0.05) heavier than the MUZ x VR and GAYA x VR genetic groups by 7.74 and 5.72 percentage, respectively. The average percentage of albumen was observed to be the lowest (52.75%) in MUZ x VR which was significantly (P<0.05) lower than the GAYA x VR genetic group by 2.02 percent. The significant effect of genetic group on percent albumen observed in the present study was also been reported by Zita *et al.*(2009), Padhi *et al.*(2013), Sreenivas *et al.*(2013), Sinha (2014) and Alam (2015). The average percentage of albumen for Vanaraja at 30 weeks age observed in the present study was very closer to the findings of Padhi *et al.*(2013) who reported the average percentage of albumen in Vanaraja to be varied from 57.12 to 61.18% from 40 to 72 weeks of age. However, they have reported the higher percentage of albumen at 28 weeks of age. The average percentage of albumen reported by Sreenivas *et al.* (2013) for various strains of White Leghorn were similar to the findings of the present study for VR x VR genetic group. The information on percent albumen of Vanaraja in crosses with Desi chicken was observed in the available literature, however, the average percentage of albumen for Vanaraja in crosses with Desi chicken of Bihar observed in the present study were lower than the findings of Zita *et al.*(2009), Padhi *et al.* (2013) and Sinha (2014).

$\sqrt{Percentage}$) of albumen weight, yolk weight and shell weight in different genetic groups of chicken.

Genetic group	No. of obs.	Albumen weight (%)		Yolk weight (%)		Shell weight (%)	
		Mean ±S.E.	C.V.%	Mean ±S.E.	C.V.%	Mean ±S.E.	C.V.%
VR ♂♂ X VR ♀♀	50	$51.00^{b}\pm1.14$ (66.49)	25.01	$32.83^{a}\pm2.42$ (29.47)	58.06	$18.44^{ab}\pm0.18$ (10.03)	6.90
MUZ ♂♂ X VR ♀♀	50	$46.55^{c}\pm1.32$ (52.75)	17.69	$36.87^{b}\pm1.11$ (36.06)	60.98	$19.41^{b}\pm0.11$ (11.19)	70.14
GAYA ♂♂ X VR ♀♀	50	$47.70^{a}\pm1.56$ (54.77)	20.14	$37.11^{b}\pm1.33$ (36.48)	25.77	$17.16^{a}\pm0.11$ (8.75)	4.53

NB : 1. Values present within the parentheses indicating actual percentage.

2. Means with similar superscripts (column wise –abc) did not differ significantly.

Yolk Weight and Percentage of Yolk

On perusal of the data (Table -21), the least squares means, SE and CV% of average weight of egg yolk have been presented in table -19. The average egg yolk weight was found to be varied from 12.83g in MUZ x VR genetic group to 14.05 g in VR x VR genetic group. The average yolk weight of Vanaraja observed in the present study was in close proximity with the findings of Padhi *et al.*(2013) who reported the average yolk weight of Vanaraja to be 13.05 g at 28 weeks of age. However, the yolk weight reported to be increased with the advancement of age. The values observed by Padhi *et al.* (2013) from 40 to 72 weeks of age in Vanaraja to be ranged from 17.18 to 20.81 g which is much higher than the findings of the present study. The average yolk weight of Vanaraja reported by Mohanty *et al.* (2011) was 8.7 g, which is much lower than the findings of the present study. However, the authors have reported higher estimates of yolk weight for Black Rock, Red Cornish and Chabro (Red Cornish X Plymouth Rock) than the findings of the present study. Sinha (2014) reported the average yolk weight of Vanaraja to be 12.69 g, which is also lower than the findings of the present study. The average yolk weight of different strains of White Leghorn reported by Sreenivas *et al.* (2013) was very closer to the findings of the present study. The information on average yolk weight for Vanaraja in crosses with Desi chicken is not available in the literature, however, the average yolk weight for VR x MUZ and VR x GAYA genetic groups observed in the present study were closer to the findings of Mohanty *et al.* (2011) for indigenous breeds of chicken. Parmar *et al.* (2006) reported the average yolk weight of Kadaknath to be 15.18 g which is higher than the findings of the present study for VR x Desi chicken.

Effect of genetic group on yolk weight

The least squares analysis of variance (Table-20) revealed highly significant (P<0.01) effect of genetic group on yolk weight. The VR x VR genetic group was found to have the heaviest yolk weight (14.05g) which was significantly (P<0.05) heavier than the MUZ x VR and GAYA x VR genetic group by 1.22 and 1.142 g, respectively. MUZ x VR genetic group was found to have the lowest average yolk weight which is lower than the GAYA x VR by 0.078 g but did not differ significantly. Significant (P<0.05) effect of genetic group on yolk weight observed in the present study has also been reported by Niranjan *et al.* (2008) , Mohanty *et al.*(2011), Islam and Dutta (2010), Sreenivas *et al.* (2013) and Sinha (2014).

Least squares means, SE and Coefficient of Variation percentage of angles corresponding to percentage of yolk weight have been depicted in table-21 and the analysis of variance for the effect of genetic group on the angles corresponding to percentage of yolk weight has been presented in table-22.

The table- 22 revealed highly significant (P<0.01) effect of genetic group on angles corresponding to percentage of yolk weight. GAYA x VR genetic group was found to have the highest percentage (36.48) of yolk weight which was significantly (P<0.05) higher than the VR x VR genetic group by 7.01 percent but did not differ significantly from MUZ x VR genetic group. Significant effect of genetic group on percentage of yolk weight has also been reported in the literature by Zita *et al.* (2009), Padhi *et al.*(2013), Sreenivas *et al.* (2013) and Sinha (2014).

The average percentage of yolk weight for Vanaraja observed in the present study was in agreement with the findings of Padhi *et al.* (2013).

Table 22. Analysis of variance showing the genetic effect on angles (Angles = Arcsin $\sqrt{Percentage}$) corresponding to the percentage on albumen weight, yolk weight and shell weight in chicken.

Traits	Source of variation	D.F.	M.S.	F.
Albumen weight (g)	Between groups	2	511.896	70.23**
	Error	147	7.288	
Yolk weight (g)	Between groups	2	227.920	103.88**
	Error	147	215.127	
Shell weight (g)	Between groups	2	11.197	25.45**
	Error	147	0.434	

** Significant at P<0.01

The findings of Sreenivas *et al.* (2013) for different strains of White Leghorn reported in the literature were very closer to the findings of the present study. The findings of Sinha (2014) were also very closer to the findings of the present study for Vanaraja. The information on percentage of yolk weight for Vanaraja in crosses with Desi chicken were not observed in the available literature hence it could not be compared with the findings of the present study. However, in general, the yolk percentage of Vanaraja in crosses with Desi chicken was observed to be higher than the findings reported in available the literature.

Shell Weight

Least squares means, SE and CV percentage of shell weight have been presented in table -19. The average estimates of shell weight in VR x VR, MUZ x VR and GAYA x VR genetic groups were found to be 4.783±0.114, 3.980±0.020 and 3.096±0.147g, respectively. The least squares analysis of variance (Table-20) revealed highly significant (P<0.01) difference within genetic groups on egg shell weight. The VR x VR genetic group was found to have the highest shell weight which was found to be significantly (P<0.05) higher than the GAYA x VR by 1.687 g but did not differ significantly from MUZ x VR in respect to this trait. The MUZ x VR genetic group was found to have higher egg shell weight than the GAYA x VR genetic group but did not differ significantly. Effect of genetic group on egg shell weight has also been reported in the literature by Sinha (2014) and Alam (2015). The average shell weight of Vanaraja reported by Sinha (2014) is in agreement with the findings of the present study. The average shell weight for MUZ x VR and GAYA x VR observed in the present study could not be compared due to lack of information in the available literature.

The least squares means SE and CV percentage of angles corresponding to percentage of egg shell weight of different genetic groups of chicken have been presented in table-21 and the analysis of variance showing the genetic effect on the angles corresponding to the percentage of shell weight is depicted in table-22. The analysis of variance revealed highly significant (P<0.01) effect of genetic group on shell weight percentage. MUZ x VR genetic group was found to have higher percentage of shell weight which was significantly (P<0.05) different from GAYA x VR genetic group but did not differ significantly from VR x VR.

