Genetic Influence on Fertility, Hatchability, Egg Weight and Egg Quality Charactiristics in Pure and Crossbred Chicken

By

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BIHAR VETERINARY COLLEGE

PATNA - 800 014

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THESIS

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RAJENDRA AGRICULTURAL UNIVERSITY

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FOR THE DEGREE OF

Master of Veterinary Science

(ANIMAL BREEDING AND GENETICS)

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PATNA - 800 014

2000

Dedicated To

My Dear Grandfather

Department of Animal Breeding and Genetics
Bihar Veterinary College, Patna – 800014.
(Rajendra Agricultural University, Bihar)

Dr. Mani Mohan
M.V.Sc., Ph.D.
University Professor and
Dean-cum-Principal
Bihar Veterinary college
Patna - 800014

CERTIFICATE – I

This is to certify that the thesis entitled "*GENETIC INFLUENCE ON FERTILITY, HATCHABILITY, EGG WEIGHT AND EGG QUALITY CHARACTERISTICS IN PURE AND CROSSBRED CHICKEN*" submitted in partial fulfilment of the requirements for the **Degree of Master of Veterinary Science (Animal Breeding and Genetics) of the faculty of Post-graduate studies, Rajendra Agricultural University, Pusa, Bihar** is the record of bonafide research carried out by **Dr. Shambhu Kumar** under my supervision and guidance. No part of the thesis has been submitted for any other Degree or Diploma.

It is further certified that such help or information received during the course of this investigation and preparation of the thesis have been duly acknowledged.

30.12-2000

(Mani Mohan)

Major Advisor

Endorsed :

30.12-2000

(Chairman/Head of the Department)

CERTIFICATE – II

We, the undersigned, members of Advisory Committee of **DR. SHAMBHU KUMAR**, a candidate for the degree of **Master of Veterinary Science** with **Major in Animal Breeding and Genetics**, have gone through the manuscript of the thesis and agree that the thesis entitled *"GENETIC INFLUENCE ON FERTILITY, HATCHABILITY, EGG WEIGHT AND EGG QUALITY CHARACTERISTICS IN PURE AND CROSSBRED CHICKEN "* may be submitted by **DR. SHAMBHU KUMAR** in partial fulfilment of the requirement for the degree.

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Place : Patna

Date : 30.12.2000

(Shambhu Kumar)

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Introduction

INTRODUCTION

Poultry keeping in India was mostly a backyard system almost unto 1960s, and indigenous desi birds, though hardy and poor in productivity, were used for the production of eggs and meat. During the last three and half a decades, the entire scenario of poultry farming in the country has changed and the indigenous desi birds have gradually been replaced by highly specialized layers and broilers. The poultry farming is now taken a shape and recognized as an organized industry with tremendous employment opportunity and a potential tool to fight poverty and malnutrition. The substantial progress made by poultry industry is due to scientific approach towards its breeding, feeding, management and health control. In fact, poultry is emerged as a 'commercial crop' in many farming communities.

The egg production in India has increased to the tune of 3000 crore as compared to 800 crore in two and half a decades ago. The production of broilers has also increased with the same pace to the tune of 60 crore from just 40 lakh during the same period. Though the egg production has been increased tremendously yet the annual per capita availability of eggs in our country is only 30 eggs as compared to 300-350 eggs in developed countries. For meeting the minimum nutritional requirements the Nutritional Advisory

Committee of India has recommended only half an egg per person per day to maintain the normal health. Even at this low level, the annual egg production would have to exceed 18,000 crore nearly six times of the present level. Although it may seems to be absurd but it is not difficult to achieve this figure. India has crossed 100 crore mark of human population during the year 2000. For meeting the minimum animal protein requirements of this vast population, in terms of eggs and meat, India has a long way to go.

The vast increase in egg production during the last two to three decades is mainly due to the use of specialized layer strains of high genetic potency and its crosses. It can not be certain that all the eggs laid by genetically improved layers are of high internal quality even though the number of eggs laid by them is more than double to that of the desi birds. Therefore, it is important to maintain high external and internal quality of eggs right from the egg is laid till it is consumed. Eggs having good internal quality can stand preservation better than the eggs with poor quality. Egg quality is important from economic as well as from breeding point of view. The number of eggs laid by a bird is not the only criterion to be considered, the emphasis must also be given to the egg weight and other egg quality too since these adds equally well to the economics of egg production.
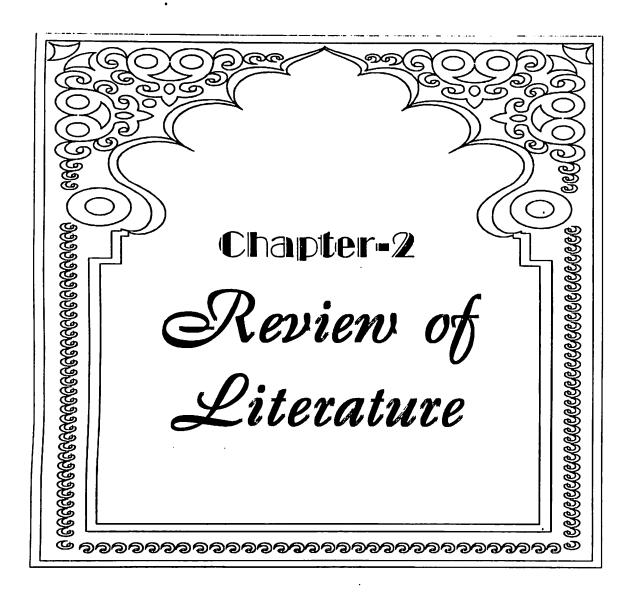
For commercial broiler production, the sire lines and dam lines are developed separately. Sire lines are developed exclusively for high growth and conformation traits, while the dam lines are concentrated on egg production in addition to its growth rate. Therefore, for increasing the number of broiler production and to make this enterprise profitable too the large number of eggs with good quality are the prerequisite. In addition to this, very high percentage of fertility and hatchability is also essential. Both fertility and hatchability are under the control of heredity and environment. Certain physical characters of eggs such as size, shape, shell quality and internal quality are reported to be moderately heritable and are said to be associated with hatchabilty. Several workers (Olsen and Haynes, 1949; Singh and Desai, 1962; and Kumar and Kapri, 1967) have reported a higher percentage of hatchability from the eggs of normal size and shape. Reddy et al. (1965) observed a significant positive relationship of egg size with hatchability. Varadarajulu et al. (1966) reported significant positive association of egg shape with hatchability. Eggs with very thin or very thick shells do not hatch well.

Therefore, for the profitable marketing of eggs, either for table purpose or for hatching purpose, it is desirable that a reasonable uniformity in quality of eggs is maintained within the flock and also during the different periods of the year. This can be

achieved by reproducing only those birds which produce eggs of good quality and retain their progeny for future breeding. 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. An attempt has therefore been made to study the genetic effect and heterosis in crosses of White Plymouth Rock with White Cornish and Red Cornish breeds of chickens for their egg quality with the following objectives.

1. To estimate the mean, standard error and coefficient of variation percentage of fertility, hatchabitity, egg weight and egg quality traits under study in different genetic groups.

2. To study the effect of different genetic groups on fertility, hatchability, egg weight and egg quality traits.

3. To evaluate the percentage of heterosis for various traits under study in chicken.

4. To estimate the coefficient of phenotypic correlation among various traits under study.

5. To study the effect of egg weight on egg quality traits in chicken.

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Chapter-2

Review of Literature

REVIEW OF LITERATURE

Egg weight :

The number of eggs laid by a bird is not the only criterion to be considered in breeding for egg production. 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 (Hicks, 1958; Kheireldin *et al.* 1968; Kondra *et al.* 1968), however, Saito *et al.* (1956) did not observe breed differences on egg weight. Hafez *et al.* (1955) tabulated the proportion of egg components from different breeds of chicken and reported that breed differences were more marked in the egg weight than in the proportion of egg components. The influence of breed on egg weight was studied by Johari and Singh (1968) and reported significant breed differences for this trait. The eggs laid by Rhode Island Red were significantly heavier than the eggs of White Leghorn. Sapra and Aggarwal (1971) estimated the egg weight of various indigenous breeds of chicken like Desi, Black Bengal, Aseel, Naked Neck and exotic breeds such as New Hampshire, White Plymouth Rock, and White Cornish. They also

egg weights of exotic breeds were significantly heavier than the eggs laid by the indigenous breeds, however, they did not observe significant difference in egg weight among the exotic breeds as well as among the indigenous breeds. In an experiment Ramappa and Pillai (1972) observed significant breed differences for egg weight. They reported that exotic breeds (RIR and WL) laid significantly heavier eggs than the Desi breeds of chicken, but the differences among the exotic breeds were not statistically significant. However, Rahmatullah et al. (1978) reported the existence of breed and strain differences for egg weight among the exotic breeds. The average egg weight of exotic breeds reported to be ranged from 52.11g (White Leghorn) to 60.60g (White Plymouth Rock). Reddy et al. (1980) reported significant strain differences for egg Weight at 40 weeks of age in 2-way and 3-way crosses of White Leghorn.

Singh et al. (1981) conducted experiment on egg parameters in reciprocal crosses of two strains of White Leghorn birds. They observed significant differences between the reciprocal crosses for egg weight. Arad and Marder (1982) studied the egg quality characteristics of Sinai Bedoui fowl, White Leghorn and their reciprocal crosses. They reported significant breed differences for egg weight, the White Leghorn birds laid significantly heavier eggs than the Sinai fowl. However, the differences for the egg weight among the reciprocal crosses reported to be statistically non-significant. Arafa et al. (1982) reported the existence of strain differences for egg

weight in White Leghorn chicken. Mahapatra *et al.* (1982) evaluated the different Desi breeds such as Karaknath (KN), Aseel Kagar (AK), Aseel Peela (AP) and their crosses with exotic like KN × WL and KN × NH for egg quality traits. They reported significant breed differences for egg weight and Aseel Kagar was reported to be significantly superior than others for this trait. The average egg weight of crossbreds were far bellow than the average egg weight of Aseel Kagar. Sharma *et al.* (1992) measured the combining ability effect for production traits in the crosses between the strains of White Leghorn and Rhode Island Red. The general combining ability (gca) and reciprocal crosses were reported to be have significant effect on egg weight at 32 and 40 weeks of age.

Highly significant strain differences were observed by Pandey *et al.* (1984) among different strains of White Leghorn at 40 weeks of age. In another experiment Panday *et al.* (1986) also found significant strain differences for egg weight in White Leghorn chicken. For egg weight in Rhode Island Red chicken, significant strain differences were observed by Pandey *et al.* (1987).

Diwan Chand (1987) measured the egg weight of 3 broiler breeds of chicken such as White Plymouth Rock, White Cornish and New Hampshire in pullet year of production. They observed significant breed differences for this trait, the hens of White Plymouth Rock laid significantly heavier eggs than the White Cornish and New Hampshire breeds. Pandey *et al.* (1988) developed

strain crosses from 5 different strains of White Leghorn to examine the effect of male and female parents on egg quality traits. They observed no significant difference between male parents for egg weight at any period of time, however, the differences were significant between female parents at all ages with better performance of IWI strain over the others.

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

Rose *et al.* (1966) studied the influence of age on egg weight. They reported that the age of hens was significantly influenced the egg weight. Johari and Singh (1968) reported that egg weight increased steadily with the increase of age. The eggs laid in the second year of production were significantly heavier than the eggs laid in the pullet year. Wolford and Tanaka, (1970) reported that egg weight increases with the time of laying after peak egg production. Arafa *et al.* (1982) measured the egg weight in 5 different strains of hens at 52 and 64 weeks of age at different hours of the

day. They reported that eggs laid by all the strains were heavier at 64 weeks of age. Nair and Elizabeth (1983) measured the egg weight from a flock of White Leghorn birds from 26 weeks of age to 74 weeks of age. They observed that egg weight gradually increased with the advancement of age, the eggs laid in the second year of production were larger than the eggs laid in the pullet year.

The average egg weight of various breeds of chicken reported in the available literature have been presented in Table-1.

The average egg weight reported to be ranged from 49.47 to 56.90g in New Hampshire, 50.83 to 60.16g in White Leghorn, 52.74 to 56.92g in Rhode Island Red, 52.25 to 60.06g in White Plymouth Rock and 52.72 to 59.20g in White Cornish. In Sinai breed the average egg weight reported to be ranged from 47.77 to 47.81g.

The average egg weight of Aseel and its strains reported to be ranged from 46.52 to 52.80g. The average egg weight of Desi fowls reported to be ranged from 39.53 to 46.02g. The average egg weight for strain crosses in White Leghorn reported to be ranged from 53.67 to 55.18g. The average egg weight for crosses of indigenous (KN) breed with exotics reported to be ranged from 40.64 to 45.39g. The strain crosses between White Leghorn and Sinai reported to be ranged from 56.19 to 57.22g.

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

Breed/strain	No. of obs.	Mean	Reference
New Hampshire	--	56.8	Hicks (1958)
"	--	56.9	"
"	--	56.8	"
"	92	55.66	Sapra & Aggarwal (1971)
"	100	56.57	Rahmatella *et al* (1978)
"	195	49.47	Diwan Chand (1987)
White Leghorn	500	60.16	Eisen & Bohren (1963)
"	-	51.43	Johari & Singh (1968)
"	1443	56.07	Kumar & Shingari (1969)
"	60	52.55	Ramappa & Pillai (1972)
"	500	52.11	Rahmatullah *et al.* (1978)
WL Strain IWI	-	52.9	Kumar *et al.* (1981)
WL Strain IWH	-	53.7	"
WL Strain L_{33}	125	54.90	Pandey *et al* (1984)
WL Strain L_{55}	112	54.20	"
WL Strain L_{77}	77	55.05	"
WL Strain L_{99}	115	53.66	"
WL Strain Control	106	56.49	"
WL Strain IWG	164	52.92	Pandey *et al* (1986)

Breed/strain	No. of obs.	Mean	Reference
WL Strain IWH	164	52.05	"
WL Strain IWI	164	54.43	"
WL Strain IWJ	164	53.33	"
WL Strain IWX	164	51.97	"
WL Strain Control	164	54.33	"
Breed/strain	No. of obs.	Mean	Reference
White leghorn	1,089	50.83	Khan et al (1989)
WL strain, IWH	--	52.12	Sharma et al (1992)
Rhode Island Red	--	52.74	Johari & Singh (1968)
RIR	60	53.15	Ramappa & Pillai (1972)
RIR line EN	105	54.34	Pandey et al (1987)
RIR line EM	111	56.92	"
RIR line R	144	54.29	"
RIR line C	47	55.06	"
RIR Strain RIR	--	52.86	Sharma et al (1992)
RIR Strain RIW	--	53.18	"
White Plymouth Rock	85	57.39	Sapra & Aggarwal (1971)
"	100	60.06	Rahmatullah et al (1978)
"	209	54.25	Diwan Chand (1987)
White Cornish	75	55.51	Sapra & Aggarwal(1971)
"	100	59.51	Rahmatullah et al (1978)

Breed/strain	No. of obs.	Mean	Reference
"	203	52.72	Diwan Chand (1987)
Sinai	22	47.81	Arad & Marder (1982)
"	21	47.77	"
Desi	85	40.78	Sapra & Aggarwal (1971)
Bown Desi	60	39.53	Ramappa & Pillai (1972)
Desi fowl	30.6	46.02	Kumar & Acharya (1980)
Black Bengal	69	47.61	Sapra & Aggarwal (1971)
Aseel	25	52.80	"
Aseel Pella (AP)	40	46.52	Mahapatra et al (1982)
Aseel Kagar (AK)	40	48.32	"
Naked Neck	24	48.54	Sapra & Aggarwal (1971)
White Leghorn (IWH × IWI)	120	55.18	Singh et al (1981)
White Leghorn (IWI × IWH)	120	53.67	"
White Leghorn × Sinai	24	56.19	Arad & Marder (1982)
"	40	56.86	"
Sinai × White Leghorn	"	56.66	"
"	22	57.22	"
KN × WL	40	45.39	Mahapatra et al (1982)
KN × WL	40	40.64	"
KN × NH	40	42.85	"

WL – White Leghorn;   RIR –   Rhode Island Red

NH – New Hampshire;   KN –   Karaknath.

Egg length and egg width :

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 egg length.

Significant breed differences were observed for egg length and egg width by Sapra and Aggarwal (1971). The White Plymouth Rock is reported to have significantly higher egg length and width than White Cornish, New Hampshire, Aseel, Naked Neck and other indigenous breeds.

Singh *et al.* (1981) reported that birds produce lesser number of eggs generally have 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.

Arad and Marder (1982) did not observe breed differences for egg length and width.

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

The average length of eggs reported to be ranged from 52.48 mm in Sinai breed to 57.56 mm in White Plymouth Rock. The average width of the egg reported to be ranged from 39.46 mm in Desi to 43.17mm in White Leghorn.

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	53.51	39.46	Sapra& Aggarwal (1971)
Black Bengal	69	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	"
Sinai	21	52.48	40.04	Arad & Marder (1982)
White Leghorn	23	57.42	43.17	Arad & Marder (1982)
"	089	54.90	40.70	Khan et al (1989)
Sinai × White Leghorn	22	56.92	42.30	Arad & Marder (1982)
White leghorn × Sinai	40	56.30	42.28	Arad & Marder (1982)

Shape index :

Shape is one of the most important characters of eggs, large deviations from the normal shape increase the tendency towards breakage and manipulation, and to reduce hatchability. Egg shape 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 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 a clear cut dominancy. If dam and sire's dam lay eggs of identical type, the progeny lay eggs of the same shape. However, when parents are derived from strains which produce the extremes of egg shape, the eggs of offsprings are intermediate in shape (Benjamin, 1920 and Axelsson, 1938). 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. Marble (1943) established two strains characterised 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 that were more or less uniform in colour and shape.