Significant (P<0.05) effect of genetic group on the angles corresponding to shell weight observed in the percent study has also been reported in the literature by Sinha (2014) and Alam (2015). Sinha (2014) reported the average percentage of shell weight of Vanaraja, Gramapriya (GP) and their crosses to be ranged from 8.8 to 9.6% and Alam 2015 reported the average shell weight percentage of Gramapriya and its crosses with Desi chicken of Bihar to be ranged from 8.9 to 9.6 % which is observed to be lower than the findings of the present study.

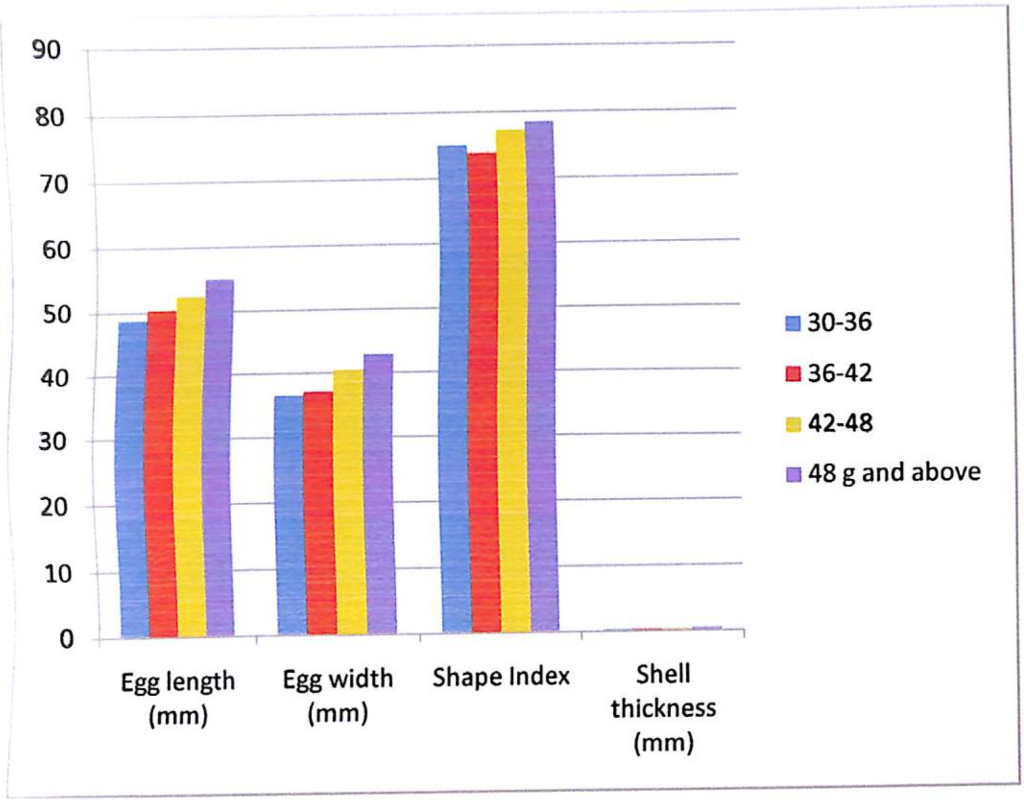
Effect of Egg Weight on Egg Quality Traits

External Egg Quality Traits: The least squares means, SE and CV percent of external egg quality traits in different egg weight groups pooled over various genetic groups of chicken have been presented in table -23. According to egg weight all the eggs were grouped in four groups namely 32-36g, 36-42g, 42-48g and 48g and above.

Table -23. Least squares means, SE and CV% of external egg quality traits in different egg weight groups of chicken pooled over various genetic groups.

Egg weight (g) groups	No. of obs.	Egg length (mm)		Egg width (mm)		Shape Index		Shell thickness (mm)	
		Means ±S.E.	C.V.%	Means ±S.E.	C.V.%	Means ±S.E.	C.V.%	Means ±S.E.	C.V.%
30-36	36	$48.68^{a}\pm0.45$	5.54	$36.50^{a}\pm0.41$	6.73	$74.99^{a}\pm0.75$	6.00	$0.292^{a}\pm0.008$	16.438
36-42	18	$50.39^{b}\pm0.64$	5.38	$37.14^{a}\pm0.58$	6.62	$73.78^{a}\pm1.06$	6.09	$0.308^{ab}\pm0.011$	15.152
42-48	29	$52.52^{c}\pm0.50$	5.12	$40.51^{b}\pm0.46$	6.11	$77.24^{a}\pm0.34$	5.85	$0.335^{ab}\pm0.009$	14.467
48 g and above	67	$54.98^{d}\pm0.33$	4.91	$42.89^{b}\pm0.30$	5.72	$78.45^{a}\pm0.55$	5.73	$0.428^{b}\pm0.006$	11.474

NB : Means with similar superscripts (column wise –abc) did not differ significantly.



Graph showing: Average estimates of external egg quality traits in different egg weight groups of chicken pooled over various genetic groups.

Egg length

The average estimates of egg length in 32-36g, 36-42g, 42-48g and 48g and above egg weight groups were found to be 48.68±0.45, 50.9±0.64, 52.52 ±0.50 and 54.98±0.33 mm, respectively. The analysis of variance for the effect of egg weight on egg length has been depicted in *table*-24 which revealed significant (P<0.01) difference between egg weight groups for egg length. The egg length was found to be increased significantly (P<0.05) with the increase in egg weight in subsequent groups. The egg weight of 48g and above weight group was found to have maximum egg length which was significantly (P<0.05) lengthier than the 32-36g, 36-42g and 42-48g groups by 6.30, 4.59 and 2.46 mm, respectively. The 42-48 egg weight group was also found to have significantly (P<0.05) lengthier eggs than the 32-36 and 36-42g egg weight groups by 3.84 and 2.13 mm , respectively. Thirty six to forty two (36-42) g egg weight group was also found have significantly (P<0.05) longer eggs than the 30-36g egg weight group. Significant (P<0.05) effect of egg weight on egg length observed in the present study has also been reported in the literature by Sinha (2014) and Alam (2015).

Egg Width

The average estimates of egg width in 30-36g, 36-42g, 42-48 g and 48g and above egg weight groups were observed to be 36.50±0.41, 37.14±0.58, 40.51 ±0.46 and 42.89±0.30 mm, respectively. The Analysis of variance for the effect of egg weight on egg width has been shown in table -24 which shows significant (P<0.01) difference between egg weight groups for egg width.

The forty eight and above egg weight group achieved the maximum egg width which was significantly ($P<0.05$) wider than the 36-42 g and 30-36g weight group by 5.75mm and 6.39 mm , respectively. The 42-48g egg weight group was found to have the highest egg width which was wider by 3.37 and 4.07mm than the 36-42g and 30-36 g weight groups respectively. The 48 g and above group had the maximum number of eggs in this category. The significant ($P<0.05$) effect of egg weight on egg width as observed in present study has also been reported in the literature by Sinha (2014) and Alam (2015).

Shape Index

The average estimates of shape index in 30-36g, 36-42g, 42-48g and 48g and above weight groups were found to be 74.99±0.75, 73.78±1.06, 77.24±0.34 and 78.45± 0.55 percent respectively. The shape index was found to be increased with the increase in egg weight. However, the differences were observed to be non-significant. Effect of egg weight on shape index observed in the present study has also been reported by Alam (2015). However, Sinha (2014) reported significant effect of egg weight on shape index in chicken which is contrary to the findings of preset study.

Shell Thickness

The average estimates of shell thickness in 30-36, 36-42, 42-48 and 48 g and above egg weight groups were measured to be 0.292±0.008, 0.308±0.011, 0.335±0.009 and 0.428±0.006 mm, respectively. The average estimates of shell thickness were observed to be increased with the increase in egg weight. The analysis of variance (Table-24) revealed significant (P<0.01) effect of egg weight on shell thickness. The 48 g and above egg weight group was found to have the highest shell thickness which was significantly (P<0.05) thicker by 0.136 mm from 30-36 g egg weight group. However, though this group had the thicker shell than the 36-42 and 42-48 g egg weight groups but did not differ significantly. Effect of egg weight on shell thickness observed in the present study has also been reported by Sinha (2014) and Alam (2015). The increase in egg shell thickness with the increase in egg weight as observed in the present study has also been reported by the above authors.

Table 24. Analysis of variance showing the effect of egg weight on external egg quality traits in chicken.

Traits	Source of variation	D.F.	M.S.	F.
Egg length (mm)	Between egg weight groups	3	82.9584	11.28**
	Error	146	7.3519	
Egg width (mm)	Between egg weight groups	3	92.5963	15.12**
	Error	146	6.1246	
Shape index	Between egg weight groups	3	64.0479	1.76^{NS}
	Error	146	36.4125	
Shell thickness (mm)	Between egg weight groups	3	0.1805	77.76**
	Error	146	0.0023	

** Significant at P<0.01

NS= Non-significant

Effect of Egg weight on Internal Egg quality Traits

The least squares means, SE and CV% of internal egg quality traits in different egg weight groups pooled over various genetic groups of chicken have been presented in table- 25.

Albumen Height:

The average estimates of albumen height pooled over genetic groups was found to be ranged from 2.745±0.001 mm in 30-36 g egg weight group to 5.957±0.001 mm in 48 g and above egg weight groups, respectively. The analysis of variance (Table -26) revealed highly significant ($P<0.01$) effect of egg weight on albumen height. In 48 g and above egg weight group the albumen height was found to be significantly ($P<0.05$) thicker than the 30-36, 36-42 and 42-48 g egg weight groups by 3.212, 1.344 and 1.633 mm , respectively. Similarly, 36-42 and 42-48 g egg weight groups were also found to have significantly ($P<0.05$) thicker albumen than the 30-36g egg weight group by 1.868 and 1.579 mm, respectively. The trend in increase in thickness of albumen with the increase in egg weight as observed in the present study was also reported by Sinha (2014) and Alam (2015). The findings of the present study are corroborated with the findings of Alam (2015) who has also reported significant effect of egg weight on albumen height. The albumen height is the indicator of egg quality. The eggs with thicker albumen indicate better egg quality. Thus, the eggs of 48 g and above egg weight groups have better egg quality.

Albumen diameter

The average estimates of albumen diameter pooled over genetic groups in 30-36, 36-42, 42-48 and 48 g and above egg weight groups were recorded to be 66.69±0.90, 69.31±1.27, 63.64±1.00 and 70.66±0.66 mm, respectively. The analysis of variance (Table-26) revealed highly significant (P<0.01) effect of egg weight on albumen diameter. Forty eight gram and above egg weight group had the largest albumen diameter which was found to be significantly (P<0.05) larger than the albumen diameter of 42-48 g egg weight group but did not differ significantly from 30-36 g and 36-42g egg weight groups. The 42-48g egg weight group was found to have significantly (P<0.05) shorter albumen diameter than the 36-42 g egg weight group. The 30-36 g egg weight group though had larger albumen diameter than the 42-48 g egg weight group but did not differ significantly. Significant effect of egg weight on egg diameter observed in the findings of the present study could not be compared as the information was not available in the literature.

Albumen Index

The least squares means of albumen index pooled over genetic groups were found to be ranged from 4.09±0.21 to 8.46±0.15 (Table-25) which is in close proximity with the findings of Jha and Prasad (2013), Sreenivas *et al.*(2013), Sinha (2014) and Alam (2015). The analysis of variance revealed highly significant (P<0.01) effect of egg weight on albumen index. The 48 g and above egg weight group was found to have the highest albumen index which was significantly (P<0.05) higher than the 30-36, 36-42 and 42-48 g egg weight groups by 4.37, 1.67 and 1.4 percent, respectively. Significant ($P<0.05$) effect of egg weight on albumen index as observed in the present study has also been reported by Sinha (2014) but Alam (2015) did not observe significant effect of egg weight on this trait. Albumen index was observed to be increased significantly ($P<0.05$) with the increase in egg weight. The albumen index was noted to be the lowest in 30-36 g egg weight group which was significantly ($P<0.05$) lower than the 36-42 and 42-48 g egg weight groups by 2.70 and 2.73, respectively. Increase in albumen index with the increase in egg weight as observed in the present study was also reported by Sinha (2014).

Yolk height

The average estimates of yolk height pooled over genetic groups were observed to be varied from 12.72±0.27 to 14.03±0.20 mm (Table -25). Irrespective of genetic groups the average estimates of yolk height observed in the present study were found to be lower as compared to the findings of Alam (2015) who reported the average yolk height to be ranged from 15.76 to 19.78 mm, similar results were also reported by Sinha (2014). The analysis of variance revealed highly significant ($P<0.01$) effect of egg weight on yolk height (Table -26). The average yolk height was found to be increased significantly ($P<0.05$) with the increase in egg weight. The 48 g and above egg weight group was observed to have the largest egg yolk which was significantly ($P<0.05$) thicker than the 30-36 g egg weight groups by 1.31 mm but did not differ significantly from 36-42 and 42-48 g groups. The trend of increase in yolk height with the increase in egg weight observed in the present investigation was also reported by Sinha (2014) and Alam (2015).

groups pooled over various genetic groups of chicken.

Egg weight (g) groups	No. of obs.	Albumen height (mm)		Albumen diameter (mm)		Albumen Index		Yolk height (mm)		Yolk diameter (mm)		Yolk Index	
		Mean ±S.E.	C.V. %	Mean ±S.E.	C.V. %	Mean ±S.E.	C.V. %	Mean ±S.E.	C.V. %	Mean ±S.E.	C.V. %	Mean ±S.E.	C.V. %
30-36	36	2.745^{a} ±0.001	0.218	66.69^{ab} ±0.90	8.097	4.09^{a} ±0.21	30.80	12.72^{a} ±0.027	1.27	38.04^{a} ±0.63	9.93	33.49^{a} ±1.03	18.45
36-42	18	4.613^{b} ±0.002	0.183	69.31^{b} ±1.27	7.773	6.79^{b} ±0.29	18.12	13.66^{b} ±0.38	11.80	38.43^{a} ±0.89	9.82	35.76^{a} ±1.46	17.32
42-48	29	4.324^{b} ±0.002	0.249	63.64^{a} ±1.0	8.46	6.82^{b} ±0.23	18.16	13.84^{b} ±0.30	11.67	41.442^{b} ±0.71	9.22	33.49^{a} ±1.15	18.49
48 g and above	67	5.957^{c} ±0.001	0.137	70.66^{b} ±0.66	7.645	8.46^{c} ±0.15	14.51	14.03^{b} ±0.20	11.66	42.06^{b} ±0.46	10.44	39.85^{b} ±0.76	15.61

NB : Means with similar superscripts (column wise –abc) did not differ significantly.

Yolk Diameter

The least squares means along with SE of yolk diameter irrespective of genetic groups were found to be varied from 38.04±0.63 to 48.06±0.46mm (Table- 25). The values observed in the present study were in agreement with the findings of Sinha (2014) and Alam (2015) who also reported the average yolk diameter, irrespective of genetic groups, to be ranged from 36.47 to 40.27 mm and from 36.47 to 40.28 mm, respectively.

The analysis of variance revealed highly significant ($P<0.01$) effect of egg weight on yolk diameter (Table -26). The yolk diameter was found to be increased significantly ($P<0.05$) with the increase in egg weight. The 48 g and above egg weight group was found to have the highest (42.06 mm) yolk diameter which was significantly ($P<0.05$) higher than the 30-36 and 36-42 g egg weight groups by 4.02 and 3.63 mm, respectively but did not differ significantly from 42-48 g egg weight group. The 42-48 g egg weight group was found to have significantly ($P<0.05$) larger yolk diameter than the 30-36 and 36-42 g egg weight groups. Significant ($P<0.05$) effect to egg weight on yolk diameter as observed in the present study has also been reported by Sinha (2014) and Alam (2015). The trend of increase in yolk diameter with the increase in egg weight observed in the findings of the present study has also been reported by the above scientists.