King and Hall (1955) observed significant differences between strains within breed for shape index but the differences between breeds were not significant. Carter and Jones (1970) also noted significant strain differences in shape index. Ramappa and Pillai (1972) did not find any significant difference in the mean shape index between Desi, Rhode Island Red and Single Comb White Leghorn. Rahmatullah et al. (1978) measured egg quality traits of the different strains of White Leghorn as well as different breeds of chicken. They reported significant variation for shape index due to both strains and breeds. Singh et al. (1981) found significant variations for shape index in reciprocal crosses between two strains of White Leghorn . However, Kumar et al. (1981) did not find significant variation in shape index between two strains of White Leghorn. Arad and Marder (1982) studied the shape index in Sinai Bedouin fowl, the commercial White Leghorn and their crossbreds, and found the shape index of similar magnitude in all the strains. Mahapatra et al. (1982) measured shape index of different indigenous breeds like Karaknath, Aseel Kagar, Aseel Peela and their crosses with White Leghorn and New Hampshire. They

reported significant differences in shape index due to breeds and their crosses. Pandey et al. (1986) reported significant variation for shape index in different strains of White Leghorn but they (Pandey et al. 1987) did not observe any significant variation for shape index among different strains of Rhode Island Red.

In an experiment with Single Comb White Leghorn, Benjamin, 1920) did not find significant difference in shape index between first and second year of egg production. Hicks (1958) and Hicks et al. (1961) also reported similar observations in New Hampshire. Mueller et al. (1960) reported that the shape indices of eggs produced during the pullet year were significantly higher than that of eggs produced during the second year of laying. Richards and Swanson (1965) expressed that shape indices alone is accounted for 15 to 35% of the variability in breaking strength and remaining percentage of variation depends on egg shell thickness. Ishibashi and Takabashi (1967) observed decrease in shape index with the advancement of age.

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

Among the pure breeds the mean shape index in poultry reported to be ranged from 69.90 in New Hampshire to 76.06 in White Leghorn. However, the maximum value of shape index is reported to be 76.25 in the crosses of Karaknath and New

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

Breed/strain	No. of obs.	Mean	Reference
New Hampshire	-	69.90	Hicks (1958)
"	--	70.70	"
"	--	70.80	"
"	100	70.79	Rahmatullah *et al* (1978)
White Leghorn	1443	75.38	Kumar & Shingari (1969)
"	60	74.50	Ramappa & Pillai (1972)
" .	500	72.53	Rahmatullah *et al* (1978
WL strain IWI	--	74.91	Kumar *et al* (1981)
WL strain IWH	--	75.09	"
WL strain IWG	164	73.98	Pandey *et al* (1986)
WL strain IWH	"	73.25	"
WL strain IWI	"	72.64	"
WL strain IWJ	"	73.78	"
WL strain IWX	"	76.06	"
WL strain Control	"	73.83	"
WL	1089	74.27	Khan *et al* (1989)
Rhode Island Red	60	73.55	Ramappa & Pillai (1972)
RIR line EN	105	74.52	Pandey *et al* (1987)
RIR line EM	111	75.08	"
RIR line R	144	75.20	"
RIR line C	47	74.20	"

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Breed/strain	No. of obs.	Mean	Reference
White Plymouth Rock	100	74.10	Rahmatulla *et al* (1978)
White Cornish	100	73.39	,,
Brown Desi	60	73.13	Ramappa & Pillai (1972)
Aseel Peela	40	75.08	Mahapatra *et al* (1982)
Aseel Kagar	40	73.65	,,
Karaknath (KN)	40	73.78	,,
KN × WL	40	74.10	,,
KN × WL	40	73.82	,,
KN × NH	40	76.25	,,
Eggs obtained form market			
I (38-44 g)	22	73.632	Mohan *et al* (1992)
I (45-52 g)	353	72.438	,,
III (53-60g) .	280	72.048	,,
IV (above 60g)	44	70.907	,,

WL   -   White leghorn, RIR – Rhode Island Red

NH   -   New Hampshire

Hampshire. In New Hampshire the mean shape index reported to be ranged from 69.90 to 70.80, in White Leghorn and its strains ranged from 71.43 to 76.06 and in Rhode Island Red ranged from 73.55 to 75.20. The mean shape index in White Plymouth Rock and White Cornish reported to be 74.10 and 73.39 respectively. The mean shape index of indigenous breeds reported to be ranged from 73.13 to 75.08. The mean shape index in crosses of Karaknath with exotics reported to be ranged from 73.82 to 76.25. However, the mean shape index of the eggs collected from the marketed eggs reported to be ranged from 70.907 to 73.632.

Shell thickness :

Since shell thickness of the individual hen's egg is a 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 exist (Taylor and Martin, 1928), lines differing in shell thickness can be established by selection (Taylor and Lerner, 1939; Quinn et al. 1945).

In an experiment on internal egg quality traits, Johari and Singh (1968) noted significant differences in shell thickness between Single Comb White Leghorn and Rhode Island Red. M Jand (1970) noted no marked difference in shell thickness between White Leghorn and Australorp, where as the values for New Hampshire

were lower than the above breeds. Ramappa and Pillai (1972) reported significant difference in shell thickness between Brown Desi and exotic breeds but they did not observe any significant variation for this character among the exotic breeds (WL and RIR). Rahmatullah *et al.* (1978) observed significant difference in shell thickness among the various lines of White Leghorn as well as between breeds.

Reddy *et al.* (1980) reported significant difference in shell thickness between strain crosses of White Leghorn.

A comparison of shell thickness was made by Arad and Marder (1982) between Sinai and White Leghorn breeds of poultry and their reciprocal crosses. The Sinai eggs reported to have thicker and stronger shell than the eggs of White Leghorn. They were of the opinion that thicker shell of Sinai breed is attributed due to its genetic effect. No significant breed differences reported to be observed in shell thickness between different Desi breeds and their crosses by Mahapatra *et al.* (1982). Verma *et al.* (1983) reported significant difference in shell thickness between the strains. However, Pandey *et al.* (1984) did not observe any significant difference in shell thickness between the strains. However, Pandey *et al.* (1986 and 1987) observed significant variation in shell thickness between strains of White Leghorn.

Roland *et al.* (1975) noted decrease in shell thickness as the birds aged. Since the eggs get larger as the bird aged, the

constant amount of calcium deposition may be responsible for declining in shell quality.

Nair and Elizabeth (1983) reported that pullet year eggs had greater thickness than the eggs laid in the second year.

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

The mean shell thickness reported to be ranged from 0.25 to 0.37 mm in White Leghorn, 0.326 to 0.36 mm in Rhode Island Red. The average shell thickness in White Cornish, White Plymouth Rock and New Hampshire reported to be 0.32 mm, 0.31 mm and 0.29 mm respectively. The average shell thickness of indigenous breeds of poultry reported to be ranged from 0.33 to 0.34 mm. The average shell thickness of Karaknath in crosses with White Leghorn and New Hampstire reported to be ranged from 0.32 to 0.34 mm.

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).

Hamilton (1978) studied the changes of shell quality in 10 strains of White Leghorn and concluded that changes in shell weight were more variable for the commercial strains than the two-

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

Breed/strain	No. of obs.	Mean	Reference
White Leghorn	60	0.354	Ramappa & Pillai (1972)
"	500	0.29	Rahmatullah et al (1978)
"	10	0.31	Arad & Marder (1982)
WL strain	315	0.288	Verma et al (1983)
WL	--	0.25	Maan et al (1983)
WL strain L 33	125	0.33	Pandey et al (1984)
WL strain L 55	112	0.34	"
WL strain L 77	77	0.32	"
WL strain L 99	115	0.33	"
WL strain control	106	0.36	"
WL strain IWG	164	0.321	Pandey et al (1986)
WL strain IWH	164	0.331	"
WL strain IWI	164	0.317	"
WL strain IWJ	164	0.326	"
WL strain IWX	164	0.327	"
WL strain control	164	0.338	"
WL	1089	0.37	Khan et al (1989)
Rhode Island Red	--	0.326	Johari & Singh (1968)
RIR	60	0.347	Ramappa & Pillai (1972)
RIR line EN	105	0.36	Pandey et al (1987)
RIR line EM	111	0.341	"

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Breed/strain	No. of obs.	Mean	Reference
RIR line R	144	0.33	,,
RIR line C	47	0.326	,,
Karaknath	40	0.33	Mahapatra et al (1982)
Aseel Peela	40	0.33	,,
Aseel Kagar	40	0.34	,,
White Cornish	100	0.32	Rahmatullah et al (1978)
White Plymouth Rock	100	0.31	,,
New Hampshire	100	0.29	,,
KN × WL	40	0.32	Mahapatra et al (1982)
KN × WL	40	0.34	,,
KN × NH	40	0.34	,,

WL   -   White Leghorn

RIR -   Rhode Island Red

NH   -   New Hampshire

KN   -   Karaknath

way or three-way strain crosses. Arad and Marder (1982) were of the opinion that the differences in egg shell properties were of the genetic origin. Arafa et al. (1982) found significant differences among different strains of hens for shell weight. Pandey et al. (1984) compared the 5 different strains of White Leghorn and obtained significant strain differences for percent shell.

Johari and Singh (1968) have reported breed differences in the shell weight of poultry. They observed that White Leghorn had higher shell weight than Rhode Island Red.

In an experiment Perek and Snapir (1970) reported significant breed differences in shell weight. They reported that White Rock had significantly higher shell weight than the White Leghorn.

Rahmatullah et al. (1978) reported that shell weight of the poultry eggs is genetically controlled. They observed significant differences between breeds and between strains for shell weight. White Cornish is reported to have significantly higher shell weight than New Hampshire and White Leghorn but did not differ significantly from White Rock.

Pandey et al. (1987) reported strain differences for shell weight and percent shell. The percent shell in different line of Rhode Island Red was reported to be ranged from 9.82 to 9.98 percent.

Mohan et al. (1992) reported that egg weight has no significant effect on percent shell.

The mean values of shell weight of different breeds of poultry available in the literature are presented in Table-5

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

Breed/Strain	No. of obs.	Mean	Reference
Shell Weight (g)			
Rhode Island Red (RIR)	-	4.94	Johar &Singh (1968)
RIR line EN·	105	5.39	Pandey *et al* (1987)
RIR line EM	111	5.68	"
RIR line R	144	5.34	"
RIR line C	47	5.40	"
White Leghorn (WL)			
WL strain A	100	5.80	Rahmatullah *et al* (1978)
WL strain B	100	5.59	"
WL strain C	100	5.60	"
WL strain D	100	5.29	"
WL strain E	100	5.75	"
WL	1089	5.57	Khan *et al* (1989)
White Plymouth Rock	100	6.79	Rahmatullah *et al* (1978)
White Cornish	100	5.80	"
New Hampshire	100	6.42	"
Percent Shell (Wt)			
WL strain L 33	125	9.86	Pandey *et al* (1984)

Breed/Strain	No. of obs.	Mean	Reference
WL strain L 55	112	10.27	Pandey *et al* (1984)
WL strain L 77	77	9.95	"
WL strain L 99	115	10.14	"
WL strain control	106	10.51	"
WL strain IWG	164	9.47	Pandey *et al* (1986)
WL strain IWH	164	9.98	"
WL strain IWI	164	9.49	"
WL strain IWJ	164	9.77	"
WL strain IWX	164	10.02	"
WL strain control	164	10.35	"
RIR line EN	105	9.95	Pandey *et al* (1987)
RIR. line EM	111	9.98	"
RIR line	144	9.83	"
RIR line C	47	9.82	"
Karaknath (KN)	40	12.11	Mahapatra *et al* (1982)
Aseel Peela	40	11.93	"
Aseel Kagar	40	11.40	"
KN × WL	40	12.02	"
KN × WL	40	12.66	"
KN × NH	40	13.82	"

WL - White Leghorn

RIR - Rhode Island Red

NH - New Hampshire

KN - Karaknath

The average shell weight is reported to be ranged from 4.94 g in RIR to 6.74g in WPR. The average percentage of shell weight of exotic breeds and their strains reported to be ranged from 9.47 to 10.5. Indigenous breeds reported to have higher percentage of shell as compaired to the exotic breeds and ranged from 11.4 to 12.11. Still higher percentage of shell weight is reported in the crosses of exotics with indigenous breeds of chicken ranging from 12.02 to 13.82.

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 Haugh 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.

Studies 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 (1940) found that it is possible to establish two lines characterised by different amounts of thick albumen.

The work of Cotterill and Winter (1954); King and Hall (1955); Johnson and Gowe (1956); and Strain and Johnson (1956) demonstrated that the breeds and strains may vary in albumen quality.

Johari and Singh (1968) reported significant breed differences for albumen index, albumen height, total albumen weight, albumen percentage. The Rhode Island Red breed reported to be superior in comparison to White Leghorn for these traits.

Romanoff and Romanoff (1949) have stated that albumen index is significantly influenced by the breeds. The albumen index of chicken eggs varied throughout the year. They observed better albumen quality in White Leghorn. Baker and Vadehra (1969) observed very high and significant differences between strains of White Leghorn in the percent of thick albumen. Kheireldin et al. (1968) reported significant breed differences for percent albumen.

Kidwell et al. (1964) reported significant differences between commercial strains of chicken for the albumen height and in the regression of albumen height on egg weight of fresh eggs.

Saeki et al. (1968) studied that various interior quality characters of eggs from White Leghorn and meat type breeds. They observed that the internal quality of eggs from individual hen is more uniform in dimension and vary from breed to breed and strain to strain.

Study of Kotaiah et al. (1976) with two strains of White Leghorn and one strain of Australorp at different ages revealed highly significant differences between strains within age and between ages within strains for albumen height and albumen index. Verma et al. (1983); Pandey et al. (1984); found significant strain differences in albumen height and albumen index in White Leghorn measured at 40 weeks of age. Rahmatullah et al. (1978) reported significant breed differences for albumen index and albumen weight. They observed that White Plymouth Rock was significantly superior for these traits as compared to the White Cornish, New Hampshire and White Leghorn. Pandey et al. (1986) also observed significant strain differences for these traits in White Leghorn including albumen weight.

In an experiment with 2-way and 3-way White Leghorn strain crosses Reddy et al. (1980) reported the superiority of 3-way crosses over 2-way crosses for albumen height and albumen index. In reciprocal crosses between two strains of White Leghorn breed. Singh et al. (1981) observed the influence of reciprocal cross on albumen index but they did not find such effect on albumen weight and albumen percentage. Verma et al. (1983) reported significant effect of strain crosses on albumen height and albumen index. The general combing ability, specific combing ability and reciprocal effects were reported to have significant influence on the albumen quality .

A number of studies have shown that albumen quality as measured by albumen height or albumen index declines as the bird aged (Henderson *et al.* 1941; Pope and Watts 1955; and Prell *et al.* 1962) and as the production advances (King and Hall, 1955). It has also been reported that the pullets produce better albumen quality than hens (Yao, 1958).

Olsson (1936) reported that pullets coming into production laid eggs with a lower proportion of yolk and a higher proportion of albumen as compared to the eggs laid by older birds.

Arafa *et al* (1982) reported significant variation for albumen weight and percent albumen of the eggs laid during pullet year than the eggs laid in the second year. They found that although the albumen weight of eggs laid in the second year increased non-significantly but albumen percent decreased significantly as compared to the eggs laid in the pullet year.

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 are presented in Table - 6.

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

Breed/Strain	No. of obs.	Mean	Reference
Albumen Index			
White Leghorn (WL)	-	9.58	Johari & Singh (1968)
WL strain A	100	7.06	Rahmatullah *et al* (1978)
WL strain B	100	6.27	"
WL strain C	100	7.20	"
WL strain D	100	6.51	"
WL strain E	100	7.53	"
WL strain	500	6.27	"
WL strain	315	10.99	Verma *et al* (1983)
WL strain L 33	125	9.3	Pandey *et al* (1984)
WL strain L 55	112	9.6	"
WL strain L 77	77	9.8	"
WL strain L 99	115	10.3	"
WL strain Control	106	10.5	"
WL strain IWG	150	7.3	Pandey *et al* (1986)
WL strain IWH	150	8.5	"
WL strain IWI	150	9.5	"
WL strain IWJ	150	8.8	"
WL strain IWX	150	9.5	"
WL strain control	150	7.7	"

Breed/strain	No. of obs.	Mean	Reference
Rhode Island Red (RIR)	--	9.89	Johari & Singh (1968)
RIR line EN	105	7.4	Pandey *et al* (1987)
RIR line EM	111	7.9	"
RIR line R	144	7.6	Pandey *et al* (1987)
RIR line C	47	7.8	"
White Cornish	100	7.39	Rahmatullah *et al* (1978)
White Plymouth Rock	100	8.10	"
New Hampshire	100	7.83	"
Aseel Peela	40	9.0	Mahapatra *et al* (1982)
Aseel Kagar	40	9.0	"
Karaknath (KN)	40	7.4	"
KN × WL	40	11.0	"
KN × WL	40	11.0	"
KN × NH	40	8.8	"
IWH × IWI (WL)	120	7.21	Singh *et al* (1981)
IWI × IWH (WL)	120	8.43	"
WL$_1$ × WL$_2$ (WL)	448	11.44	Verma *et al* (1983)
Albumen Height (mm)			
White Leghorn (WL)	416	5.21	Eisen & Bohren (1963)
WL	--	6.91	Johari & Singh (1968)
WL	315	7.45	Verma *et al* (1983)

Breed/strain	No. of obs.	Mean	Reference
WL strain L 33	125	6.79	Pandey *et al* (1984)
WL strain L 55	112	6.94	"
WL strain L 77	77	7.20	"
WL strain L 99	115	7.49	"
WL strain control	106	7.48	"
WL strain IWG	150	5.56	Pandey *et al.* (1986)
WL strain IWH	150	6.12	"
WL strain IWI	150	6.80	"
WL strain IWJ	15	6.52	Panday *et al.* (1986)
WL strain IWX	150	6.68	"
WL strain Control	150	5.83	"
Rhode Island Red (RIR)	--	6.93	Johari & Singh (1968)
RIR line EN	105	5.59	Pandey *et al* (1987)
RIR line EM	111	5.99	"
RIR line R	144	6.63	"
RIR line C	47	5.72	"
Albumen Weight (g)			
Rhode Island Red	--	32.63	Johari & Singh (1968)
White Cornish	100	34.72	Rahmatullah *et al* (1978)

Table 6 to continue ....