Table 26. Analysis of variance showing the effect of egg weight on internal egg quality traits in chicken.

Traits	Source of variation	D.F.	M.S.	F.
Albumen height (mm)	Between groups	3	8260.8953	119.92**
	Error	146	68.8846	
Albumen diameter (mm)	Between groups	3	370.1041	12.66**
	Error	146	29.2424	
Albumen index	Between groups	3	114936.1538	97.83**
	Error	146	152.6716	
Yolk height (mm)	Between groups	3	13.8667	5.30**
	Error	146	2.6156	
Yolk diameter (mm)	Between groups	3	198.7396	13.75**
	Error	146	14.4534	
Yolk index	Between groups	3	449.3862	11.72**
	Error	146	38.3530	

** **Significant at P<0.01**

Yolk Index

The least squares means of yolk index along with SE and CV % pooled over genetic groups were found to be ranged from 33.49 to 39.85 percent. The values observed in the findings of the present study were not in agreement with the findings of Sinha (2014) and Alam (2015) who reported the higher average estimate. Yolk index is a good indicator of egg quality. The higher the index value is the better egg quality. The analysis of variance revealed highly significant (P<0.01) effect of egg weight on yolk index. Significant (P<0.01) effect of egg weight on yolk index observed in the findings of the present study has also been reported in the literature by Sinha (201) and Alam (2015), however, no definite trend could not be observed in the literature as well as in the present study.

Effect of egg weight on albumen weight, yolk weight and shell weight

The least squares means of albumen weight, yolk weight and shell weight pooled over genetic groups have been presented in table-27 and analyses of variance for the effect of egg weight on these traits have been depicted in table- 28.

Effect of egg weight on albumen weight

The least squares means of albumen weight pooled over genetic groups in 30-36, 36-42, 42 -48 and 48 g and above egg weight groups were estimated to be 17.68±0.70, 21.69±0.99, 27.31±0.51 and 32.08±0.78 g , respectively.

The analysis of variance revealed highly significant (P<0.01) effect of egg weight on albumen weight pooled over of genetic groups. Significant (P<0.05) effect of egg weight on albumen weight observed in the findings of the present study has also been reported by Sinha (2014) and Alam (2015). The mean estimates of albumen weight of 36-42, 42-

48 and 48 g and above egg weight groups were observed to be increased significantly (P<0.05) over the 30-36 g group by 4.01, 9.63 and 14.40 g , respectively. The increase in albumen weight with the increase in egg weight as recorded in the findings of the present investigation has been corroborated with the findings of Sinha (2014) and Alam (2015). The average estimates of albumen weight in 42-48 and 48 g and above egg weight groups were also found to be increased significantly (P<0.05) over the 36-42 g group by 5.62 and 10.39 g , respectively. The mean albumen weight was estimated to be the highest in 48 g and above egg weight group which was found to be increased significantly (P<0.05) over the 42-48 g group by 4.77 g.

Yolk weight

The least squares means of yolk weight pooled over genetic groups in 30-36, 36-42, 42-48 and 48 g and above egg weight groups were found to be 12.72±0.32, 13.44±0.45, 13.28±0.36 and 15.50±0.23g , respectively. The findings of the present study is corroborated with the findings of Sinha (2014) and Alam (2015) who reported the mean yolk weight irrespective of genetic groups to be varied from 12.76 to 13.65 g and 12.77 to 14.6 g , respectively. The analysis of variance (Table -28) revealed that egg weight has no significant effect on yolk weight. The mean yolk weight in subsequent egg weight group was found to be increased gradually but the differences were statistically non-significant. The findings of the present study indicated that the increase in size and weight of eggs is mainly depended on the variation in quantity of albumen but not due to variation in yolk weight. Similar findings have also been reported by Sinha (2014) and Alam (2015).

Table -27. Least squares means, SE and CV% of albumen weight, yolk weight and shell weight in different egg weight groups pooled over various genetics groups of chicken.

Genetic group	No. of obs.	Albumen weight (g)		Yolk weight (g)		Shell weight (g)	
		Mean ±S.E.	C.V.%	Mean ±S.E.	C.V.%	Mean ±S.E.	C.V.%
30-36	36	$17.68^{a}\pm0.70$	23.78	$12.72^{a}\pm0.32$	15.09	$3.87^{a}\pm0.054$	8.37
36-42	18	$21.69^{b}\pm0.99$	23.53	$13.44^{a}\pm0.45$	14.20	$4.26^{b}\pm0.038$	3.78
42-48	29	$27.31^{c}\pm0.51$	10.05	$13.28^{a}\pm0.36$	14.59	$4.34^{bc}\pm0.082$	10.17
48 g and above	67	$32.08^{d}\pm0.78$	19.93	$13.50^{a}\pm0.23$	13.94	$4.48^{c}\pm0.052$	9.62

NB : Column-wise means with similar superscripts did not differ significantly.

Shell weight

The average estimates of shell weight pooled over genetic groups were observed to be varied from 3.87±0.054 g to 4.48±0.052 g (Table-27). The mean shell weight was found to be increased gradually with the increase in egg size and egg weight. The analysis of variance (Table -28) revealed significant (P<0.01) effect of egg weight on shell weight which is in consonance with Sinha (2014) and Alam (2015). The mean shell weight was found to be the highest in 48 g and above egg weight group which was found to be increased significantly (P<0.05) over the 30-36 g and 36-42 g groups by 0.61 and 0.22 g, respectively but did not differ significantly from 42-48 g egg weight group.

Table 28. Analysis of variance showing the effect of egg weight on albumen weight, yolk weight and shell weight in chicken.

Traits	Source of variation	D.F.	M.S.	F.
Albumen weight (g)	Between groups	3	629.8312	35.58**
	Error	146	17.7022	
Yolk weight (g)	Between groups	3	4.9478	1.35^{NS}
	Error	146	3.6635	
Shell weight (g)	Between groups	3	0.8464	9.15**
	Error	146	0.09246	

NS - Non significant
** Significant at P<0.01

Table -29. Least squares means, SE and CV% of angles corresponding to percentage (Angles = Arcsin $\sqrt{Percentage}$) of albumen weight, yolk weight and shell weight in different egg weight groups pooled over various genetic groups of chicken.

Genetic group	No. of obs.	Albumen weight (g)		Yolk weight (g)		Shell weight (g)	
		Mean ±S.E.	C.V.%	Mean ±S.E.	C.V.%	Mean ±S.E.	C.V.%
30-36	36	48.76^{a}±0.18 (51.59)	2.21	31.46^{a}±0.08 (37.11)	1.53	17.64^{a}±0.05 (11.30)	3.075
36-42	18	51.75^{b}±0.15 (55.06)	1.22	31.733^{b}±0.077 (34.27)	2.533	17.466^{a}±0.054 (10.81)	1.70
42-48	29	52.69^{c}±0.11 (60.79)	1.12	32.14^{c}±0.09 (29.55)	1.50	17.32^{a}±0.06 (9.66)	1.86
48 g and above	67	53.04^{d}±0.09 (64.04)	1.38	32.58^{d}±0.07 (27.00)	1.75	18.06^{a}±0.08 (8.96)	3.62

NB : 1. Values present within the parentheses indicating actual percentage.

2. Means with similar superscripts (column wise –abc) did not differ significantly.

Effect of egg weight on percentage of albumen, egg yolk and egg shell weight

The least squares means, standard error and coefficient of variation percentage of angles corresponding to percentage of albumen, egg yolk and egg shell weight in respect to egg weight pooled over genetic groups have been presented in table -29 and the analysis of variance for the effect of egg weight on the angles corresponding to the percentage of albumen weight (g), yolk weight (g) and shell weight of chicken eggs have been depicted in table- 30.

Effect of egg weight on the percentage of albumen

The average percentages of albumen in respect to egg weight pooled over genetic groups were observed to be varied from 51.59 in 30-36 g egg weight group to 64.04 percent in 48 g and above egg weight groups. The mean angles corresponding to the percentage of albumen weight were found to be differed significantly (P<0.01) among the different egg weight groups as revealed from the analyses of variance (Table-30). The highest percentage of albumen was calculated to be 64.04 percent in 48 g and above egg weight group which was found to have significantly (P<0.05) more albumen than the 30-36, 36-42 and 42-48 g egg weight groups by 12.45, 8.98 and 3.25 percent , respectively. The highest percentage of albumen was recorded to be 60.79 in 42-48 g egg weight group which was found to have significantly (P<0.05) more albumen than the 30-36 and 36-42 g egg weight groups by 9.20 and 5.73 percent, respectively and the lowest percentage of albumen was observed in 30-36 g group which was significantly (P<0.05) lower than the 36-42 g egg weight group by 3.47 percent. Significant (P<0.01) effect of egg weight on the percentage of albumen observed in the findings of the present investigation have also been reported by Sinha (2014) and Alam (2015). The trend of increase in percentage of albumen with the increase in egg weight as observed in the present study is corroborated with the findings of Sinha (2014) and Alam (2015).

Effect of egg weight on egg yolk percentage

The least squares means of the angles corresponding to the percentage of yolk weight were found to be varied significantly (P<0.01) as revealed from the analysis of variance (Table-30). The highest percentage of egg yolk was calculated to be 37.11 in 30-36 g egg weight group which was found to be decreased significantly (P<0.05) in subsequent groups. Decrease in percentage of egg yolk with the increase in egg weight indicating that albumen percentage increases with the increase in egg weight. Significant (P<0.01) effect of egg weight on yolk percentage observed in the findings present study has also been reported in the literature by Sinha (2014) and Alam (2015). The yolk percentage in 36-42, 42-48 and 48 g and above egg weight groups were found to be reduced by 2.84, 7.56 and 10.1 percent than the 30-36 g group. The yolk percentage was found to be the lowest in 48g and above egg weight group which was significantly (P<0.05) lower than all the groups. The trend of decrease in yolk percentage observed in the present study has also been reported in the literature (Sinha, 2014 and Alam, 2015).

Table 30. Analysis of variance showing the effect of egg weight on angles (Angles = Arcsin $\sqrt{Percentage}$) corresponding to the percentages of albumen weight, yolk weight and shell weight in chicken

Traits	Source of variation	D.F.	M.S.	F.
Albumen weight (g)	Between groups	3	84.8224	24.36**
	Error	146	3.4819	
Yolk weight (g)	Between groups	3	96.6412	38.22**
	Error	146	2.5286	
Shell weight (g)	Between groups	3	9.4526	1.12^{NS}
	Error	146	8.331	

NS - Non significant

** Significant at P<0.01

Effect of egg weight on Shell percentage

The least squares means of the angles corresponding to the percentage of shell weight revealed that percentage of shell weight decreased with the increase in size and weight of the eggs but the differences were not statistically significant among the various groups (Table -29). The highest percentage of shell weight (g) was estimated to be 11.30 in 30-36 g egg weight group which was observed to be higher than the 36-42, 42-48 and 48 g and above egg weight groups by 0.49, 1.64 and 2.34 percent but did not differ significantly. The analysis of variance (Table – 30) also revealed non-significant effect of egg weight on shell percentage. The non-significant effect of egg weight on the shell percentage observed in the findings of the present investigation has also been reported by Sinha (2014) and Alam (2015).

Table 31. Egg production of different genetic groups of chicken upto 40 weeks of age.

Traits	20-24 weeks	24-28 weeks	28-32 weeks	32-36 weeks	36-40 weeks	Total	Av. Flock size at 40 weeks of age	Av. No. of eggs laid/bird
VR ♂♂ X VR ♀♀	42	220	436	608	742	2048	782	26.26
MUZ Desi ♂♂ X VR ♀♀	114	312	542	756	874	2598	86	30.21
GAYA Desi ♂♂ X VR ♀♀	102	283	508	679	808	2380	84	28.33

Table 32. Hen-day egg production percentage of Vanaraja and its crosses with Desi chicken of Bihar upto 40 weeks of age.

Traits	20-24 weeks	24-28 weeks	28-32 weeks	32-36 Weeks	36-40 weeks
VR ♂♂ X VR ♀♀	1.61	8.93	18.76	27.14	33.97
MUZ Desi ♂♂ X VR ♀♀	4.29	11.98	21.27	30.34	35.47
GAYA Desi ♂♂ X VR ♀♀	3.88	11.11	20.39	27.87	34.24

Egg Production

Egg production of Vanaraja and its crosses with Desi (Local) chicken of Muzaffarpur and Gaya districts of Bihar has been presented in table -31. Vanaraja in crosses with Desi chicken of Muzaffarpur (MUZ Desi x VR) was found to have laid highest number of eggs (2598) followed by Gaya Desi x VR (2380) and lowest number (2048) of eggs was produced by VR x VR genetic group. The average number of eggs laid per bird was calculated to be 30.21 up to 40 weeks of age which was found to be the highest in MUZ Desi x VR. The average number of eggs laid per bird was estimated to be 28.33 in Gaya Desi x VR and 26.26 in VR x VR.

Four weekly hen-day egg production percent of Vanaraja and its crosses with Desi chicken of Muzaffarpur and Gaya districts has been shown in table -32 which has also reflected similar trend. The MUZ Desi x VR genetic group was found to have the highest hen-day egg production percent throughout upto 40 weeks of age followed by Gaya Desi x VR and lowest in VR x VR. The hen-day egg production percentage was found to be increased gradually upto 40 weeks of age. At 36-40 weeks of age the hen-day egg production in VR x VR, MUZ Desi x VR and Gaya Desi x VR genetic groups was calculated to be 33.97, 35.47 and 34.24 percentage, respectively. The hen-day egg production of MUZ Desi x VR was found to be higher than the Gaya Desi x VR and VR x VR by 1.50 and 1.23 percent, respectively at 36-40 weeks of age. Hen-day egg production of Gaya Desi x VR was also observed to be higher than the Vanaraja by 0.27 percent at the same age.

Fertility and Hatchability Percentage:

Fertility

Fertility percentage of Vanaraja and its courses with Desi chicken native to Muzaffarpur and Gaya districts of Bihar has been presented in table -33. The fertility percentage among all the genetic groups was found to be varied from 81.16 to 84.20 percent. The fertility percentage in both the crosses was observed to be higher than the purebred. The fertility percentage was found to be the highest (84.20) in MUZ Desi x VR genetic group which was higher than the VR x VR and Gaya Desi x Vanaraja genetic groups by 3.04 and 0.86 percent, respectively. The fertility percentages observed in the present study were comparable with the findings reported in the available literature (Sinha, 2014; Alam, 2015). However, Islam *et al.*(2002) reported higher fertility percentage than the findings of the percent study for layers as well as in dual purpose type of breeds. Fertility percentage for meat type breed like Cornish reported by Bhardwaj *et al.*(2006) to be much lower than the findings of the present study. Fertility percentages of indigenous breeds like Kadaknath and Aseel were also reported to be much lower than the findings of the present study (Bhardwaj *et al.*, 2006). The fertility percentage of Vanaraja in crosses with local Desi chicken observed in the present study were also higher as reported by Bhardwaj *et al.* (2006) in the crossbreds developed by crossing between exotic breeds and indigenous breeds. However, the fertility percentage of White Leghorn in crosses with indigenous breeds reported by Ahmad *et al.* (2012) was higher than the findings of the present study. Variation of fertility percentage reported in the available literature is expected as it depends largely on breeds, nutritional management, sex ratio, and age of birds which may vary from population to population.

... its crosses with Desi chicken of Bihar.