Breed/strain	No. of obs.	Mean	Reference
White Plymouth Rock	100	35.22	”
New Hampshire	100	32.53	”
White Leghorn (WL)	416	31.38	Eisen & Bohren (1963)
”	--	30.96	Johari & Singh (1968)
WL Strain A	100	33.03	Rahmatullah *et al* (1978)
WL Strain B	100	30.92	”
WL Strain C	100	32.87	Rahmatullah *et al* (1978)
WL Strain D	100	30.57	”
WL Strain E	100	32.36	”
WL	500	30.92	”
WL Strain IWG	150	30.44	Pandey *et al* (1986)
WL Strain IWH	150	30.43	”
WL Strain IWI	150	31.85	”
WL Strain IWJ	150	31.40	”
WL Strain IWX	150	29.87	”
WL Strain Control	150	31.16	”
IWH × IWI (WL)	120	30.71	Singh *et al* (1981)
IWI × IWH (WL)	120	29.87	”
Percent Albumen (Wt)			
White Leghorn	--	56.40	Kheireldin *et al* (1968)
White Leghorn	--	60.11	Johari & Singh (1968)

Table 6 to continue ....

Breed/strain	No. of obs.	Mean	Reference
WL Strain L 33	125	56.07	Pandey *et al* (1984)
WL Strain L 55	112	57.83	"
WL Strain L 77	77	58.34	"
WL Strain L 99	115	58.09	"
WL Strain Control	106	57.62	"
WL Strain IWG	150	57.50	Pandey *et al* (1986)
WL Strain IWH	150	58.37	"
WL Strain IWI	150	58.40	"
WL Strain IWJ	150	58.80	"
WL Strain IWX	150	57.56	"
WL Strain Control	150	57.50	"
White Plymouth Rock	-	56.50	Kherieldin *et al.* (1968)
New Hampshire	-	57.50	"
Rhode Island Red	-	62.11	Johari & Singh (1968)
RIR Line EN	105	53.97	Panday *et al.* (1987)
RIR Line EM	111	54.89	"
RIR Line R	144	53.60	"
RIR Line C	47	52.82	"
Karaknath	40	52.65	Mahapatra *et al.* (1982)
Aseel Peela	40	53.21	"
Aseel Kagar	40	52.30	"
KN X WL	40	58.37	"
KN X WL	40	56.80	"
KN X NH	40	51.17	"

The average albumen index in White Leghorn is reported to be ranged from 6.27 to 10.99. In Rhode Island Red it is reported to be ranged from 7.4 to 9.89. The average albumen index of exotic breeds such as White Cornish, White Plymouth Rock and New Hampshire reported to be 7.39, 8.10 and 7.83 respectively. The average index value of indigenous breeds like Aseel and Karaknath reported to be 9.0 and 7.4 respectively. In strain crosses of White Leghorn the average albumen index reported to be ranged from 7.21 to 11.44 and in crosses between indigenous breeds with exotics reported to be ranged from 8.8 to 11.0.

The average albumen height of White Leghorn eggs reported to be ranged from 5.21 to 7.49 mm. The average albumen height of Rhode Island Red eggs reported to be ranged from 5.59 to 6.93 mm.

The average albumen weight of White Leghorn eggs reported to be low, in general, as compared to that of meat type breeds. In White Leghorn strain crosses the average albumen weight reported to be ranged from 29.87 to 30.71. The average albumen weight of Rhode Island Red, White Cornish, White Plymouth Rock and New Hampshire reported to be 32.63, 34.72, 35.22 and 32.53g respectively.

The average estimates of albumen percentage in exotic breeds of chicken and their strains reported to be ranged from 52.82 to 62.11 and in indigenous breeds ranged from 52.30 to 53.21. In the

crossbred of exotics with indigenous it is reported to be ranged from 51.17 to 58.37%.

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. Some breed differences for yolk index have been observed (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.

Kaufman and Baczkowski (1937) and Hall (1939) reported that the portion of total egg weight represented by yolk varies slightly between breeds. Kumar and Kapri(1966) found no significant differences between sires for Yolk Index, while Johari and Singh (1968) recorded the differences for yolk index between eggs of White Leghorn and Rhole Island Red breeds. Comparative study of breeds like Desi, Naked Neck, Aseel, White Leghorn, Rhode Island Red and White Plymouth Rocks by Lohchuba and Kumar (1971)

revealed significant differences among breeds for yolk index and albumen/yolk ratio. They noted greater albumen/yolk ratio in exotic breeds. Rahmatullah et al. (1978) reported significant influence of breeds and strains on yolk index. Singh et al. (1978) reported significant differences between the egg laying commercial stocks for yolk index.

Kotaiah et al. (1976) observed highly significant differences between strains within age and between ages within strain for yolk index in their study with two strains of White Leghorn and one strain of Australorp.

Reddy et al. (1980) conducted an experiment of 2 -way and 3 -way strain crosses of White Leghorn for egg quality traits. They observed superiority of 3-way crosses over 2-way crosses for yolk index. Singh et al (1981) observed the effect of reciprocal crosses of two strains of White Leghorn birds on yolk weight but not to yolk index. Mahapatra et al. (1982) evaluated the egg quality traits from different desi breeds like Karaknath (KN), Aseel Peela (AP), Aseel Kagar (AK) and their crosses with exotics such as KN × WL and KN × NH which revealed significant differences between breeds and their crosses for yolk index. KN × WL and KN × NH crosses reported to have significantly higher yolk indices than the pure breeds. Verma et al. (1983) did not note any significant difference among the

various genetic groups of White Leghorn chicken for yolk index. Pandey *et al.* (1984,' 86,' 87) in their studies found significant difference between strains of White Leghorn and Rhode Island Red for yolk index.

According to Brant *et al.* (1955) the yolk index of fresh eggs affected by the age of laying hen.

Yolk height and yolk diameter :

Tarabrina (1957) ascertained that in addition to considerable individual variation, there were breed differences in the relation between yolk height and diameter.

Bornstein and Lipstein (1962) stated that yolk height and yolk diameter are unacceptable as measures of yolk quality due to their significant correlation with egg weight. Nevertheless, under certain circumstances, they may be highly correlated with yolk index. 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.

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.

Yolk weight :

The proportion of total egg weight represented by yolk reported to be vary slightly between breeds (Kaufmen and Baezkowski, 1937 and Hall, 1939). Similar observation was also made by Johari and Singh (1968). They did not observe breed differences for yolk weight and yolk percentage between eggs of White Leghorn and Rhode Island Red breeds of chicken. However, Rahmatullah *et al.* (1978) reported significant influence of breeds on yolk weight but did not ascertain for strain differences. The existence of non significant differences in egg weight between the strains indicated that the portion of total egg weight represented by yolk varies only slightly between strains. They reported the superiority of White Plymouth Rock over White Cornish, New Hampshire and White Leghorn breeds for these traits. The superiority of White Plymouth Rock is expected due to its genetic superiority for better adaptability. Singh *et al.* (1981) observed the effect of reciprocal crosses of two strains of White Leghorn birds on yolk weight but not on yolk percentage.

Arafa *et al.* (1982) reported significant differences for yolk weight and yolk percentage between commercial strains of layers both at 52 and 64 weeks of age.

In a study of egg quality traits from different desi breeds like Karaknath (KN), Aseel Peela, Aseel kagar and their cross with exotics such as KN × WL and KN × NH, Mahapatra et al. (1982) did not observe heterotic effect on yolk percentage. The higher percentage of yolk, estimated on volume and weight basis, reported in Karaknath breed. They reported significant difference between breed crosses for yolk percentage.

Pandey et al. (1984) reported significant strain differences for yolk percent and in 1986 they reported significant strain differences for both yolk weight and yolk percentage in the eggs of White Leghorn chickens. In another study Pandey et al. (1987) did not observe strain differences for yolk percent in eggs of Rhode Island Red breed.

Diwan Chand (1987) conducted an experiment on yolk quality in three meat type breeds viz., White Plymouth Rock, White Cornish and New Hampshire at different periods from June to May in the first year of laying. They reported significant differences for yolk weight, and White Plymouth Rock reported to be superior over the other breeds.

Hunter et al. (1936), Sauter et al. (1954) and Johari and Singh (1968) observed that the yolk weight though increased in second year of production but yolk percentage decreased indicating that the proportion of total egg weight represented by yolk is not

increased with the proportionate increase of egg weight in the second year.

Hafez *et al.* (1955) reported that yolk percentage increased while albumen percentage decreased in eggs laid by pullets during the first year of laying. They reported that the actual weight of egg components increased continuously throughout the experimental period while the relative weight showed continuous decline. They observed 35.37% of yolk of the total egg weight. Saito *et al.* (1956) reported 30.60 and 28.66% of yolk of total egg weight in Nagoya and White Leghorn breeds respectively. Anorova (1966) found 25.25% yolk of total egg weight in first month of lay and 39.69% in the 6th month of lay. Kheireldin *et al.* (1968) observed 32.0, 32.2 and 31.7% of egg yolk in White Leghorn, White Plymouth Rock and New Hampshire breeds respectively.

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.

The mean values of yolk index of fresh eggs reported to be ranged from 35.96 to 46.13 in White Leghorn, 41.7 to 48.57, in Rhode Island Red and 41.0 to 46.55 in indigenous breeds. The mean yolk index of White Cornish, White Plymouth Rock and New Hampshire breeds reported to be 38.22, 39.11 and 38.10 respectively.

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

Breed/Strain	No. of obs.	Mean	Reference
Yolk Index			
White Leghorn	500	36.05	Rahmatullah *et al* (1978)
WL strain A	100	36.73	"
WL strain B	100	36.05	"
WL strain C	100	37.30	"
WL strain D	100	35.96	"
WL strain E	100	36.06	"
White Leghorn	--	46.13	Maan *et al* (1983)
WL strain L 33	125	44.90	Pandey *et al* (1984)
WL strain L 55	112	43.50	"
WL strain L 77	77	42.70	"
WL strain L 99	115	41.80	"
WL strain control	106	43.70	"
WL strain IWG	150	43.30	Pandey *et al* (1986)
WL strain IWH	150	41.60	Pandey *et al* (1986)
WL strain IWI	150	41.80	"
WL strain IWJ	150	40.70	"
WL strain IWX	150	41.70	"

Breed/Strain	No. of Obs.	Mean	Reference
WL strain Control	150	41.50	"
White Longhorn	--	41.74	Khan *et al* (1989)
Rhod. Island Red	--	48.57	Johari & Singh (1968)
RIR line EN	105	44.30	Pandey *et al* (1987)
RIR line EM	111	43.10	"
RIR line R	144	41.70	"
RIR line C	47	42.40	"
White cornish	100	38.22	Rahmatullah *et al* (1978)
White Plymouth Rock	100	39.11	"
New Hampshire (NH)	100	38.10	"
Karaknath (KN)	40	43.00	Mahapatra *et al* (1982)
Aseel peela	40	41.00	"
Aseel Kagar	40	41.00	"
WPR × WL	30	47.50	Bornstein & Lipstein (1962)
KN × WL	40	44.00	Mahapatra *et al* (1982)
KN × WL	40	45.00	"
KN × NH	40	43.00	"
Yolk Width (mm)			
White Leghorn (7 months age)	30	37.01	Bornstein & Lipstein (1962)

Breed/Strain	No. of Obs.	Mean	Reference
White Leghorn (16 months age)	30	41.40	,,
White Leghorn	--	38.38	Khan *et al* (1989)
WPR × WL	30	41.53	Bornstein & Lipstein (1962)
Yolk Height (mm)			
White Leghorn (7 months age)	30	18.98	Bornstein & Lipstein (1962)
White Leghorn (16 months age)	30	19.28	Bornstein & Lipstein (1962)
White Leghorn	--	16.01	Khan *et al* (1989)
WPR × WL	30	19.75	Bornstein & Lipstein (1962)
Yolk Weight (g)			
White Leghorn	500	15.60	Rahmatullah *et al* (1978)
WL Strain A	100	15.89	,,
WL Strain B	100	15.60	,,
WL Strain C	100	15.76	,,
WL Strain D	100	15.73	,,
WL Strain E	100	16.10	,,
WL Strain IWG	150	15.86	Pandey *et al* (1986)
WL Strain IWH	150	14.53	,,
WL Strain IWI	150	15.37	,,
WL Strain IWJ	150	14.65	,,
WL Strain IWX	150	14.79	,,
WL Strain Control	150	15.71	,,
White Leghorn	--	14.77	Khan *et al* (1989)
Rhode Island Red	--	14.86	Johari & Singh (1968)
White Cornish	100	17.67	Rahmatullah *et al* (1978)
White Cornish	203	15.94	Diwan Chand (1987)
White Plymouth Rock	100	18.21	Rahmatulah *et al* (1978)
White Plymouth Rock	209	16.42	Diwan Chand (1987)
New Hampshire	100	17.45	Rahmatullah *et al* (1978)
,,	195	14.26	Diwan Chand (1987)

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Breed/Strain	No. of Obs.	Mean	Reference
Percent Yolk (Wt.)			
Rhode Island Red	--	28.45	Johari & Singh (1968)
RIR line EN	105	32.56	Pandey *et al* (1987)
RIR line EM	111	32.59	"
RIR line R	144	33.03	"
RIR line C	47	33.74	"
White Leghorn (WL)	-	28.93	Johari & Singh (1968)
WL Strain L 33	125	31.14	Pandey *et al* (1984)
WL Strain L 55	112	28.86	"
WL Strain L 77	77	29.64	"
WL Strain L 99	115	28.88	"
WL Strain Control	106	29.02	"
WL Strain IWG	150	29.97	Pandey *et al* (1986)
WL Strain IWH	150	28.00	"
WL Strain IWI	150	28.30	"
WL Strain IWJ	150	27.54	"
WL Strain IWX	150	28.58	"
WL Strain Control	150	28.96	"
Karaknath(KN)	40	34.06	Mahapatra *et al* (1982)
Aseel Peela	40	31.86	"
Aseel Kagar	40	31.93	"
KN × WL	40	27.61	"
KN × WL	40	28.68	"
KN × NH	40	32.38	"

The mean values of yolk diameter and yolk height as reported in the available literature are very scanty. The average yolk diameter of fresh eggs reported to be ranged from 37.01 to 41.40 mm in White Leghorn.

The mean yolk height reported in the available literature ranged from 16.01 to 19.28 mm. in White Leghorn. However, in crosses between WPR × WL the mean yolk height reported to be 19.75 mm.

The average yolk weight in exotic breeds of chicken reported to be ranged from 14.26g in New Hampshire to 18.21 g in White Plymouth Rock.

The average estimates of yolk percentage in exotic breed of the chicken reported from 27.54 to 33.74. The indigenous breeds reported to have higher percentage of egg yolk than the exotic breeds and ranged from 31.86 to 34.06. In the crosses of indigenous with exotic breeds of chicken it is reported to be ranged from 27.61 to 32.38%.

Correlation :

Correlation between various egg quality traits :

Baelum (1954) reported that there was no correlation between weight of egg shell and thickness of albumen. Baker and Curtiss (1958) and reported that internal quality of eggs was not significantly correlated to any of the external quality traits.

Rauch (1959) investigated the relationships between external quality characters such as shell thickness and breaking strength with interior quality such as yolk height and index, albumen height and index and concluded that internal quality characters were not significantly correlated to any of the external quality characters considered in the study.

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

Egg weight Vs. egg shape :

The phenotypic correlations between egg weight and egg shape have been reported variously in the literature as either positive or negative and generally of a low order (Dickerson, 1955 and Hicks, 1958). Hicks (1958) reported that the low phenotypic correlation between these traits were due to environmental and genetic correlations of opposite sign. He concluded that any environmental factor which tends to increase egg weight causes a relaxation in the egg shape index.

Asmundson (1931) reported that egg length was more variable Sapra and Aggarwal (1971) studied the phenotypic correlation between egg quality traits of various indigenous breeds like Desi, Black Bengal, Aseel, Naked Neck and exotic breeds like New Hampshire, White Plymouth Rock and White Cornish.

Table – 8 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 × Egg shape/shape index		
New Hampshire	0.170	Hicks (1958)
,,	0.129	,,
,,	0.029	,,
White Leghorn	0.029	,,
,,	-0.082	Tung *et al* (1968)
,,	0.03	Maan *et al* (1983
Egg Weight × Albumen height		
White Leghorn	0.231	Eisen & Bohren (1963)
,,	0.251	,,
,,	0.239	Marks & Kinney (1964)
,,	0.42	Kumar & Kapri (1968)
,,	0.17	Pandey *et al* (1984)
Rhode Island Red	0.21	Pandey *et al* (1987)
Egg weight × Shell weight		
White Leghorn	0.707	Marks & Kinney (1964)
,,	0.640	Tung *et al* (1968)
Rhode Island Red	0.57	Pandey *et al* (1987)
Egg Weight × Shell thickness		
White Leghorn	0.362	Marks & Kinney (1964)
White Leghorn	0.241	Tung *et al* (1968)

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Traits	r_p	Reference
"	0.09	Kumar & Kapri (1968)
".	0.09	Maan *et al* (1983)
"	0.007	Pandey *et al* (1984)
Karaknath	0.41	Mahapatra *et al* (1982)
Aseel Kagar	0.599	"
Aseel Peela	0.489	"
KN × WL	-0.345	Mahapatra *et al* (1982)
KN × WL	0.009	"
KN × NH	0.034	"
RIR	0.16	Pandey *et al* (1987)
Egg Weight × Egg width		
White Leghorn	0.867	Tung *et al* (1968)
"	0.98	Kumar and Kapri (1968)
Egg weight × Egg length		
White Leghorn	0.737	Tung *et al* (1968)
"	0.52	Kumar & Kapri (1968)
Egg weight × Albumen index		
Karaknath	0.139	Mahapatra *et al* (1982)
Aseel kagar	0.010	"
Aseel Peela	0.065	"
KN × WL	-0.060	"
KN × WL	0.100	"

Table No. 8 to continue ....

Traits	r_p	Reference
KN$_2$ × NH	0.098	,,
Rhode Island Red	0.080	Pandey *et al* (1987)
Egg weight × Albumen weight		
White Leghorn	0.855	Eisen & Bohren (1963)
,,	0.93	Kumar & Kapri (1968)
Egg weight × percent albumen	0.25	Pandey *et al* (1987)
Rhode island red	0.25	Pandey *et al* (1987)
Egg weight × Yolk weight		
White Leghorn	0.73	Kumar & Kapri (1968)
Rhode Island Red	0.36	Pandey *et al* (1987)
White Plymouth Rock	0.83	Diwan Chand (1987)
White Cornish	0.79	,,
New Hampshire	0.78	,,
Egg weight × Yolk Height		
White Leghorn	0.44	Pandey *et al*(1984)
Egg weight × Yolk Index		
Karaknath	-0.052	Mahapatra *et al* (1982)
Aseel kagar	-0.176	,,
Aseel Peela	-0.041	,,
KN × WL	-0.172	,,
KN × WL	-0.335	,,
KN × NH	-0.118	,,
White Leghorn	0.05	Maan *et al* (1983)

Traits	r_p	Reference
Rhode island Red	0.18	Pandey *et al* (1987)
Egg length ×Shape Index		
White Leghorn	-0.718	Tung *et al* (1968)
Egg length × shell thickness		
White leghorn	0.194	Tung *et al* (1968)
Egg length × Shell weight		
White Leghorn	0.479	Tung *et al* (1968)
Egg width × Egg length		
White Leghorn	0.347	Tung *et al* (1968)
Egg width × Shape index		
White leghorn	0.400	Tung *et al* (1968)
Egg width × Shell thickness		
White leghorn	0.131	Tung *et al* (1968)
Egg width × Shell weight		
White Leghorn	0.490	Tung *et al* (1968)
Shape index × Shell thickness		
White Leghorn	-0.091	Tung *et al* (1968)
White Leghorn	0.21	Maan *et al* (1983)
Rhode Island Red	0.09	Pandey *et al* (1987)
Shape index × Shell weight		
Rhode Island Red	0.06	Pandey *et al* (1987)

Table No. 8 to continue ....

Traits	r_p	Reference
Shape index × Albumen height		
Rhode Island Red	0.12	Pandey *et al* (1987)
Shape index × Albumen index		
Rhode Island Red	0.12	Pandey *et al* (1987)
Shape index × Yolk weight		
Rhode Island Red	-0.07	Pandey *et al* (1987)
Shape index × Yolk index		
White Leghorn	0.70	Maan *et al* (1983)
Rhode Island Red	0.0020	Pandey *et al* (1987)
Shell thickness × Albumen height		
White Leghorn	0.02	Pandey *et al* (1984)
Rhode Island Red	-0.12	Pandey *et al* (1987)
Shell thickness × Albumen index		
Rhode Island Red	-0.14	Pandey *et al* (1987)
Shell thickness × Yolk weight		
Rhode Island Red	-0.06	Pandey *et al* (1987)
Shell thickness × Yolk index		
Rhode Island Red	0.16	Pandey *et al* (1987)
Shell thickness × Shell weight		
White Leghorn	0.783	Marks & Kinney (1964)
"	0.860	Tung *et al* (1968)
Rhode Island Red	0.80	Pandey *et al* (1987)

Traits	r_p	Reference
Shell weight × Albumen index		
Rhode Island Red	-0.10	Pandey *et al* (1987)
Shell weight × Yolk index		
Rhode Island Red	0.22	Pandey *et al* (1987)
Shell weight × Yolk weight		
Rhode Island Red	0.14	Pandey *et al* (1987)
Albumen height × Yolk height		
White Leghorn	0.07	Pandey *et al* (1984)

They found highly significant and positive correlation of egg weight with egg length and egg width in all the breeds. They commented that increase in egg size is accompanied by the increase in length and width of the egg so that the egg shape remain oval.

Maan et al. (1983) studied the genetic and phenotypic correlations among egg quality traits in White Leghorn. The genetic correlation of egg weight with shape index was reported to be high and positive.

Egg weight Vs. shell quality :

Mueller et al. (1960) studied the relationship between average egg wt, shape index and shell thickness of the pullet year and corresponding averages for the second year of production and reported correlation coefficient of 0.676, 0.580 and 0.658 respectively. Perek and Snapir (1970) found significant and negative correlations between egg weight and shell quality in White Leghorn when analyzed on the basis of individual averages and on weekly averages for the breed throughout the experimental period. However, they did not observe significant correlation between these traits in case of White Plymouth Rock. Acharya et al. (1970) also found negative correlation between these two traits.

Mahapatra et al. (1982) studied the correlation coefficients of egg weight with other external quality traits in desi breeds like Karanath (KN), Aseel Peela (AP), Aseel Kagar (AK) and

their crosses with exotic breeds of chicken such as KN × WL and KN × NH. They stated that egg weight was positively correlated with shell thickness in pure breeds and negatively correlated in KN × WL crosses. The egg weight was positively correlated with shell weight in all the groups.

Egg shape Vs. Shell quality :

Helmy (1964) reported non-significant correlation of shape index with egg weight and shell thickness. King and Hall (1955) found no relationship between shell thickness and shape index.

In the study of genetic and phenotypic correlations among various egg quality traits in White Leghorn chicken Maan *et al.* (1983) reported very high and positive phenotypic correlation between shape index and shell thickness.

Shell thickness Vs. egg weight :

The egg weight is reported to be correlated with the thickness of the shell (Olsson, 1936). Wilhem (1940) found an association of egg size with shell quality and opined that the larger the egg the thicker the shell.

Foster and Neil (1972) were of the opinion that small amount of variation in shell thickness could be attributed to variation in egg weight between birds. They obtained small correlation coefficient between shell thickness and egg weight due to

common seasonal and aging affects and so there was a little tendency for the egg shells to become thinner as the birds aged. Pandey *et al.* (1984) reported positive but very negligible amount of correlation between shell thickness and egg weight. Pandey *et al.* (1987) also observed positive correlation with low magnitude between these traits but coefficient was highly significant.

Shell thickness Vs. shell weight :

Positive and very high magnitudes of correlation of shell thickness with percent shell and shell weight were observed by Marks and Kinney (1964).

Pandey *et al.* (1984) studied the physical quality traits of eggs from different strains of White Leghorn and observed that the different shell quality traits such as shell thickness and shell weight were highly correlated.

Albumen quality Vs. other traits :

The phenotypic correlation of albumen height with egg weight and shell thickness were reported to be significant and positive (Ishibashi and Takabashi, 1968). Kotaiah *et al.* (1975) found non- significant correlation between albumen index and shell thickness.

Eisen *et al.* (1962) observed relatively low but highly significant correlation between albumen height and egg weight. The regression of albumen height on egg weight were reported to be linear and highly significant.

Saeki *et al.* (1968) studied the relationship between albumen quality traits with egg weight of White Leghorn and some meat type breeds of chicken. They observed positive and significant correlation between egg weight and albumen weight but the correlation of egg weight with albumen height was considerably low.

The genetic and phenotypic correlations among egg quality traits in White Leghorn chickens were studied by Maan *et al.* (1983). They were of the opinion that selection on the basis of shape index may lead to an improvement in the internal egg quality traits as compaired to the selection on the basis of egg weight. Campos *et al.* (1964) also stated the similar facts.

Pandey *et al.* (1984) showed positive correlation of albumen height with egg weight. The positive correlations of egg weight with albumen height and percent albumen were observed by Pandey *et al.* (1987).

Among different albumen quality traits :

In the study of relationship among various albumen quality traits, Rauch (1959) and Kotaiah *et al.* (1975) reported highly significant correlation between albumen height and albumen index.

Yolk quality Vs. other traits :

Henderson *et al.* (1941) recorded significant and positive correlation between yolk and albumen indices. Rauch (1959) also obtained a positive and significant correlation between albumen and yolk indices and between yolk height and yolk indices.

A comparative study was made by Bornstein and Lipstein (1962) between the largest eggs from young flocks and the smallest eggs from older ones which demonstrated that yolk height of fresh eggs is completely independent of the age of layer and instead there exists a highly positive correlation between egg weight and yolk height.

Saeki *et al.* (1968) in their study of egg quality traits found significant correlation between egg weight and yolk weight in different breeds of chicken. They reported that correlations between these two traits were lowest in White Plymouth Rock and highest in White Leghorn chicken.

The yolk index was reported to be negatively correlated with egg weight in all the desi breeds of chicken like Karaknath, Aseel Peela and Aseel kagar and their crosses with exotics like KN × WL and KN × NH (Mahapatra *et al.*, 1982). They also reported that the percent yolk weight was positively correlated with egg weight in KN × NH crosses.

Maan *et al.* (1983) studied phenotypic correlations among egg quality traits of White Leghorn chicken. The phenotypic correlation between yolk index and shape index reported to be very high.

Pandey *et al.* (1984) in their study of relationship among egg quality traits reported that yolk weight had negative correlation

with egg weight where as yolk height was positively correlated with egg weight in White Leghorn chicken.

Pandey *et al.* (1987) reported positive correlation of egg weight with yolk index and yolk weight.

Very high, significant and positive correlation coefficients were observed by Diwan Chand (1987) between yolk weight and egg weight in White Plymouth Rock, White Cornish and New Hampshire breeds of chicken.

Relationship among different yolk quality traits :

Rauch (1959) studied the phenotypic correlation between different yolk quality characters such as yolk height and index of the eggs from laying hens of 6 different breeds and found significant correlation among these traits.

Borantein & Lipstein (1962) showed a positive and very high magnitude of phenotypic correlation between yolk height and yolk index.

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 breeders (Singh, 1961), laying capacity of strains (Bernier *et al*, 1951), Stage of laying cycle (Tomohave, 1958) etc.

Certain strains and breeds have found to differ in fertility. Munro (1940) found that White Wyandottes were less fertile in comparison to some of the other breeds of domestic chickens. Mahadevan (1954) could not find any significant difference in fertility between Australorp and RIR. Gleichauf (1963) found that fertility was 85.9 and 90.7% for Australorp and White Leghorn eggs in a comparative study, respectively. The highest percentage of infertility in New Hampshire reported by Hussaini (1963). Reddy *et al*. (1965) reported the significant breed differences for fertility. The White Leghorn was reported to be superior for fertility over the Rhode Island Red and White Plymouth Rock, however, these two breeds did not differ significantly in their fertility. Chaudhary and Alvi (1967) also did not observe significant differences for fertility among the meat type breeds like Rhode Island Red and New Hampshire. Chhabra and Sapra (1972) observed that White Rock produces the eggs with inferior fertility as compared to New Hampshire and White Cornish. Hussaini and Desai (1972) found that the purebreds had infertility of only 9.2% whereas the crossbred eggs showed an over all infertility of 12.8%. A comparative study on fertility was made by Sapra *et al*. (1972) in various meat type breeds of chicken like White Plymouth Rock, White Cornish, New Hampshire and their crosses, and reported the existence of significant differences between breeds and their crosses in respect to fertility. The hightest fertility was reported in New Hampshire

among the pure breeds (78.18%) and WC × WPR among the crosses (80.20%).

The breeding system is also found to have a significant effect on fertility. The difference in fertility between various type of mating system is either a function of the strain of male and females used for crossing or is due to preferential matings 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), Funk and Irwin (1955).

Bernier et al. (1951) reported that fertility was a property of parents and not of prospective zygotes resulting from the matings. They also found that inbreeding did not influence the fertility directly, but that hens of an inbred origin were less fertile than hens of an outbreed origin irrespective of the kind of males to which they were mated. Similarly the crossbreeding and out-breeding were not found to affect fertility.

Wodzinoswski (1954) compared reciprocal crosses of Sussex, Rhode Island Red, Leghorn and Poliah Green Leg and found fertility was low in crossbreeds.

Hussaini (1963) observed infertility of only 9.2% in purebreds as compared to crossbreeds in which it was 12.8%. He also concluded that percentage of infertile eggs laid by females mated to males of their own breed are comparatively lower than by those mated to males of other breeds.

Colotiva and Morandici (1966) reported 88.8% fertility in Cornish × Plymouth Rock cross against 90.9% in Plymouth Rock purebreds.

Galjpern and Vinogaadova (1969) observed heterosis of fertility in Cornish male × White Plymouth Rock female crosses at -6.2 and + 6.3 over dam and sire breeds respectively. For the reciprocal crosses, the values were -6.5 and -19.0.

Basu (1969) found lower fertility in the crossbreeds as compared to purebreds and strain cross.

Husain (1972) also observed that purebreds are better in fertility than crossbreeds and Aseel × White Rock cross had least fertility.

Sapra *et al.* (1972) have reported that White Rock × New Hampshire mating had the fertility as low as 68.16%, which is attributed to incompatability of two breeds.

Mohapatra *et al.* (1974) found significant differences for fertility in White Rock, White Cornish and New Hampshire crossbred chickens.

Singh (1978) reported that crossbreeds are not superior to purebreds in fertility.

Hussaini and Desai (1972) are of the opinion that the fertility is basically a function of dam and as such, the system of breeding may not influence the difference in fertility between breeds and strains.

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

Table – 9 Fertility percentages in various pure and crossbred chicken reported in the available literature.

Breed	Fertility percentages	Reference
New Hampshire	84.3	Hussaini (1963)
"	78.18	Sapra et al (1972)
"	91.37	Yadev & Sengar (1983)
Rhode Island Red	93.5	Hussaini (1963)
"	76.3	Reddy et al (1965)
"	98.60	Husain (1972)
White Plymouth Rock	69.4	Reddy et al (1965)
"	90.9	Colotiva & Morandici (1966)
"	98.6	Husain (1972)
"	70.67	Sapra et al (1972)
"	89.38	Yadav & Sengar (1983)
"	90.22	Sharma (1984)
White Leghorn	90.7	Gleichauf (1963)
"	87.1	Reddy et al (1965)
White Cornish	75.01	Sapra et al (1972)
"	97.2	Ramappa & Gowda (1973)
Red Cornish	89.60	Sharma (1984)
WC (M) × WPR (F)	88.8	Colotiva & Morandici (1966)

Table No. 9 to continue

Breed	Fertility percentages	Reference
WC (M) × WPR (F)	80.20	Sapra et al (1972)
WC (M) × WPR (F)	95.5	Ramappa & Gowda (1973)
WC (M) × WPR (F)	64.86	Yadav & Sengar (1983)
RC (M) × WPR (F) ·	85.18	Sharma (1984)
RIR (M) × NH (F)	61.4	Hussaini (1963)
NH (M) × RIR (F)	94.3	Hussaini (1963)
WPR (M) × RIR (F)	98.68	Husain (1972)
RIR (M) × WPR (F)	95.2	Husain (1972)
WPR (M) × WC (F)	79.67	Sapra et al (1972)
WPR (M) × NH (F)	68.16	Sapra et al (1972)
NH (M) × WPR (F)	72.19	Sapra et al (1972)
NH (M) × WC (F)	76.92	Sapra et al (1972)
WC (M) × NH (F)	71.47	Sapra et al (1972)
WPR (M) × RC (F)	83.69	Sharma (1984)

M – Male;   F - Female

WC – White Cornish;   WPR – White Plymouth Rock

RC – Red Cornish;   NH – New Hampshire

RIR – Rhode Island Red;   WL – White Leghorn

The average fertility percentage in various pure breeds of chicken reported to be ranged from 69.4 in White Plymouth Rock to 98.60 in Rhode Island Red and White Plymouth Rock. The average fertility percentage in New Hampshire reported to be ranged from 78.18 to 91.37, in Rhode Island Red reported to be ranged from 76.3 to 98.60, in White.Plymouth Rock ranged from 69.4 to 98.6, in White Leghorn from 87.1 to 90.7, in White Cornish from 75.01 to 97.2 and in Red Cornish as 89.60.

Among the crossbreeds the fertility percentages reported to be ranged from 61.40 in RIR × NH crosses to 98.68 in WPR × RIR crosses.

Hatchability :

Generally the term hatchablity 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 frequencies 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 breeders, genetic background of the breeding stock etc. (Arora, 1970).