Traits	No. of eggs set	No. of fertile eggs	Total no. of chicks hatched	Fertility %	Hatchability % on total no. of eggs set	Hatchability % on fertile eggs set basis
VR ♂♂ X VR ♀♀	1824	1480	1191	81.16	65.28	80.47
MUZ Desi ♂♂ X VR ♀♀	2286	1925	1662	84.20	72.70	86.34
GAYA Desi ♂♂ X VR ♀♀	2056	1714	1470	83.34	71.50	85.76

Hatchability

The hatchability percentages of Vanaraja and its crosses with Desi chicken native to Muzaffarpur and Gaya districts of Bihar have been presented in table-33. The hatchability percentage on the basis of total number of eggs set was calculated to be ranged from 65.28 to 72.70 percent. The hatchability percentage of the crosses was found to be higher than the purebred. The hatchability percent was observed to be the highest (72.70%) in MUZ Desi x VR which was higher than Vanaraja and Gaya Desi x VR by 7.42 and 1.20 percent, respectively. The hatchability percentages on the basis of total number of eggs set observed in the present study were in close proximity with the findings of Sinha (2014) and Alam (2015). From research point of view the term hatchability means the number of chicks hatched out of 100 fertile eggs incubated. Hatchability percentage on the basis of fertile eggs set was calculated to be varied from 80.47 percent to 86.34 percent. The hatchability percentages in crosses were higher than the purebred. The hatchability percentage was observed to be the highest (86.34) in MUZ Desi x VR which was higher than the Vanaraja by 5.87 percent and was also higher than the Gaya Desi x VR by 0.63 percent. The values obtained in the percent study were in close proximity with the findings of Sinha (2014) and Alam (2015). However, Jha and Prasad (2013) reported the higher hatchability percent in Vanaraja than the findings of the present study. The hatchability percentage for the crosses obtained in the present study were in close proximity with the findings of Ahmad *et al.* (2012) who reported the hatchability percent on the basis of fertile eggs to be varied from 76.2 percent to 85.3 percent.

Phenotypic correlation

The estimates of phenotypic correlation coefficient between egg weight and other egg quality traits as well as among various egg quality traits of chicken pooled genetic groups have been presented in table -34.

Correlation between egg weight and egg quality traits

The estimates of phenotypic correlation coefficient between egg weight and various egg quality traits pooled over genetic groups were, in general, found to be highly significant (P<0.01), positive and very high in magnitude except the correlation between egg weight and shape index as well as between shell thickness and albumen index where the coefficients of phenotypic correlation were found to be very low in magnitude, positive and non-significant. However, egg weight was found to have negative correlation coefficient with yolk index, moderate in magnitude and non-significant. Highly significant (P<0.01), positive and moderate to very high in magnitude of correlation between egg weight and various egg quality traits observed in the findings of the present investigation have also been reported in the literature by Sapra and Aggarwal (1971), Amankwah (2013), Sinha (2014) and Alam (2015). Non-significant, negative and very low magnitude of coefficients of correlation between egg weight and yolk index observed in the present study have also been reported by Sinha (2014) and Alam (2015). Significant (P<0.01), positive and very high in magnitude of correlation coefficients of egg weight with egg length, egg width and shape index observed in the present experiment have also been reported by Sapra and Aggarwal (1971), Kumar (2000), Alipanah *et al.*(2011), Sinha (2014) and Alam (2015). Highly significant

(P<0.01), positive and very high magnitude of correlation coefficient between egg weight and albumen weight as well as yolk weight observed in the findings of the present study have also been reported in the literature by Islam and Dutta (2010), Alipanah *et al.* (2013), Sinha (2014) and Alam (2015).

Correlation between egg length and other egg quality traits

The estimates of correlation coefficient between egg length and other egg quality traits like egg width, albumen height, albumen weight and albumen index were found to be highly significant (P<0.01), positive and moderate in magnitude. Significant (P<0.05) and positive correlation coefficients with low magnitude were also observed between egg length and yolk weight and between egg length and yolk width. Results observed in the findings of the present study have also been reported in the literature by Sinha (2014) and Alam (2015). Highly significant (P<0.01) and positive correlation coefficients with low to moderate magnitude observed in the present study revealed that egg width, albumen height and albumen weight may be improved simultaneously by considering the egg length as a selection criteria. Egg length was found to have significant (P<0.05) and negative phenotypic correlation with shape index and yolk height. The results obtained in the findings of the present study have also been reported in the literature by Kumar (2000), Amankwah (2013), Sinha (2014) and Alam (2015).

Correlation between egg width and other egg quality traits

The estimates of correlation coefficient of egg width with other egg quality traits like shape index, albumen height, yolk weight and yolk width were found to be highly significant (P<0.01), positive and low to high in magnitude. Positive correlation was also observed with albumen index. Positive and significant (P<0.05) correlation coefficients of egg width with shape index, albumen weight, yolk weight and yolk width observed in the findings of the present study have also been reported in the literature by Amankwah (2013), Sinha (2014) and Alam (2015) and it indicated that egg width may be considered as one of the selection criteria for increase in albumen weight and yolk weight. Contrary to this, the egg width was found to have negative association with shell thickness, albumen diameter, albumen height and yolk index but coefficients of correlation were statistically non-significant.

Correlation between shape index and other egg quality traits

The coefficient of correlation between shape index and other egg quality traits were, in general, observed to be negative and statistically non-significant. The non-significant and negative phenotypic correlation between shape index and other egg quality traits such as albumen height, albumen diameter, yolk height, yolk width and yolk index observed in the findings of the present study have also been reported by Kumar (2000), Sinha (2014) and Alam (2015). However, contrary to this, shape index was found to have highly significant (P<0.01) and positive phenotypic correlation with albumen weight indicating that shape index may be considered as a selection criterion for increase is albumen weight.

Correlation between shell thickness and other egg quality traits

Shell thickness was found to have, in general, highly significant ($P<0.01$), positive and low to moderate in magnitude phenotypic correlation with albumen diameter, yolk height, yolk weight and yolk width indicating the fact that yolk weight and yolk quality might have significance on the shell thickness of the eggs. The results obtained in the findings of the present study have also been reported by Amankwah (2013), Kumar (2000), Sreenivas (2013), Sinha (2014) and Alam (2015).

Correlation between albumen diameter and other egg quality traits

The estimates of correlation coefficient between albumen diameter and albumen height as well as between albumen diameter and albumen weight were observed to be negative but statistically non-significant, whereas albumen diameter was observed to have, in general, highly significant ($P<0.01$) and positive phenotypic correlation with all the yolk qualities except with yolk height indicating the fact that yolk qualities may be improved by increasing the albumen diameter as one of the selection criteria. The findings of the present study could not be compared due to lack of information in the available literature.

Table 34. Coefficient of phenotypic correlation between egg weight and various egg quality traits of chicken pooled over genetic groups.

Traits	$r_p \pm SE$
Egg Weight X Egg Length	0.669**±0.114
X Egg Width	0.359**±0.102

X Shape Index	0.023±0.130
X Shell Thickness	0.065±0.136
X Albumen Diameter	0.155**±0.128
X Albumen Height	0.135*±0.138
X Albumen Weight	0.692**±0.032
X Albumen Index	0.046**±0.137
X Yolk Height	0.141**±0.119
X Yolk Weight	0.0348**±0.063
X Yolk Width	0.399**±0.122
X Yolk Index	-0.230**±0.133
Egg Length X Egg Width	0.259**±0.127
X Shape Index	-0.236**±0.137
X Shell Thickness	-0.027**±0.139
X Albumen Diameter	-0.020**±0.137
X Albumen Height	0.473**±0.134
X Albumen Weight	0.376**±0.120
X Albumen Index	0.414**±0.140

X Yolk Height	-0.027±0.131
X Yolk Weight	0.027±0.113
X Yolk Width	0.104*±0.131
X Yolk Index	-0.045**±0.137
Egg Width X Shape Index	0.877**±0.128
X Shell Thickness	-0.154±0.138
X Albumen Diameter	-0.105±0.139
X Albumen Height	-0.006±0.139
X Albumen Weight	0.147**±0.107
X Albumen Index	0.049±0.136
X Yolk Height	-0.028±0.138
X Yolk Weight	0.036**±0.116
X Yolk Width	0.093**±0.113
X Yolk Index	-0.057**±0.139
Shape Index X Shell Thickness	-0.136±0.139
X Albumen Diameter	-0.084±0.139