The average size eggs give better hatchability than that of large size eggs as reported by many workers (Godfrey, 1936 and

Skoglund *et al.*, 1948). They also found the lower hatchability in extremely large and small size 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 hatachability in eggs of White Leghorn weighing from 46-64g and concluded that normal shaped eggs had hatchability of 87% against 49% of unshaped eggs. Czarnecka (1954) observed good hatchability (74.8%) from the large eggs weighing over 65g although medium sized eggs weighing between 60-65g gave the better hatchability (81.1%). Their study also revealed that hatchability of the large eggs may be low if they come from the hens that normally lay small eggs. Singh and Desai (1962) also observed less hatchability from large size eggs than the smaller eggs. However, Arboleda *et al.* (1960) reported that size of eggs did not affect hatchability.

Skoglund (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 hathability than the extremes.

Breed effect :

The existence of breed differences and different breeding systems on hatchability have been reported by many authors in the available literatures. Mahadevan (1954) reported the significant differences in hatchability between Australorp and Rhode Island Red

pullets eggs and observed the hatchability of 83.4 and 76.3% respectively. Kawahara (1961) reported that average hatchability of fertile eggs was significantly higher in White Leghorn than the Barred Plymouth Rock. Gleichauf (1963) also observed the significant breed differences for hatchability and found the hatchability of 75.5 and 80.9% in Australorp and White Leghorn respectively. The significant difference in hatchability between light and heavy breeds observed by Rainford (1954). Reddy et al. (1965) studied the hatchability of White Leghorn, Rhode Island Red and White Plymouth Rock and observed the significant breed differences for hatchability. The superior hatchability of fertile eggs was reported to be achieved in White Leghorn over the hatchability in Rhode Island Red and White Plymouth Rock eggs. A comparative study was made by Sapra et al. (1972) in various meat type breeds like White Plymouth Rock, White Cornish and New Hampshire and their crosses. They reported the existence of significant breed differences and their crosses for hatchability.

Inbreeding has been reported to adversely affect the hatchability by Cole and Halpin (1961).

Hatchability has been reported to be improved through crossbreeding as reported by Byerly et al. (1934), Warren (1942), Knox et al. (1943), Dickerson et al. (1950), Hutt and Cole (1952), Nordskog and Ghostley (1954). However, Kushner et al. (1952) compared NH x WL and found no appreciable difference in

percentage of hatchability while Fomin (1952) found that New Hampshire or Pervomai Cock × Leghorn female crossing improves the hatchability in comparison to purebreds. Redith (1956) also got 95% haltchability in crossbreeds, while only 80.2 and 91.9% in parental breeds.

Colotiva and Morandici (1966) observed 87% hatchability in Cornish × Plymouth Rock Crosses while only 83.29% in Plymouth Rock purebred. Hussaini (1963) obtained 70.3% hatchability in crossbreeds against 57.5% in pure breeds showing the superiority of cross breeding for improving hatchability over pure breeding.

Galipern and Vinogaadova (1969) estimated heterosis value for Cornish male × White Rock female cross as + 3.8 and + 6.1 over dams and sire breeds. While for reciprocal cross, values were -3.3 and -5.6 respectively. Basu (1969) reported non-significant differences in hatchability percentage of Rhode Island Red and White Leghorn purebreds, strain cross, top cross and crossbreds. Sinickin (1969) reported a heterosis from 0.8 to 11.7% in different crosses over parental breeds for hatchability percentage.

Sapra et al. (1972) found superiority of crossbreeds over purebreds for hatchability, in general. Husain (1972) reported that hatchability is more in crossbreeds and the cross involving Rhode Island Red were better than others. Singh et al. (1974) compared various groups of purebreds and crossbreeds and found that all crossbreeds were better than the purebreds as the hatchability is

concerned. Heterosis was also noted by Agrawal *et al.* (1978) for hatchability percentage in crossbreeds over White Rock and White Cornish purebreds and strain crosses. Singh (1978) studied the hatchability of New Hampshire, Australorp and White Cornish breeds of chicken and their crosses and found that crossbreeds were not superior to purebreds in hatchability.

The average hatchability percentage of various pure and crossbred chickens reported in literature is presented in Table - 10.

The hatchability percentage of fertile eggs reported to be ranged from 44.10 to 94.20 in pure breeds and 37.54 to 95.20 in crossbreeds. The average hatchability percentage in Rhode Island Red reported to be ranged from 52.43 to 94.2, in New Hampshire from 49.10 to 80.01, in White Leghorn from 66.8 to 80.9, in White Plymouth Rock ranged from 44.1 to 91.0, in White Cornish 73.77 to 93.50 and 55.36 in Red Cornish.

From the available literature it appears that fertility percentages in purebreds reported to be ranged from 69.40 to 98.60 and in crosses from 61.40 to 98.68. The hatchability on the basis of fertile eggs set reported to be ranged from 42.60 to 93.50% in purebreds and 37.54 to 95.40% in crossbreds.

It appears that egg weight is significantly influenced by breeds, strain and their crosses and exotic breeds reported to have produced significantly heavier eggs than the indigenous breeds. The average egg weight of indigenous breeds of chicken is reported to be ranged from 39.53 to 52.80 g and in exotics from 49.47 to 60.16 g.

Table – 10 Hatchability percentages of pure and crossbred chicken as reported in the available literature.

Breed	Hatchability percentages	Reference
Rhode Island Red	56.7	Hussaini (1963)
"	59.6	Reddy et al (1965)
"	80.25	Chaudhary & Alvi (1967)
"	52.43	Latif & Salam (1970)
"	94.2	Husain (1972)
New Hampshire	49.1	Hussaini (1963)
"	80.01	Chaudhary & Alvi (1967)
"	54.16	Latif & Salam (1970)
"	69.00	Sapra et al (1972)
White Leghorn	80.9	Gleichauf (1963)
"	66.8	Reddy et al (1965)
White Plymouth Rock	44.1	Reddy et al (1965)
"	83.29	Colotiva & Morandici (1966)
"	91.0	Sinickin (1969)
"	90.7	Husain (1972)
"	53.10	Sapra et al (1972)
"	78.4	Ramappa & Gowda (1973)
"	58.33	Yadav and Sengar (1983)
"	58.33	Sharma(1984)
White Cornish	93.50	Sinickin (1969)
"	73.77	Sapra et al (1972)
"	78.4	Ramappa & Gowda (1973)
"	90.37	Singh et al (1974)
Red Cornish	55.36	Sharma (1984)

Breed	Hatchability percentages	Reference
NH (M) × RIR (F)	67.3	Hussaini (1963)
RIR (M) × NH (F)	55.5	Hussaini (1963)
RIR (M) × NH (F)	37.54	Latif & Salam (1970)
WC (M) × WPR (F)	87.00	Colotiva & Morandici (1966)
WC (M) × WPR (F)	60.38	Sapra *et al* (1972)
WC (M) × WPR (F)	80.4	Ramappa & Gowda (1973)
WC (M) × WPR (F)	64.58	Yadav & Sengar (1983)
WPR (M) × RIR (F)	83.07	Latif & Salam (1970)
WPR (M) × RIR (F) ·	92.4	Husain (1972)
RIR (M) × WPR (F)	95.2	Husain (1972)
WPR (M) × WC (F)	84.00	Sapra *et al* (1972)
WPR (M) × NH (F)	80.21	Sapra *et al* (1972)
NH (M) × WPR (F)	85.18	Sapra *et al* (1972)
NH (M) × WC (F)	76.50	Sapra *et al* (1972)
WC (M) × NH (F)	62.56	Sapra *et al* (1972)
WPR (M) × WC (F)	80.2	Ramappa & Gowda (1973)
NH (M) × WC (F)	85.42	Singh *et al* (1974)
NH (M) × Australorp (F)	91.27	Singh *et al* (1974)
WC (M) × NH (F)	88.43	Singh *et al* (1974)
WC (M) × Australorp (F)	83.90	Singh *et al* (1974)
Australorp (M) × NH (F)	77.87	Singh *et al* (1974)
Australorp (M) × WC (F)	76.16	Singh *et al* (1974)
WPR (M) × RC (F)	67.53	Sharma (1984)
RC (M) × WPR (F)	70.65	Sharma (1984)

M – Male;   F - Female

WC – White Cornish;   WPR – White Plymouth Rock

RC – Red Cornish;   NH – New Hampshire

RIR – Rhode Island Red; WL – White Leghorn

Shape index, one of the most important characters of the eggs, varies widely. The deviation from its normal shape increase the tendency towards breakage during transportation and handling and reduced hatchability. The shape indices of normal eggs reported to be ranged from 69.0 to 77.0%.

The shell thickness and shell weight are the other important traits of the external egg quality varies significantly from breed to breed and strain to strain as reported in the literature. The average percentage of shell weight in exotic breeds of chicken reported to be ranged from 9.47 to 10.5 and 11.4 to 12.11 in indigenous breeds. The overall shell thickness reported to be ranged from 0.25 to 0.36 mm.

Among the interior quality traits the albumen quality is the most important character of eggs. The yolk quality is also largely depends on albumen quality. Like shape index the albumen quality varies significantly between breeds and strains, whereas yolk quality do not. The average albumen index and yolk index reported to be ranged from 6.27 to 12.3 and 35.96 to 51.10 respectively. The albumen and yolk percent reported to be ranged from 51.17 to 64.11 and 27.54 to 34.32% respectively.

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Chapter-3

Materials & Methods

MATERIALS AND METHODS

Eggs of five genetic groups, consisting of three purebreds and two crossbreds of chicken, maintained at Central Poultry Farm, Patna on random mating for a large number of generations, constituted the experimental materials for the present study. The five genetic groups were as follows

Purebreds	Crossbreds

1. White Cornish (WC)   4. WC ♂♂ × WPR ♀♀

2. White Plymouth Rock(WPR)   5. RC ♂♂ × WPR ♀♀

3. Red Cornish (RC).

Six males and 42 females were taken from each genetic group and maintained separately under deep litter system in a flock with a mating ratio of 1 Male : 7 Females during the experimental period. To study the genetic effect on egg weight and egg quality traits a total of 600 eggs were collected at random at the rate of 120 eggs from each genetic group at 36 weeks of age. To examine the effect of egg weight on egg quality traits all these eggs were divided into 5 different groups according to the egg weight with the difference of 3 g from each. These groups were designated as group I (< 50 g), group II (50-53 g), group III (53-56 g), group IV (56-59 g) and group V (> 59 g) respectively. The eggs were weighed with the help of monopan balance to the nearest of 0.5 g. Similar number of

eggs from each genetic group were also collected at 24 weeks of age to record the egg weight. For the study of fertility and hatchability eggs ranging from 160 to 208 in number were collected from each genetic group for a period of 7 consecutive days at 40 weeks of age. The eggs were stored in the cold storage for a period of 7 days at 15°C prior to the incubation. The eggs were set in the incubation trays and incubated for 14 days at 100°F temperature with relative humidity of 60-70%. The eggs were candled on 7th day of incubation and removed the unfertile eggs. On 14th day of incubation the eggs were transferred to the hatcher maintained at the temperature of 100°F with relative humidity of 80-90% until the chicks hatched out.

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

TRAITS UNDERTAKEN

The following traits were under taken for the present study :-

1. Egg weight at 24 weeks of age

2. Egg weight at 36 weeks of age

3. Egg quality characteristics:

(a) External egg quality	(b) Internal egg quality
i) Egg length	i) Albumen height
ii) Egg width	ii) Albumen index
iii) Shape index	iii) Albumen weight
iv) Egg shell thickness	iv) Percent Albumen weight
v) Shell weight	v) Yolk height
vi) Percent shell weight	vi) Yolk width
	vii) Yolk index
	viii) Yolk weight
	ix) Percent Yolk weight

4.   Fertility parentage

5.   Hatchability parentage

MEASUREMENTS OF TRAITS

Egg Weight : The weight of eggs were taken with the help of monopan balance to the nearest of 0.5g accuracy.

Egg Length & Width : The length and width of the eggs were measured with the help of Verniar Caliper to the nearest of 0.1 cm.

Shape Index : The shape index was calculated as the ratio of egg width to the egg length as given by Shultz (1953).

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

Egg Shell Thickness : The 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 then weight of egg shell was taken with the help of Top Pan Sartorious 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 egg was broken on a perfectly leveled glass plate. The height of thick albumen was measured by Spherometer (S - 6428 model with 0.1 mm. graduation from Walthan mass USA) at the highest and lowest points of the albumen. The average of two measurements was taken as mean height.

Albumen Index : Albumen index was calculated by the following formula, given by Heiman and Carver (1936).

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

Albumen and Yolk Weight and Percentage : The egg albumen and yolk were separated and poured in two clean beakers after cleaning the residual albumen from the shell and weighted by Top Pan Sartorious 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 Index :- Yolk index was calculated as per the formula given by Funk (1948).

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

Height is determined by Spherometer and width (diameter) of egg yolk was measured with the Vernier Caliper. The width was multiplied by 10 to convert it into millimeter 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 of eggs set and expressed as percentage.

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

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 analysed by SPECTRUM-3, FORTRAN - 4, Computer system of DCM at CARI, Izatnagar, Bareilly (UP). Some of the minor calculations were carried out by a programmable scientific calculator.

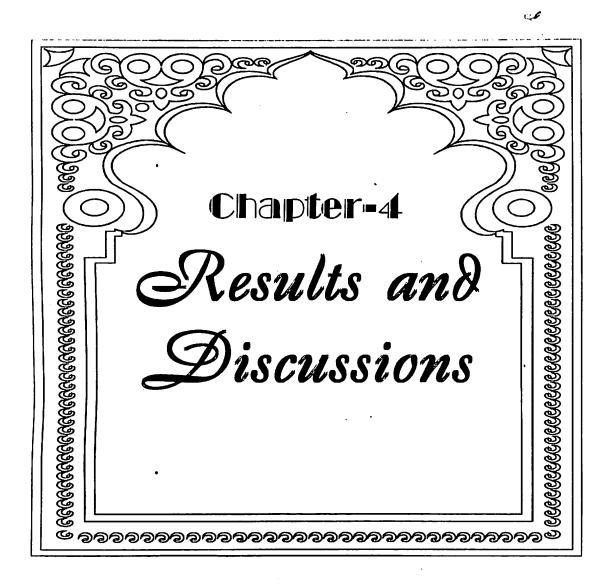## Mean, Standard error and Coefficient of Variation :

The least squares means, standard error and coefficient of variation percentage of each trait were calculated as per standard statistical methods (Harvey, 1966).

To examine the effect of egg weight on egg quality traits the analysis of variance was conducted as per the standard statistical methods (Snedecor and Cochran, 1967). Significant differences were revealed by multiple range test (Duncan, 1955; Kramer, 1957).

The coefficient of phenotypic correlation between the traits were estimated as per standard statistical methods (Snedecor and Cochran, 1967). Heterosis percentage was calculated as per following formula :

$$\text{Heterosis\%} = \frac{\text{Crossbred average - Midparent value}}{\text{Midparent value}} \times 100$$

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Chapter-4

Results and Discussions

RESULTS AND DISCUSSIONS

Egg weight :

Least squares means alongwith standard error (SE) and coefficient of variation percentage (CV%) of egg weight at different weeks of age in pure and crossbred chickens have been presented in Table - 11. The average egg weight at 24 weeks of age was found to be 44.61, 46.92, 45.78, 47.24 and 47.19 g in WC, WPR, RC, WC × WPR and RC × WPR respectively. The analysis of variance for the genetic effect on egg weight is presented in Table - 12 which revealed significant (P<0.01) effect of breeds and their crosses on egg weight. Among the purebreds WPR was observed to be superior over WC and RC. The average egg weight of WPR was found to be significantly (P<0.01) heavier than the eggs of WC and RC by 2.31 and 1.14 g respectively and RC had significantly (P<0.01) heavier eggs than the eggs of WC. Both the crosses were observed to be superior for egg weight over WC and RC. The average egg weight of WC × WPR and RC × WPR crosses was found to be significantly (P<0.01) heavier than the eggs of WC by 2.63 and 2.58 g respectively and from RC by 1.46 and 1.41 g respectively but did not differ significantly from WPR. However, the average egg weight of WC × WPR did not differ significantly from RC × WPR.

Table - 11 Least squares means, SE and CV% of egg weight at different weeks of age in different genetic groups of chicken.

Genetic groups	No. of obs.	Egg weight (g)				% increase in egg weight
		24 weeks		36 weeks		
		Mean ± S.E.	CV%	Mean ± S.E.	CV%	
WC	120	44.61[c] ± 0.283	6.968	53.70[b] ± 0.324	6.610	20.38
WPR	120	46.92[a] ± 0.309	7.221	55.47[a] ± 0.386	7.618	18.22
RC	120	45.78[b] ± 0.327	7.830	54.18[b] ± 0.345	6.964	18.35
WC X WPR	120	47.24[a] ± 0.361	8.375	55.85[a] ± 0.293	5.749	18.23
RC X WPR	120	47.19[a] ± 0.345	7.997	55.98[a] ± 0.308	6.027	18.63

NB : Means with different superscripts (column wise) differ significantly (P < 0.01).