X Albumen Height	-0.237±0.139
X Albumen Weight	0.223**±0.130
X Albumen Index	-0.159±0.136
X Yolk Height	-0.006±0.139
X Yolk Weight	-0.091±0.137
X Yolk Width	-0.039±0.140
X Yolk Index	0.027±0.140
Shell Thickness X Albumen Diameter	0.172**±0.105
X Albumen Height	0.150±0.139
X Albumen Weight	-0.216±0.136
X Albumen Index	0.052±0.134
X Yolk Height	0.056**±0.104
X Yolk Weight	0.222**±0.128
X Yolk Width	0.514**±0.125
X Yolk Index	-0.096**±0.121
Albumen Diameter X Albumen Height	-0.135±0.137

X Albumen Weight	-0.052**±0.125
X Albumen Index	
X Yolk Height	0.441**±0.082
X Yolk Weight	-0.334**±0.114
X Yolk Width	0.217**±0.123
X Yolk Index	0.297**±0.106
Albumen Height X Albumen Weight	-0.072±0.139
X Albumen Index	0.904**±0.122
X Yolk Height	-0.025**±0.130
X Yolk Weight	-0.131±0.136
X Yolk Width	0.299*±0.132
X Yolk Index	0.093±0.136
Albumen Weight X Albumen Index	-0.056±0.135
X Yolk Height	-0.441**±0.119
X Yolk Weight	0.334**±0.082
X Yolk Width	0.217**±0.120

X Yolk Index	0.297**±0.134
Albumen Index X Yolk Height	-0.190±0.139
X Yolk Weight	-0.261±0.139
X Yolk Width	-0.361±0.138
X Yolk Index	-0.027±0.139
Yolk Height X Yolk Weight	0.103**±0.100
X Yolk Width	0.345**±0.113
X Yolk Index	0.952**±0.084
Yolk Weight X Yolk Width	-0.582**±0.042
X Yolk Index	-0.273**±0.123
Yolk Width X Yolk Index	-0.609**±0.119

Correlation between albumen height and other egg quality traits

The albumen height was found to have significant (P<0.05) and positive phenotypic correlation with albumen index and yolk width indicating the fact that by using albumen height as one of the selection criteria the correlated response may be obtained in albumen index and yolk width. Albumen height was found to have highly significant (P<0.01) but negative phenotypic correlation with yolk height. The findings of the present study were in close proximity with the findings of Kumar (2000), Amankwah (2013), Sinha (2014) and Alam (2015).

Correlation between albumen weight and other egg quality traits

The albumen weight was found to have, in general, highly significant ($P<0.01$) and positive phenotypic correlation of moderate magnitudes with all the yolk quality traits except with the yolk height which was negative and highly significant ($P<0.01$). Significant and positive phenotypic correlation of albumen weight with yolk weight, yolk width and yolk index indicated that by considering the albumen weight as one of the selection criteria the correlated response may be obtained in yolk weight, yolk width and yolk index through indirect selection. The findings of the present study were corroborated with the findings of Islam and Dutta (2010), Sinha (2014) and Alam (2015) who have also observed similar trend of correlation between albumen weight and all the yolk quality traits in chicken. However, coefficient of correlation between albumen weight and albumen index was found to be negative but statistically non-significant which is similar to the findings of Alam (2015) but not in agreement with the findings of Sinha (2015) who observed positive correlation but statistically non-significant and very low in magnitude.

Correlation between albumen index and all the yolk quality traits

The estimates of phenotypic correlation between albumen index and all the yolk quality traits were, in general, observed to be negative, low to moderate in magnitude and statistically non-significant. The non-significant and negative correlation between albumen index and yolk index, yolk weight and yolk height observed in the present study were also reported by Sinha (2014). However, significant and positive correlation coefficients among these traits were reported by Alam (2015).

Correlation between yolk height and other yolk quality traits

The estimates of phenotypic correlation between yolk height and other yolk quality traits such as yolk weight, yolk width and yolk index were observed to be highly significant ($P<0.01$), positive and moderate to very high in magnitude. The findings of the present study is in agreement with the findings of Sinha (2014) and Alam (2015), however, Alam (2015) reported significant ($P<0.05$) and negative correlation between yolk height and yolk index which is contrary to the findings of the present study.

Correlation between yolk weight and other yolk quality traits

Yolk weight was found to have highly significant ($P<0.01$) but negative phenotypic correlation with yolk width and yolk index. The values were moderate in magnitude. The findings of the present study is not in agreement with the findings of Alam (2015) who found highly significant ($P<0.01$) and positive correlation between yolk weight and yolk index. The findings of the present study indicated that yolk index may be considered as selection criterion for improvement in correlated traits. The findings of the present study were in agreement with the findings of Sinha (2014) who has also reported highly significant ($P<0.01$) and negative phenotypic correlation between yolk weight and yolk index.

Correlation between yolk width and yolk index

The coefficient of correlation between yolk width and yolk index was found to be highly significant ($P<0.01$) but negative and very high in magnitude. The finding of the present study was in agreement with the findings of Sinha (2014) and Alam (2015) who have reported highly significant ($P<0.01$) and negative correlation between yolk width and yolk index. The yolk index may be used as selection criterion for increase or decrease in yolk width as correlated response.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The present study was conducted on Vanaraja and its crosses with local Desi chicken native to Gaya and Muzaffarpur districts of Bihar. Gaya is situated on the South Gangetic plane of Bihar, whereas Muzaffarpur is present on the North Gangetic plane. Vanaraja a meat type breed of chicken developed for backyard poultry farming was maintained in the Instructional Livestock Farm complex (ILFC), Bihar Veterinary College, Patna on random mating. Local Desi chicken cocks were brought into the farm (ILFC) from Gaya and Muzaffarpur districts of Bihar for crossing with the Vanaraja females under flock mating system. Thus, altogether following three genetic groups were constituted.

Purebreds	Crossbreds
VR♂♂ x VR♀♀	MUZ Desi ♂♂ x VR♀♀
	GAYA Desi ♂♂ x VR♀♀

Twenty (20) males and 100 (hundred) females were taken from each genetic group at 18 weeks of age and maintained separately under deep litter system with a mating ratio of 1 male: 5 females to study the genetic effect on egg weight and egg quality traits. To study the genetic effect on egg quality traits a total of 50 eggs from each genetic group were collected at random from each of three genetic groups. To find out the effect of egg weight on egg quality traits all the eggs were taken together and divided into four different groups irrespective of genetic groups with a difference of 6 g from each group.

Traits taken to study

The following traits were recorded to fulfil the objectives of the present experiment:

1. Age at sexual maturity (Age at 1^{st} egg lay).
2. Egg weight (g)
3. Egg production up to 40 weeks of age
4. Hatchability percentage
5. Fertility percentage
6. Egg quality traits

(a) External egg quality traits

- Egg length (mm)
- Egg width (mm)
- Egg shape index
- Egg shell weight (g)
- Egg shell thickness (mm)

(b) Internal egg quality traits

- Albumen diameter (mm)
- Albumen height (mm)

- Albumen index
- Albumen weight (g)
- Yolk diameter (mm)
- Yolk height (mm)
- Yolk index
- Yolk weight (g)

Objectives

The work was done with the following objectives.

1. To estimate the mean, standard error and coefficient of variation percentage of fertility, hatchability, egg production, egg weight and egg quality traits.
2. To study the effect of genetic groups on egg weight and egg quality traits.
3. To study the effect of egg weight on egg quality traits.
4. To estimate the coefficient of phenotypic correlation between egg weight and egg quality traits, and correlation coefficient among various egg quality traits.

Findings

Age at sexual maturity (days)

The average age at sexual maturity was found to be the lowest

(152 days) in MUZ Desi x VR and highest (165 days) in VR x VR.

Egg weight (g)

The analysis of variance revealed highly significant (P<0.01) effect of genetic group on egg weight. Eggs laid by Vanaraja were significantly (P<0.05) heavier than the eggs laid by Muzaffarpur (MUZ) Desi x Vanaraja (VR) and Gaya Desi x Vanaraja (VR) crosses both at 30 and 40 weeks of age as well as at sexual maturity. However, there was no significant difference between the crosses for egg weight.

External egg quality traits:

The analysis of variance (Table -16) revealed highly significant (P<0.01) effect of genetic group on all the external egg quality traits i.e. egg length, egg width, shape index and shell thickness.

Vanaraja laid the lengthier and wider eggs than its crosses with Desi chicken of Bihar. The shape index of Vanaraja was observed to be 76.96±0.74 which was significantly (P<0.05) higher than both the crosses. However, there was no significant difference among the crosses for external egg quality traits except for shell thickness which was significantly (P<0.05) thicker in Gaya x VR than the MUZ x VR genetic group.

Internal egg quality traits

The least squares analysis of variance (Table -18) revealed highly significant (P<0.01) effect of genetic group on all the interval equality traits i.e. albumen height, albumen diameter, albumen index, yolk height, yolk width and yolk index.

Eggs laid by Vanaraja had significantly (P<0.05) thicker albumen, higher albumen index and wider egg yolk than its crosses with Muzaffarpur Desi and Gaya Desi, however, Vanaraja was found to have the lower yolk index which was significantly (P<0.05) lower than the MUZ Desi x VR and Gaya Desi x VR genetic groups.

The average estimates of albumen weight of VR x VR, MUZ Desi x VR and Gaya Desi x VR were observed to be 28.842±0.482, 18.770±0.346 and 19.376±0.411 g, respectively. The average estimates of yolk weight of aforesaid genetic groups were found to be 14.050±0.276, 12.830±0.233 and 12.908±0.272 g, respectively. The average shell weight of VR♂♂ x VR♀♀, MUZ♂♂ x VR♀♀ and GAYA♂♂ x VR♀♀ genetic groups was measured to be 4.783±0.114, 3.980±0.020 and 3.096±0.147 g, respectively.

The least squares analysis of variance (Table-20) revealed significant (P<0.05) effect of genetic groups on albumen weight, yolk weight and egg shell weight. Vanaraja was found to have significantly (P<0.05) higher albumen weight and yolk weight than both the crosses. Vanaraja though had the heavier shell weight than the MUZ Desi x VR but did not differ significantly.

Least squares analysis of variance (Table -22) revealed highly significant (P<0.01) effect of genetic group on the angles corresponding to the percentages on albumen weight, yolk weight and egg shell weight in chicken. Vanaraja had significantly (P<0.05) higher percentage of albumen than the MUZ Desi x VR and Gaya Desi x VR genetic groups whereas MUZ Desi x VR and Gaya Desi x VR were found to have significantly (P<0.05) higher percentage of egg yolk than the Vanaraja. MUZ Desi x VR was found to have significantly (P<0.05) higher percentage of shell weight than the Gaya Desi x VR but did not differ significantly from Vanaraja.

Egg Production

The average flock size of Vanaraja, MUZ Desi x VR and Gaya Desi x VR at 40 weeks of age was found to be 78, 86 and 84, hens respectively. The average number of eggs laid per bird of the aforesaid genetic groups up to 40 weeks of age was observed to be 26.26, 30.21 and 28.33, respectively. The average hen-day egg production percent was observed to be the highest (35.47%) in MUZ Desi x VR which was higher than the VR x VR and Gaya Desi x VR genetic groups.

Fertility and hatchability percentage

The average estimates of fertility percentage of VR x VR, MUZ Desi x VR and Gaya Desi x VR genetic groups were found to be 81.16, 84.20 and 83.34 percent, respectively. The average hatchability percentage on the basis of total number of eggs set in VR x VR, MUZ Desi x VR and Gaya Desi x VR was calculated to be 65.28, 72.70 and 71.50 percent, respectively. On the basis of fertile eggs, the hatchability percentages of three genetic groups were estimated to be 80.47, 86.34 and 85.76 percent, respectively.

Effect of egg weight on egg quality traits

The egg weight pooled over genetic groups at 40 weeks of age was found to have significant ($P<0.01$) effect on all the egg quality traits except in shape index and yolk weight. The heavier egg weight groups had longer and wider eggs, higher shell thickness, higher albumen height, albumen diameter, yolk height, yolk diameter and yolk index. The heavier egg weight groups were also found to have higher albumen weight and shell weight but did not differ significantly from yolk weight.

Phenotypic correlation

The estimates of phenotypic correlation between egg weight and all the egg quality traits were, in general, highly significant ($P<0.01$), positive and moderate to high in magnitude except the correlation with albumen index and yolk index where the values were very low and non-significant. In general, highly significant ($P<0.01$) but both positive and negative phenotypic correlations were observed among the various egg quality traits. Shape index was observed to have negative correlation with all the egg quality traits but the magnitudes were very low and statistically non-significant. Similarly, albumen index was also found to be negatively correlated with all the yolk quality traits i.e. yolk height, yolk width, yolk weight and yolk index but the values were very low and statistically non-significant.

CONCLUSIONS:

- The average age at sexual maturity (age at 1st egg lay) was observed to be the lowest in MUZ Desi x Vanaraja genetic group and highest in Vanaraja.
- The genetic group was found to have significant ($P<0.05$) effect on egg weight at ASM, at 30 and 40 weeks of age. Vanaraja was found to have laid the heavier eggs than both the crosses.
- All the egg quality traits, in general, were significantly ($P<0.05$) influenced by the genetic groups. Vanaraja was found to have lengthier and wider eggs than its crosses with local Desi chicken of Muzaffarpur and Gaya districts; however, Gaya Desi x VR had thicker egg shell than the Vanaraja as well as MUZ Desi x VR. Vanaraja was found to have higher albumen height, albumen diameter and larger egg yolk than both the crosses. Eggs laid by Vanaraja were also found to have highest albumen weight, yolk weight and shell weight than both the crosses. Similarly, Vanaraja was also found to have higher percentage of albumen and egg yolk. However, both the crosses did not differ significantly for most of the egg quality traits.
- Egg weight was found to have significant ($P<0.05$) influence on egg quality traits, and heavier egg weight groups had higher estimates for all the egg quality traits except for shape index and yolk weight.
- Both the crosses have produced large number of eggs than the Vanaraja. In terms of average number of eggs laid per bird upto

40 weeks of age was the highest (41.84) in MUZ Desi x Vanaraja crosses followed by Gaya Desi x VR and Vanaraja. Similar trend was also observed for hen-day egg production percent. The hen-day egg production percent was the highest (35.47) in MUZ Desi x VR genetic group.

- All the genetic groups were found to have higher fertility and hatchability percentage. MUZ Desi x VR was found to have the highest fertility percentage (84.20%) followed by Gaya Desi x VR and Vanaraja. Hatchability percentage on the basis of fertile eggs was higher among the crosses than the Vanaraja itself. MUZ Desi x VR had the highest hatchability percentage than the Gaya x VR followed by Vanaraja.
- Egg weight was found to have highly significant ($P<0.01$) and positive correlation with most of the egg quality traits except with albumen index and shell thickness but negative correlation with yolk height. Significant ($P<0.05$) and positive phenotypic correlations were also observed among various egg quality traits. Shape index was found to have negative correlation with all the egg quality traits but values were statistically non-significant.
- Finally, it can be concluded that Vanaraja was better than its crosses with Desi chicken of Muzaffarpur and Gaya districts of Bihar for egg weight and egg quality traits whereas crosses were better than the Vanaraja for egg production, fertility and hatchability percentage.

RECOMMENDATIONS:

It was recommended that Vanaraja may be used for crossbreeding with local Desi chicken of Bihar for production of large number of eggs with higher percentage of fertility and hatchability and such crossbreds may be used under backyard poultry farming system.

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