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Table - 12 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 24 weeks	Between groups Error	4 595	155.891 12.771	12.206**
Egg weight at 36 weeks	Between groups Error	4 595	127.624 13.277	9.613**

** Significant at P.< 0.01.

The average egg weight at 36 weeks of age in all the pure and crossbred chickens was observed to be increased by 18% except WC in Which the egg weight was found to be increased by 20%. The average egg weight of WC, WPR, RC, WC × WPR and RC × WPR at 36 weeks of age was estimated to be 53.70, 55.47, 54.18, 55.85 and 55.98 g respectively. The analysis of variance (Table-12) revealed significant effect of breeds and their crosses on egg weight. The average egg weight of WPR was found to be increased significantly (P<0.01) by 1.77 and 1.29 g than the eggs of WC and RC respectively, however, the WC and RC didn't differ among themselves. Significantly (P<0.01) heavier egg weight in both the crosses were found than the purebreds, WC and RC, indicating their superiority over the latter. The average egg weight of WPR was though observed to be slightly lower than the crossbreeds but did not differ significantly. The effect of breed and strain differences on egg weight in chicken as observed by many workers (Hicks, 1958; Kheireldin et al, 1968; Kondra et al, 1968; Johari and Singh, 1968; Sapre and Aggarwal, 1971; Arad and Marder, 1982; Arafa et al, 1982; Mahapatra et al, 1982 and Pandey et al, 1984, '86, '87) were similar to the findings of the present investigation. In an experiment Ramappa and Pillai (1972) observed significant breed differences for egg weight and reported that exotic breeds (RIR and WL) laid significantly heavier eggs than the indigenous breeds of chicken but

the differences among the exotic breeds were not statistically significant. However, Rahmatullah *et al.* (1978) reported the existence of breed and strain differences for egg weight among the exotic breeds and the average egg weight of exotic breeds reported to be ranged from 52.11 g in WL to 60.06 g in WPR. Diwan Chand (1987) also reported the significant breed differences for egg weight and observed that hens of WPR laid significantly heavier eggs than the WC and NH. The results obtained by Saito *et al.* (1957) are not in agreement with the present findings, who reported the non-existence of breed differences for egg weight.

Effect of breeds and their crosses on external egg quality traits :

The least squares means alongwith their standard errors (SE) and coefficients of variation percentage (CV%) of egg length, egg width, shape index and shell thickness have been presented in Table-13 and the analysis of variance for the genetic effect of these traits has been depicted in Table-14.

Egg length :

The means of egg length were estimated to be 5.585, 5.609, 5.515, 5.645 and 5.596 cm in WC, WPR, RC, WC × WPR and RC × WPR respectively. The analysis of variance (Table-14) revealed significant (P<0.01) breed differences as well as differences between

Table – 13 Least squares means, SE and CV% of egg length, egg width, shape index and shell thickness in different genetic groups of chicken.

Genetic groups	No. of obs.	Egg length (cm)		Egg width (cm)		Shape index		Shell thickness (mm)	
		Mean ± S.E.	CV%	Mean ± S.E.	CV%	Mean ± S.E.	CV%	Mean ± S.E.	CV%
WC	120	$5.585^b \pm 0.014$	2.787	$4.109^b \pm 0.011$	2.918	$73.595^d \pm 0.188$	2.794	$0.332^a \pm 0.002$	4.927
WPR	120	$5.609^{ab} \pm 0.020$	3.874	$4.163^a \pm 0.011$	2.973	$74.322^{bc} \pm 0.233$	3.430	$0.325^b \pm 0.002$	6.129
RC	120	$5.515^c \pm 0.013$	2.535	$4.125^b \pm 0.010$	2.585	$74.811^{ab} \pm 0.165$	2.415	$0.327^b \pm 0.002$	6.512
WC X WPR	120	$5.645^a \pm 0.013$	2.566	$4.172^a \pm 0.009$	2.289	$73.922^{cd} \pm 0.134$	2.572	$0.324^b \pm 0.002$	5.177
RC X WPR	120	$5.596^b \pm 0.017$	3.340	$4.189^a \pm 0.009$	2.214	$74.909^a \pm 0.218$	3.185	$0.329^{ab} \pm 0.002$	4.872

NB : Means with different superscripts (column wise) differ significantly ($P < 0.01$).

Table - 14 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 (cm)	Between groups	4	0.275	9.352**
	Error	595	0.029	
Egg width (cm)	Between groups	4	0.133	11.324**
	Error	595	0.012	
Shape index	Between groups	4	38.166	8.190**
	Error	595	4.660	
Shell thickness (mm)	Between groups	4	0.0013	3.894**
	Error	595	0.0003	

** Significant at $P < 0.01$.

crossbreds. Among the purebreds, WPR chicken had significantly (P<0.01) higher egg length than the RC which suggested its superiority over the latter for this trait. Although it had longer eggs than the WC but did not differ significantly. Among the crosses WC × WPR was found to have significantly (P < 0.01) longer eggs than RC × WPR. The superiority of WC × WPR was also observed over the purebreds like WC and RC but did not differ significantly from WPR. The superiority of WC × WPR may be due to better genetic combining ability of these two breeds for this trait. The RC × WPR Crosses although laid significantly shorter eggs from WC × WPR but it had significantly (P < 0.01) higher egg length than the RC, however, did not differ significantly from WC and WPR. The average egg length as observed in the present study were in close agreement with the findings of Sapra and Aggarwal (1971), Singh et al. (1981), and Arad and Marder (1982). The significant breed differences for egg length have been reported by Sapra and Aggarwal (1971). Significant differences of Crossbreeds from purebreds have been reported by Arad and Marder (1982).

Egg width :

The average egg width of WC, WPR, RC, WC × WPR and RC × WPR was estimated to be 4.109, 4.163, 4.125, 4.172 and 4.189 cm respectively. The analysis of variance (Table-14) revealed

significant (P < 0.01) differences for egg width between the genetic groups. Among the Purebreds WPR laid significantly (P<0.01) wider eggs than the WC and RC but did not differ significantly from the crossbred chickens. Both the crosses laid significantly (P<0.01) wider eggs than the WC and RC. The results obtained in the present study are in accordance with the findings of Sapra and Aggarwal (1971), Singh *et al.* (1981), Arad and Marder (1982) and Khan *et al.* (1989). Significant breed differences for egg width as observed in the present findings also reported by Sapra and Aggarwal (1971). They reported that WPR had significantly higher egg width than WC, NH and various indigenous breeds of chicken, however, Arad and Marder (1982) did not observe breed differences for this trait. Singh *et al.* (1981) reported the significant differences between line crosses for this trait.

Shape index :

The average shape indices of WC, WPR, RC, WC × WPR and RC × WPR were calculated to be 73.595, 74.322, 74.811, 73.922 and 74.909 respectively. The analysis of variance (Table-14) revealed significant differences between the genetic groups for this trait. Among the purebreds WPR and RC were found to have similar egg shape and their mean shape indices did not differ significantly. However, these two breeds were found to have significantly (P<0.0)

higher index values than the WC. Significant (P<0.01) differences for egg shape index have also been observed between the crosses. RC × WPR was found to have significantly (P<0.01) higher shape index value than WC × WPR cross as well as over the purebreds such as WC and WPR. It is indicated that RC × WPR chickens may have laid wider eggs as compared to these genetic groups. Significant breed differences for shape index as observed in the present study have also been reported in literature by Rahmatullah et al. (1978). Mahapatra et al. (1982) reported significant differences between breeds and their crosses for shape index. Singh et al. (1981) found significant variation for shape index in reciprocal crosses between two strains of WL. King and Hall (1955) observed significant differences for shape index between strains within breed, however, they did not observe the differences between breeds. Significant strain differences for shape index were also noted by Carter and Jones (1970) and Pandey et al. (1986) but Kumar et al. (1981) did not record significant strain differences. The mean shape index values as observed in the present study were in close agreement with the values reported by Ramappa and Pillai (1972), Kumar et al. (1981), Singh et al. (1981), Mahapatra et al. (1982) and Pandey et al. (1987). Skoglund (1951) classified the chicken eggs into three categories, long and narrow, normal and short and round shape, and observed that eggs of normal shape had shape index values ranging between

69 to 77. Pure and Crossbred chickens studied in the present experiment also laid eggs of normal shape as the shape index values fall within this range.

Shell thickness:

The average estimates of shell thickness of WC, WPR, RC, WC × WPR and RC × WPR chickens were measured to be 0.332, 0.325, 0.327, 0.324 and 0.329 mm respectively (Table 13). The analysis of variance (Table-14) revealed significant differences between genetic groups for shell thickness. Among the purebreds WC had significantly ($P<0.01$) thicker shell as compared to that of WPR and RC, however, the differences between WPR and RC were not significant. The WC was also found to have significantly ($P<0.01$) higher shell thickness than the WC × WPR cross but did not differ significantly from RC × WPR chickens. Among the crosses, RC × WPR was though found to have higher shell thickness than the WC × WPR but did not differ significantly. The differences for shell thickness could not be observed between WPR, RC, WC × WPR and RC x WPR. The estimates of mean shell thickness reported by Johari and Singh (1968), Ramappa and Pillai (1972) and Pandey *et al.* (1987) in RIR, by Pandey *et al.* (1984, 86) in WL, and by Rahmatullah *et al.* (1978) in WC and WPR are in close agreement with the findings of the present investigation. Mahapatra *et al.*

(1982) reported similar observation in crosses of indigenous breeds with exotics, however, Mueller *et al.* (1960) reported higher shell thickness in WL chickens ranging from 0.35 to 0.39 mm. Significant breed differences for egg shell thickness as observed in the present study have also been reported in literature by many workers (Taylor and Martin, 1928; Johari and Singh, 1968; Ramappa and Pillai, 1972; Rahmatullah *et al.*, 1978; and Reddy *et al.*, 1980). However, Mahapatra *et al.* (1982) and Pandey *et al.* (1984) did not find any significant difference for shell thickness between breeds and strains. Taylor and Lerner (1939) and Quinn *et al.* (1945) were of the opinion that lines differing in shell thickness can be established by selection.

Effect of breeds and their crosses on internal egg quality traits :

Albumen Quality :

The least squares means, standard errors (SE) and coefficients of variation percentage (CV%) of albumen height and albumen index have been presented in Table-15 and the analyses of variances showing the effect of breeds and their crosses on albumen height and albumen index have been depicted in Table-16.

Albumen height :

The average estimates of albumen height were shown to be 5.735, 6.009, 6.052, 6.081 and 6.021 mm of WC, WPR, RC, WC ×

Table – 15 Least squares means, SE and CV% of albumen height, albumen index, yolk height, yolk width and yolk index in different genetic groups of chicken.

Genetic Groups	No. of obs.	Albumen height (mm)		Albumen index		Yolk height (mm)		Yolk width (mm)		Yolk index	
		Mean±S.E.	CV%	Mean±S.E.	CV%	Mean±S.E.	CV%	Mean±S.E.	CV%	Mean±S.E.	CV%
WC	120	$5.753^b \pm 0.063$	12.113	$7.453^b \pm 0.109$	16.027	$15.758^b \pm 0.058$	4.052	$40.947^a \pm 0.133$	3.552	$38.509^c \pm 0.156$	4.423
WPR	120	$6.009^a \pm 0.059$	10.695	$7.835^a \pm 0.109$	15.196	$16.189^a \pm 0.099$	6.667	$40.917^a \pm 0.159$	4.255	$39.676^{ab} \pm 0.332$	9.159
RC	120	$6.052^a \pm 0.070$	12.639	$7.928^a \pm 0.116$	16.039	$16.099^a \pm 0.079$	5.369	$40.098^b \pm 0.166$	4.522	$40.212^a \pm 0.246$	6.688
WC X WPR	120	$6.081^a \pm 0.062$	11.091	$7.904^a \pm 0.095$	13.195	$16.120^a \pm 0.094$	6.367	$40.982^a \pm 0.131$	3.493	$39.296^b \pm 0.236$	6.579
RC X WPR	120	$6.021^a \pm 0.065$	11.824	$7.819^a \pm 0.108$	15.090	$15.858^b \pm 0.077$	5.330	$41.108^a \pm 0.118$	3.149	$38.600^c \pm 0.202$	5.718

N.B. : Means with different superscripts (column wise) differ significantly ($P < 0.01$, $P < 0.05$).

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Table - 16 Analysis of variance showing the genetic effect on albumen height, 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	4	2.336	4.781**
	Error	595	0.488	
Albumen index	Between groups	4	4.456	3.210*
	Error	595	1.388	
Yolk height (mm)	Between groups	4	4.152	5.080**
	Error	595	0.817	
Yolk width (mm)	Between groups	4	19.650	8.080**
	Error	595	2.432	
Yolk index	Between groups	4	62.388	8.940**
	Error	595	6.979	

* Significant at $P < 0.05$.

** Significant at $P < 0.01$.

WPR and RC × WPR chickens respectively. The analysis of variance (Table - 16) revealed significant influence of breeds and their crosses on albumen height. The average estimates of albumen height of all the breeds and their crosses did not show significant differences except WC which was found to have significantly (P<0.01) lower albumen height from WPR, RC WC × WPR and RC × WPR by 0.274, 0.317, 0.346 and 0.286 mm respectively. It indicated that WC × WPR and RC × WPR crosses were superior to WC chickens but did not show any significant difference from WPR and RC. The results obtained in the present study are in agreement with the findings of Johari and Singh (1968) and Rahmatullah *et al.* (1978) who reported significant breed differences for albumen height. Kidwell *et al.* (1964), Verma *et al.* (1983) and Pandey *et al.* (1984, '87) reported significant strain differences for albumen height. In an experiment with 2- way and 3-way strain crosses of WL, Reddy *et al.* (1980) reported the superiority of 3-way crosses over 2-way crosses for albumen height, which is not in accordance with the present findings of the crossbred chicken.

Albumen index :

The average estimates of albumen index were calculated to be 7.453, 7.835, 7.928, 7.904 and 7.819 of WC, WPR, RC WC × WPR and RC × WPR chickens respectively (Table 15). The analysis

of variance (Table 16) revealed significant (P<0.05) differences between genetic groups for this trait. The average albumen index of WC breed was found to be significantly (p <0.05) lower by 0.382, 0.475, 0.451 and 0.366 from WPR, RC, WC × WPR and RC × WPR respectively. It indicated that all these pure and crossbred chickens had better albumen quality than the WC. The RC breed was though found to have slightly higher index value than the WPR but did not differ significantly. The average albumen index values of WPR and RC also did not show significant differences from both the crosses suggesting that albumen quality of WC x WPR and RC x WPR was similar to that of WPR and RC breeds of chicken. However, WC x WPR though observed to have higher index value than RC x WPR but did not show any significant difference. Evidence on significant breed and strain differences for albumen quality have been reported in literature by many scientists (Farnsworth and Nordskog, 1955; Baker and Curtiss, 1958). Romanoff and Romanoff (1949) and Johari and Singh (1968) reported significant breed differences for albumen index and Rahmatullah et al. (1978), Verma et al. (1983) and Pandey et al (1984, 87) reported significant strain differences for this trait.

Yolk Quality :

Least squares means alongwith their standard error (SE) and CV% of various yolk quality traits have been presented in Table-15 and the analyses of variances for the effect of breeds and

their crosses on yolk height, yolk width and yolk index have been depicted in Table-16.

Yolk height :

The average estimates of yolk height were obtained to be 15.758, 16.189, 16.099, 16.120 and 15.858 mm of WC, WPR, RC, WC × WPR and WC × WPR chickens respectively (Table-15). The analysis of variance (Table-16) revealed significant (P<0.01) difference between pure and crossbred chickens for yolk height. Among the pure breeds WC had significantly (P<0.01) lower yolk height than the WPR and RC by 0.431 and 0.341 mm respectively. The WC was also found to have significantly (P<0.01) lower yolk height than the WC × WPR cross but did not differ significantly from RC × WPR. The WPR chickens though had slightly higher yolk height but did not differ significantly from chickens of RC. Among the crosses WC × WPR had significantly (P<0.01) higher yolk height than the RC × WPR but did not differ significantly form WPR and RC breeds. Significantly (P<0.01) lower yolk height of RC × WPR chickens from the WPR and RC suggested the genetic incompatibility of these two breeds. However, WPR and RC did not differ significantly from WC. The reports on yolk height were very scanty in the available literature and significant breed differences for this trait could not be observed.

Yolk width

The average estimates of yolk width of WC, WPR, RC, WC × WPR and RC × WPR were found to be 40.947, 40.917, 40.098, 40.982 and 41.108 mm respectively. The significant (P<0.01) differences were found to be existed between the genetic groups for this trait as revealed by analysis of variance (Table-16). WC and WPR breeds were found to have significantly (P < 0.01) more yolk width than the RC by 0.849 and 0.819 mm respectively. Significant differences were not observed between the crosses, however, the mean estimates of yolk width in both the crosses were significantly higher than RC chicken which indicated their superiority over this breed. However, the average yolk width of these crosses did not differ significantly from WC and WPR breeds. The effect of breeds and their crosses on yolk width did not observe in the available literature. Bornstein and Lipstein (1962) observed the existence of very high and negative correlation between yolk index and yolk width and stated that yolk width increases at the cost of yolk quality and the birds lay eggs with lesser yolk width having better yolk quality.

Yolk Index :

The average yolk indices of WC, WPR, RC, WC x WPR and RC x WPR were calculated to be 38.509, 39.676, 40.212, 39.296

and 38.600 respectively. The analysis of variance (Table-16) revealed significant (P < 0.01) differences between pure and crossbred chickens. Among the pure breeds, WC was found to have significantly (P < 0.01) lower index value from WPR and RC by 1.167 and 1.703 respectively, which suggested that these breeds had better yolk quality than WC. The RC breed though had higher index value but did not differe significantly from WPR. Significant (P < 0.01) difference was observed between the crosses. Higher yolk index value in WC x WPR than the RC x WPR indicated its better yolk quality. Significantly (P < 0.01) lower yolk index values were observed in WC x WPR and RC x WPR from RC breed of chicken which suggested that yolk quality may be reduced due to crossing. However, the non-significant differences were existed between WC × WPR and WPR, and between RC × WPR and WC. The results obtained in the present study corroborated with the findings of Johari and Singh (1968), Lohchuba and Kumar (1971) and Rahmatullah et al. (1978) who reported the existence of breed difference for this trait. Mahapatra et al. (1982) reported significant differences between breeds and their crosses for yolk index. Kotaiah et al. (1975) and Pandey et al. (1984, '86, '87) observed significant strain differences for this trait while Verma et al. (1983) did not report significant difference among the various genetic groups for yolk index.

Absolute weight and percentage of albumen :

The least squares means, standard errors (SE)) and coefficients of variation percentage (CV%) of absolute albumen weight have been presented in Table-17 and the analysis of variance for the effect of breeds and their crosses is depicted in Table - 18. The average estimates of absolute albumen weight were estimated to be 31.423, 32.139, 31.825, 32.740 and 32.719 g in WC, WPR, RC, WC × WPR and RC × WPR respectively. The analysis of variance revealed the existence of significant (P<0.0) difference for absolute weight of albumen between the genetic groups. The WPR was though found to have more albumen weight but did not differ significantly from WC and RC breeds of chicken. Non-significant differences were also observed between WC and RC. Both the crosses were found to have significantly (P < 0.01) more albumen weight than the WC and RC breeds of chicken but did not differ significantly from WPR. The superiority of crosses over pure breeds indicated that genes of WC and RC combined well with the genes of WPR for this trait. However, the significant differences could not be noted among the crosses.

The least squares means, SE and CV% of angles corresponding to the percentages of albumen weight have been depicted in Table-19 and the analysis of variance is presented in Table-20. The estimates of average percentage of albumen weight

Table - 17 Least squares means, SE and CV% of albumen weight, yolk weight and shell weight of different genetic groups of chicken.

Genetic groups	No. of obs.	Albumen Weight (g)		Yolk Weight (g)		Shell Weight (g)		Yolk : Albumen
		Mean ± S.E.	CV%	Mean ± S.E.	CV%	Mean ± S.E.	CV%	
WC	120	31.423[b]±0.243	8.478	16.177[b]±0.089	6.028	6.100[b]±0.047	8.490	0.5148
WPR	120	32.139[ab]±0.298	10.144	17.142[a]±0.098	6.245	6.188[ab]±0.056	9.845	0.5333
RC	120	31.825[bc]±0.256	8.798	16.093[b]±0.114	7.729	6.264[a]±0.054	9.438	0.5056
WC X WPR	120	32.470[ac]±0.218	7.356	17.109[a]±0.101	6.457	6.273[a]±0.047	8.253	0.5269
RC X WPR	120	32.719[a]±0.241	8.058	16.943[a]±0.100	6.486	6.315[a]±0.042	7.267	0.5178

NB : Means with different superscripts (column wise) differ significantly (P < 0.01; P < 0.05).

Table - 18 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	4	31.644	4.140**
	Error	595	7.644	
Yolk weight (g)	Between groups	4	31.920	26.285**
	Error	595	1.214	
Shell weight (g)	Between groups	4	0.867	2.954*
	Error	595	0.294	

* Significant at $P < 0.05$.

** Significant at $P < 0.01$.

corresponding to the angles in WC, WPR, RC, WC × WPR and RC × WPR were observed to be 58.449, 57.844, 58.691, 55.085 and 58.402 respectively. The analysis of variance (Table-20) revealed significant (P<0.05) difference between the genetic groups. WC and RC breeds of chicken were found to have significantly (P < 0.05) higher percentage of albumen over the WPR, however, WC and RC did not differ significantly. The non-significant differences were also found to be existed between the crosses but WC × WPR had significantly (P<0.05) lower percentage of albumen from RC, and RC × WPR had significantly (P<0.05) higher percentage of albumen over WPR.

The results obtained in the present study were in accordance with the findings of many research workers. Johari and Singh (1968) reported significant breed differences for total albumen weight and albumen percentage. Kheireldin et al. (1968) and Baker and Vadehra (1969) observed very high and significant differences between strains of WL in the percent of thick albumen. Significant breed differences were also observed by Rahmatullah et al. (1978) who reported the superiority of WPR over WC, WL and NH breeds of chicken for albumen weight. The average estimates of albumen percentage observed in the present study are in accordance with the findings of Saito et al. (1956), Anorava (1966), Kheireldin et al. (1968), Singh et al. (1981), Mahapatra et al. (1982) and Pandey et al. (1984, '86).

Table - 19 Least squares means, SE and CV% of angles corresponding to percentages (Angles = Arcsin$\sqrt{\text{percentage}}$) of albumen weight, yolk weight and shell weight of different genetic groups of chicken.

Genetic groups	No. of obs.	Albumen Percent (wt.)		Yolk Percent (wt.)		Shell Percent (wt.)	
		Mean ± S.E.	CV%	Mean ± S.E.	CV%	Mean ± S.E.	CV%
WC	120	49.867[ab]±0.096 (58.449)	2.116	33.320[bc]±0.091 (30.187)	3.003	19.666[b]±0.059 (11.361)	3.291
WPR	120	49.521[c]±0.112 (57.844)	2.472	33.819[a]±0.110 (30.996)	3.574	19.495[c]±0.069 (11.160)	3.670
RC	120	50.008[a]±0.112 (58.691)	2.461	33.044[c]±0.114 (29.753)	3.775	19.865[a]±0.055 (11.557)	3.008
WC X WPR	120	49.661[bc]±0.096 (58.085)	2.107	33.617[ab]±0.100 (30.664)	3.248	19.564[bc]±0.049 (11.221)	2.760
RC X WPR	120	49.841[ab]±0.104 (58.402)	2.282	33.388[b]±0.108 (30.318)	3.537	19.620[bc]±0.036 (11.280)	1.984

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

2.   Means with different superscripts (column wise) differ significantly (P < 0.05), (P<0.01).

Table - 20 Analysis of variance showing the genetic effect on angles (Angles = Arcsin $\sqrt{\text{percentage}}$) corresponding to the percentages on albumen weight, yolk weight and shell weight in chicken.

Traits	Source of variation	D.F.	M.S.	F
Albumen weight	Between groups	4	4.331	3.322*
	Error	595	1.304	
Yolk weight	Between groups	4	10.487	7.939**
	Error	595	1.321	
Shell weight	Between groups	4	2.360	6.00**
	Error	595	0.357	

* Significant at P < 0.05.

** Significant at P < 0.01.

Absolute weight and percentage of egg yolk :

The least squares means alongwith SE and CV% of yolk weight have been shown in Table - 17. The average estimates of yolk weight were found to be 16.177, 17.142, 16.093, 17.109 and 16.943 g of WC, WPR, RC, WC × WPR and RC × WPR chickens respectively. The analysis of variance (Table - 18) revealed that absolute weight of egg yolk significantly (P<0.01) influenced by the genetic groups. The WPR was found to have significantly (P<0.01) more yolk weight than WC and RC by 0.965 and 1.049g respectively which indicated the superiority of WPR over WC and RC for this trait. However, the significant differences could not be observed between WC and RC. WC × WPR chickens were found to have significantly (P<0.01) 0.932 and 1.016 g more egg yolk than the WC and RC respectively but did not differ significantly from WPR. Similarly, RC × WPR cross had significantly (P<0.01) more egg yolk than the WC and RC by 0.766 and 0.85g respectively but did not differ significantly from WPR. However, significant differences could not be observed between the crosses.

The least squares means, SE and CV% of angles corresponding to percentages of yolk weight have been presented in Table - 19. The average estimates of yolk percentage corresponding to the angles of WC, WPR, RC, WC × WPR and RC × WPR were

found to be 30.187, 30.996, 29.753, 30.664 and 30.318 respectively. The analysis of variance (Table - 20) revealed significant (P<0.01) differences between the breeds and their crosses. The WPR chickens were found to have significantly (P < 0.01) more quantity of egg yolk than the WC and RC, however, WC and RC did not differ significantly. The WPR was also found to be superior and had significantly (P<0.01) higher percentage of egg yolk than the RC × WPR cross but did not differ significantly from WC × WPR. However, both the crosses were found to have significantly (P<0.01) higher percentage of egg yolk than the RC but they did not differ significantly.

Mahapatra *et al.* (1982) reported significant differences between breed and their crosses for yolk quality. The average yolk percentage observed in the present investigation is very similar to the findings of Rahmatullah *et al.* (1978), Singh et. al. (1981) and Diwan Chand (1982). The absolute weight of egg yolk observed by Johari and Singh (1968), Singh *et al.* (1981), Mahapatra *et al.* (1982), Pandey *et al.* (1984; '86), and Mohan *et al.* (1992) were in agreement to the results obtained in the present study. However, Kaufman and Baezkowski (1937) and Hall (1939) reported that the proportion of total egg weight represented by yolk varies slightly between breeds.

Absolute weight and percentage of egg shell

The least squares means along with SE and CV% of egg shell weight have been presented in Table - 17. The average estimates of shell weight of WC, WPR, RC, WC × WPR and RC × WPR were shown to be 6.100, 6.188, 6.264, 6.273 and 6.315 g respectively. The analysis of variance (Table-18) revealed significant (P<0.01) difference between genetic groups on egg shell weight. The chickens of RC breed were found to have significantly (P<0.01) higher shell weight from WC, however, did not differ significantly from WPR as well as from WC x WPR and RC x WPR crosses. WPR though had slightly more shell weight from the WC, however, the difference was non-significant. The WC x WPR and RC x WPR crosses were found to have significantly (P < 0.01) more shell weight than the WC by 0.173 and 0.215g respectively, but differences between them were non-significant.

The least squares means, SE and CV% of angles corresponding to the percentage of shell weight have been presented in Table-19 which revealed that the average percentage of shell weight ranged from 11.160 in WPR to 11.557 in RC. The analysis of variance (Table-20) revealed significant (P<0.01) effect of genetic groups on shell weight percentage. Among all the genetic groups the RC breed was found to have significantly (P<0.01) higher percentage of shell weight. Among the purebreds WPR was found to have

significantly (P<0.01) lower percentage of shell weight from the WC and RC but did not differ significantly from WC × WPR and RC × WPR crosses. The results indicated that RC was found to be superior over the crossbreds as well as over the WC and WPR breeds of chicken for this trait.

The significant breed differences for egg shell weight and shell percentage observed in the present study have also been reported in the available literature. The average shell weight observed by Perek and Snapir (1970) were in close agreement with the values estimated in the present investigation. Arafa *et al.* (1982) reported significant strain differences for shell weight. Pandey *et al.* (1984) observed significant strain differences for shell weight and shell percentage. The higher percentage of shell weight reported by Mahapatra *et al.* (1982) as compared to the findings of the other research workers was in accordance with the findings of the present study.

Effect of egg weight on external egg quality traits :

The least squares means, SE and CV% of egg length, egg width, shape index and shell thickness have been presented in Table -21. The analyses of variances for the effect of egg weight on these traits have been depicted in Table - 22.

Egg length :

The analysis of variance revealed significant (P < 0.01) effect of egg weight on egg length (Table - 22). The average egg

Table - 21 Least squares means, S.E. and CV% of external egg quality traits in different egg weight groups pooled over various genetic groups of chicken.

Egg weight (g) groups	No. of obs.	Egg length (cm)		Egg width (cm)		Shape index		Shell thickness (mm)	
		Mean ± S.E.	CV%	Mean ± S.E.	CV%	Mean ± S.E.	CV%	Mean ± S.E.	CV%
< 50	59	$5.359^e \pm 0.018$	2.642	$3.959^e \pm 0.012$	2.257	$73.937^{bc} \pm 0.378$	3.923	$0.321^b \pm 0.003$	7.048
50 – 53	95	$5.443^d \pm 0.013$	2.277	$4.075^d \pm 0.007$	1.558	$74.917^a \pm 0.261$	3.389	$0.322^b \pm 0.002$	6.419
53 – 56	183	$5.552^c \pm 0.008$	1.985	$4.134^c \pm 0.005$	1.481	$74.522^{ab} \pm 0.162$	2.940	$0.325^b \pm 0.001$	5.397
56 – 59	183	$5.683^b \pm 0.008$	1.985	$4.202^b \pm 0.004$	1.207	$73.920^c \pm 0.142$	2.604	$0.332^a \pm 0.001$	4.997
> 59	80	$5.803^a \pm 0.010$	1.544	$4.310^a \pm 0.007$	1.349	$74.286^{ac} \pm 0.180$	2.170	$0.333^a \pm 0.002$	4.013

NB : Means with different superscripts (column wise) differ significantly (P < 0.01).

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Table - 22 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 (cm)	Between groups	4	2.700	206.636**
	Error	595	0.013	
Egg width (cm)	Between groups	4	1.310	341.772**
	Error	595	0.004	
Shape index	Between groups	4	21.262	4.445**
	Error	595	4.783	
Shell thickness (mm)	Between groups	4	0.0030	9.370**
	Error	595	0.0003	

** Significant at $P < 0.01$.

length in < 50 g egg weight group was estimated to be 5.359 cm. The average egg length in 50-53, 53-56, 56-59 and > 59 g egg weight groups were found to be increased significantly (P<0.01) by 0.084, 0.193, 0.324 and 0.444 cm from < 50 g egg weight group. The average estimates of egg length of 53-56, 56-59 and > 59 g egg weight groups were shown to be significantly (P<0.01) lengthier by 0.109, 0.240 and 0.360 cm from 50-53 g egg weight group. The eggs of 56-59 and >59 g groups were found to have significantly (P<0.01) more length from 53-56 g group by 0.131 and 0.251 cm respectively. The eggs of > 59 g group were found to be lengthier significantly by 0.120 cm from 56-59 g egg weight group.

Egg width :

The average egg width was found to be increased with the increase in egg weight in subsequent groups. The analysis of variance (Table-22) revealed significant effect of egg weight on egg width. The average egg width in <50 g group was obtained to be 3.959 cm. The average egg width of 50-53, 53-56, 56-59 and 59 g egg weight groups were shown to be increased significantly by (P<0.01) 0.116, 0.175, 0.243 and 0.351 cm respectively from <50 g egg weight group. Significantly (P<0.01) higher egg width was also observed in 53-56, 56-59 and > 59 g groups from 50-53 g. The average egg width of 56-59 and > 59 egg weight groups were shown to be significantly (P<0.01) more by 0.068 and 0.176 cm respectively from 53-56 g

group. The eggs of > 59 g group were found to have significantly (P<0.01) higher width from 56-59 g group.

Shape index :

The analysis of variance revealed significant (P<0.01) effect of egg weight on shape index. The average shape index in 50-53 g egg weight group was calculated to be 74.917 which was significantly (P<0.01) higher by 0.980 and 0.997 from < 50 and 56-59g groups respectively but did not differ significantly from 53-56 and >59 g groups. The average shape indices in <50 g and 56-59 g groups were found to be significantly (P<0.01) lower from 53-56 g egg weight group, however, the shape indices in <50, 56-59 and >59 g groups did not differ significantly.

Shell thickness :

The significnat (P<0.01) effect of egg weight on sheel thickness was observed through analysis of variance (Table 22). The shell thickness were observed to be increased with the increase of egg weight in the subsequent groups. The average shell thickness in 56-59 and > 59 g groups were estimated to be 0.332 and 0.333 mm respectively and were found to be significantly (P<0.01) more by 0.011 and 0.012 mm from < 50 g, 0.010 and 0.011 mm from 50-53 g and 0.007 and 0.008 mm from 53-56 g egg weight group respectively. However, the shell thickness between 56-59 and > 59g groups did not differ significantly. The egg shell thickness of < 50, 50-53 and 53-56g egg weight groups did not differ significantly.

Effect of egg weight on internal egg quality traits :

The least squares means, SE and CV% of albumen height, albumen index, yolk height, yold width and yolk indices of various egg weight groups pooled over genetic groups are presented in Table - 23 and the analyses of variances for the effect of egg weight on these traits is depicted in Table-24.

Albumen height :

The analysis of variance revealed significant (P<0.01) effect of egg weight on albumen height (Table 24). The average albumen height was obtained to be 6.419 mm in >59 g egg weight group which was found to be significantly (P<0.01) more by 1.128, 0.581, 0544 and 0.231 mm from the eggs of <50, 50-53, 53-56 and 56-59g groups respectively. Significantly (P<0.01) higher albumen height was also observed in the eggs of 56-59g group over <50, <50-53 and 53-56g groups. The eggs of 50-53 and 53-56g groups did not differ significantly but they had significantly (P<0.01) higher albumen height from <50 g group by 0.547 and 0.584 mm respectively.

Albumen index :

The analysis of variance (Table-24) revealed significant (P <0.01) effect of egg weight on albumen index. The highest albumen index was calculated to be 7.99 in the eggs of 56-59 g group

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

Egg weight (g) groups	No. of obs.	Albumen height (mm) Mean±S.E.	CV%	Albumen index Mean±S.E.	CV%	Yolk height (mm) Mean±S.E.	CV%	Yolk width (mm) Mean±S.E.	CV%	Yolk index Mean±S.E.	CV%
< 50	59	$5.291^d \pm 0.090$	13.036	$7.268^c \pm 0.170$	17.943	$15.444^d \pm 0.093$	4.602	$39.254^c \pm 0.176$	3.436	$39.374^a \pm 0.267$	5.204
50 – 53	95	$5.838^c \pm 0.072$	12.085	$7.828^{ab} \pm 0.129$	16.094	$15.841^c \pm 0.089$	5.455	$40.354^b \pm 0.166$	4.019	$39.250^a \pm 0.294$	7.306
53 – 56	183	$5.875^c \pm 0.049$	11.199	$7.651^b \pm 0.090$	15.916	$15.827^c \pm 0.069$	5.899	$40.714^b \pm 0.118$	3.903	$38.942^a \pm 0.223$	7.731
56 – 59	183	$6.188^b \pm 0.045$	9.869	$7.990^a \pm 0.081$	13.717	$16.233^b \pm 0.065$	5.391	$41.302^a \pm 0.099$	3.244	$39.350^a \pm 0.195$	6.716
> 59	80	$6.419^a \pm 0.061$	8.533	$7.972^{ab} \pm 0.111$	12.436	$16.498^a \pm 0.089$	4.802	$41.598^a \pm 0.143$	3.064	$39.698^a \pm 0.260$	5.867

N.B. : Means with different superscripts (column wise) differ significantly (P < 0.01).

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Table - 24 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 Error	4 595	13.824 0.411	33.612**
Albumen index	Between groups Error	4 595	7.439 1.368	5.438**
Yolk height (mm)	Between groups Error	4 595	13.942 0.751	18.561**
Yolk width (mm)	Between groups Error	4 595	64.247 2.129	30.173**
Yolk index	Between groups Error	4 595	8.997 7.337	1.226^{NS}

** Significant at P < 0.01.

NS – Non significant

which was found to be significantly (P<0.01) higher by 0.722 and 0.339 from <50 and 53-56 g groups respectively. However, the average albumen index in 50-53, 56-59 and >59 g egg weight groups did no differ significantly. The lowest albumen index was observed to be 7.268 in <50 g egg weight group which was significantly (P<0.01) lower by 0.560, 0.383 and 0.704 from 50-53, 53-56 and >59 egg weight groups respectively.

Yolk height :

The analysis of variance revealed significant (P<0.01) effect of egg weight on yolk height (Table-24). The average yolk height was found to be increased with the increase in egg size. The highest yolk height was estimated to be 16.498 mm in >59 g egg weight group which was significantly (P<0.01) more by 1.054, 0.657, 0.671 and 0.265 mm from <50, 50-53, 53-56, and 56-59 g groups respectively. The eggs of 56-59 g group were also shown to have significantly (P<0.01) higher yolk height from <50, 50-53 and 53-56g egg weight groups by 0.789, 0.392 and 0.406 mm respectively. The eggs of 50-53 and 53-56 g groups were also observed to have significantly (P<0.01) higher yolk height from <50 g egg weight group, however, the differences between them were not significant.

Yolk width :

The analysis of variance revealed significant (P<0.01) difference between various egg weight groups for yolk width. The

highest yolk width was estimated to be 41.598 mm in >59g egg weight group. The eggs of 56-59 and >59 g groups were found to have significantly (P<0.01) higher yolk width from <50, 50-53 and 53-56 g egg weight groups, however, the mean values among these groups did not differ significantly. The eggs of 50-53 and 53-56 g groups were found to have significantly (P<0.01) higher yolk width from <50 g group, however, the differences in mean values between these two groups were non-significant.

Yolk index :

Significant differences could not be observed between different egg weight groups for yolk index (Table-24). The highest and lowest yolk indices were calculated to be 39.698 and 38.942 in >59 and 53-56 g egg weight groups respectively.

Absolute weight of albumen, yolk and egg shell :

The least squares means along with SE and CV% of absolute weights of albumen, yolk and egg shell have been presented in Table-25. The analyses of variances for the effect of egg weight on these egg component traits is presented in Table 26.

Albumen Weight :

The analysis of variance (Table-26) revealed significantt (P<0.01) effect of egg weight on albumen weight. The average albumen weight was shown to be increased gradually with the

Table – 25 Least squares means, SE and CV% of albumen weight, yolk weight and shell weight in different egg weight groups pooled over various genetic groups of chicken.

Egg weight (g) groups	No. of obs.	Albumen weight (g)		Yolk weight (g)		Shell weight (g)	
		Mean ± S.E.	CV%	Mean ± S.E.	CV%	Mean ± S.E.	CV%
< 50	59	27.297^e±0.212	5.970	15.162^e±0.104	5.269	5.489^e ±0.058	8.164
50 – 53	95	29.795^d±0.119	3.891	16.096^d±0.086	5.219	5.854^d±0.035	5.765
53 – 56	183	31.741^c±0.087	3.706	16.553^c±0.076	6.232	6.076^c±0.028	6.218
56 – 59	183	33.368^b±0.090	3.653	17.225^b±0.074	5.831	6.535^b±0.027	5.644
> 59	80	36.427^a±0.170	4.166	17.633^a±0.106	5.391	6.862^a±0.031	3.992

NB : Means with different superscripts (column wise) differ significantly (P < 0.01).

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Table - 26 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	4	922.777	557.803**
	Error	595	1.654	
Yolk weight (g)	Between groups	4	74.514	80.312**
	Error	595	0.928	
Shell weight (g)	Between groups	4	24.776	186.532**
	Error	595	0.133	

** Significant at $P < 0.01$.

increase in egg weight in the subsequent groups. The average albumen weight in < 59 g egg weight group was obtained to be 36.427 g which was found to be increased significantly (P<0.01) from <50, 50-53, 53-56 and 56-59g egg weight groups by 9.148, 6.32, 4.686 and 3.059 g respectively. Similarly, the albumen weight of 56-59 g group was found to have increased significantly form <50, 50-53 and 53-56 groups. The albumen weight in 53-56 g group was also found to be increased significantly (P<0.01) over <50 and 50-53 g egg weight groups, and albumen weight of 50-53g group increased significantly (P<0.01) from <50 g group.

Yolk weight :

The egg weight groups were shown to be differed significantly (P<0.01) for yolk weight (Table-26). The average estimate of yolk weight in >59 g egg weight group was obtained to be 17.633g which was significantly (P<0.01) more by 2.471, 1.537, 1.08 and 0.408g from <50, 50-53, 53-56 and 56-59g groups respectively. The lowest average yolk weight was found to be 15.162 g in <50g egg weight group.

Shell weight :

The analysis of variance revealed significant (P<0.01) effect of egg weight on shell weight. The average shell weight was shown to be increased significantly (P<0.01) with the gradual

increase of shell weight in the subsequent egg weight groups. The minimum and maximum average shell weights were estimated to be 5.489 and 6.862 g in the eggs of <50 and >59 g groups respectively.

Percentage of albumen, Yolk and egg Shell :

The least squares means, SE and CV% of angles corresponding to the percentage of albumen, yolk and shell weight have been presented in Table-27. The analyses of variances for the effect of egg weight on angles corresponding to the percentage of these traits have been presented in Table -28.

Percent albumen :

The mean angles corresponding to the percentage of albumen weight were found to be differed significantly (P<0.01) among the various egg weight groups (Table-28). The highest albumen percentage was estimated to be 59.763 in >59 g egg weight group and had significantly (P<0.01) more albumen than the <50, 50-53, 53-56 and 56-59 g egg weight groups respectively. The next highest albumen percentage was calculated to be 58.405 in 56-59 g egg weight group but did not differ significantly from 53-56g egg weight group. The 53-56 and 56-59 g egg weight groups had significantly (P<0.01) 1.443 and 1.488% more albumen from <50g egg weight group and 0.787 and 0.832% more from 50-53g egg weight group respectively. The 50-53 g egg weight group was also found to have significantly (P<0.01) higher percentage of egg albumen.

Table - 27 Least squares means, SE and CV% of angles corresponding to the percentages (Angle = $Arcsin\sqrt{percentage}$) of albumen weight, yolk weight and shell weight in different egg weight groups pooled over various genetic groups of chicken.

Egg weight (g) groups	No. of obs.	Albumen percent (wt.)		Yolk percent (wt.)		Shell percent (wt.)	
		Mean ± S.E.	CV%	Mean ± S.E.	CV%	Mean ± S.E.	CV%
< 50	59	$48.979^d \pm 0.157$ (56.917)	2.460	$34.238^a \pm 0.156$ (31.667)	3.491	$19.772^a \pm 0.107$ (11.460)	4.159
50 – 53	95	$49.356^c \pm 0.106$ (57.573)	2.090	$33.895^a \pm 0.105$ (31.111)	3.012	$19.649^{ab} \pm 0.061$ (11.315)	3.020
53 – 56	183	$49.822^b \pm 0.082$ (58.360)	2.213	$33.470^b \pm 0.084$ (30.441)	3.411	$19.504^b \pm 0.048$ (11.174)	3.342
56 – 59	183	$49.842^b \pm 0.080$ (58.405)	2.178	$33.302^b \pm 0.082$ (30.163)	3.345	$19.755^a \pm 0.040$ (11.437)	2.764
> 59	80	$50.632^a \pm 0.097$ (59.763)	1.711	$32.542^c \pm 0.097$ (28.946)	2.652	$19.598^{ab} \pm 0.042$ (11.255)	1.932

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

2. Means with different superscripts (column wise) differ significantly (P < 0.01).

Table – 28 Analysis of variance showing the effect of egg weight on angles (Angles = Arcsin $\sqrt{\text{percentage}}$) corresponding to the percentage of albumen weight, yolk weight and shell weight in chicken.

Traits	Source of variation	D.F.	M.S.	F
Albumen weight	Between groups	4	28.133	24.648**
	Error	595	1.141	
Yolk weight	Between groups	4	31.380	26.571**
	Error	595	1.181	
Shell weight	Between groups	4	1.678	4.641**
	Error	595	0.362	

** Significant at $P < 0.01$.

Percent Yolk :

The angles corresponding to the percentage of yolk weight were found to be differed significantly (P<0.01) among various egg weight groups. The yolk percentage was shown to be varied inversely with the egg weight. The highest yolk percentage was estimated to be 31.667 in <50 g egg weight group and it had significantly (P<0.01) higher percentage of egg yolk from 53-56, 56-59 and >59 g egg weight groups but did not differ significantly from 50-53g egg weight group. The 50-53g egg weight group was also found to have significantly (P<0.01) higher percentage of yolk from 53-56, 56-59 and ·>59g groups. The eggs of 53-56 and 56-59g egg weight groups did not differ significantly but both had significantly (P<0.01) higher percentage of egg yolk from >59g egg weight group.

Percent shell :

The analysis of variance (Table-28) revealed the significant (P<0.01) effect of egg weight on angles corresponding to the percentage of egg shell. The highest and lowest percentage of shell were estimated to be 11.460 and 11.174 in <50 and 53-56 egg weight groups respectively. The <50 and 56-59 g egg weight groups were though found to have significantly (P<0.01) higher percentage of shell from 53-56g egg weight group but did not differ significantly from 50-53 and >59 g egg weight groups which suggested that in very small and very large sized eggs have higher percentage of egg shells as compared to the medium sized eggs.

The reports on the influence of egg weight on egg quality traits are very scanty in the available literature. However, Mohan *et al.* (1992) did not observe significant difference between the egg weight groups for most of the egg quality traits except yolk percent, which is not in accordance with the present findings. In the present investigation significant differences were observed between the egg weight groups for all the egg quality traits except the yolk index. The results obtained in the present investigation were similar to the findings of Kumar (2000) who studied the effect of egg weight on egg quality traits in *Coturnix coturnix japonica* and reported significant difference between different groups for all the egg quality traits. The heaviest egg weight group reported to have significantly highest egg length, egg width, yolk weight, albumen weight, yolk index, albumen index and albumen percentage as compared to the lower egg weight groups except for yolk percentage which was more in lowest egg weight group. The average estimates of shell percentage was found to be more both in large and small sized eggs as compared to the medium sized eggs.

Heterosis for egg quality traits :

The percent heterosis estimated for various egg quality traits in WC × WPR and RC × WPR crosses of chicken is presented in Table - 29. Both positive and negative heterosis were obtained for various traits in both the crosses. The positive heterosis were estimated in both the crosses for egg weight, egg length, egg width,

Table - 29 Percent heterosis in different crosses for various egg quality traits.

Crosses	Egg weight	Egg length	Egg width	Shape index	Shell thickness	Shell weight
WC X WPR	5.213	0.857	0.87	-0.049	-1.369	2.099
RC X WPR	2.103	0.611	1.086	0.46	0.92	1.429

Crosses	Albumen height	Albumen weight	Albumen index	Yolk height	Yolk weight	Yolk width	Yolk index
WC X WPR	3.559	3.168	3.401	0.92	2.701	0.122	0.522
RC X WPR	-0.149	2.304	-0.786	-1.771	1.962	1.483	-3.364

shell weight, albumen weight, Yolk weight and yolk width. The positive heterosis were also observed for albumen height, albumen index, yolk height and yolk index in WC × WPR cross while negative heterosis were observed for these traits in RC × WPR cross. The heterosis percent estimated to be ranged from -3.364 in yolk index to 5.213 in egg weight. The highest percent of heterosis was estimated for egg weight which ranged from 2.103 to 5.213. The reports on heterosis percent for egg quality traits were scanty in the available literature. However, Sheridon and Randall (1977), Gowe and Fairfull (1982), Fairfull *et al.*, (1986) and Hazary (1991) reported positive heterosis for egg weight whereas negative heterosis for this trait was reported by Vishwanath *et al.* (1984). Singh *et al.* (2000) reported negative heterosis for egg weight in all the crosses except Dahlem Red × Aseel at the age of first egg laid and both positive and negative heterosis at 40th and 64th weeks of age.

Phenotypic Correlation :

The estimates of coefficient of phenotypic correlation among various egg quality traits have been presented in Table-30.

Correlation between egg weight and egg quality traits :

The estimates of coefficient of correlation between egg weight and egg quality traits were found to be positive, in general, highly significant (P<0.01) and moderate to very high in all the genetic groups except the correlation of egg weight with shape index,

Table - 30 Coefficient of correlation between various egg quality traits in different genetic groups of chicken.

Traits	WC $r_p \pm SE$	WPR $r_p \pm SE$	RC $r_p \pm SE$	WC × WPR $r_p \pm SE$	RC × WPR $r_p \pm SE$
Egg weight × Egg length	0.780***±0.036	0.783***±0.035	0.790***±0.034	0.700***±0.046	0.785***±0.035
× Egg width	0.819***±0.030	0.863***±0.023	0.898***±0.017	0.900***±0.017	0.822***±0.029
× Shape index	0.076 ±0.091	-0.141±0.09	0.134±0.090	0.098±0.091	-0.269***±0.085
× Shell thickness	0.032±0.092	0.186±0.088	0.464***±0.072	0.307***±0.083	0.343***±0.081
× Shell weight	0.750***±0.040	0.719***±0.044	0.794***±0.034	0.780***±0.036	0.857***±0.024
× Alb. height	0.542***±0.065	0.391***±0.077	0.315***±0.082	0.392***±0.077	0.421***±0.075
× Alb. weight	0.948***±0.009	0.958***±0.007	0.920***±0.014	0.914***±0.015	0.925***±0.013
× Alb. index	0.246***±0.086	0.092±0.091	0.012±0.092	0.090±0.091	0.191±0.088
× Yolk height	0.390***±0.078	0.156±0.089	0.381***±0.078	0.395***±0.077	0.335***±0.081
× Yolk weight	0.653***±0.052	0.620***±0.056	0.584***±0.060	0.564***±0.062	0.493***±0.069
× Yolk width	0.489***±0.070	0.356***±0.080	0.464***±0.072	0.283***±0.084	0.492***±0.069
× Yolk index	-0.039±0.091	-0.056±0.091	-0.001±0.092	0.250***±0.086	0.037±0.091

Traits	WC $r_p \pm SE$	WPR $r_p \pm SE$	RC $r_p \pm SE$	WC × WPR $r_p \pm SE$	RC × WPR $r_p \pm SE$
Egg length × Egg width	0.535**±0.065	0.549**±0.064	0.568**±0.062	0.450**±0.073	0.435**±0.074
× Shape index	-0.447**±0.073	-0.674**±0.05	-0.447**±0.073	-0.606***±0.058	-0.770**±0.037
× Shell thickness	0.030 ± 0.092	0.117±0.09	0.370***±0.079	0.269**±0.085	0.233**±0.087
× Shell weight	0.619**±0.056	0.517***±0.067	0.669***±0.050	0.612***±0.057	0.687**±0.048
× Alb. height	0.414**±0.076	0.356***±0.08	0.305***±0.083	0.226*±0.087	0.381**±0.078
× Alb. weight	0.737**±0.042	0.738***±0.041	0.728***±0.043	0.577***±0.061	0.713**±0.045
× Alb. index	0.179±0.089	0.063±0.091	0.062 ±0.091	0.070±0.091	0.199*±0.088
× Yolk height	0.263***±0.085	0.159±0.089	0.332***±0.081	0.393***±0.077	0.414**±0.076
× Yolk weight	0.495***±0.069	0.549***±0.064	0.441***±0.074	0.499***±0.069	0.411***±0.076
× Yolk width	0.424**±0.075	0.271**±0.085	0.255***±0.086	0.209*±0.088	0.358***±0.080
× Yolk index	-0.103±0.091	-0.018±0.092	0.099±0.091	0.265***±0.085	0.187*±0.088

(Table No. 30 to continue ....)

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Traits	WC rₚ ± SE	WPR rₚ ± SE	RC rₚ ± SE	WC × WPR rₚ ± SE	RC × WPR rₚ ± SE
Egg width × Shape index	0.517**±0.067	0.234*±0.087	0.483**±0.070	0.437**±0.074	0.236**±0.086
× Shell thickness	-0.037±0.092	0.189*±0.088	0.406**±0.076	0.247**±0.086	0.246**±0.086
× Shell weight	·0.608**±0.058	0.662**±0.051	0:668**±0.050	0.698**±0.047	0.676**±0.049
× Alb. height	0.414**±0.076	0.335**±0.081	0.283**±0.084	0.401**±0.077	0.323**±0.082
× Alb. weight	0.766**±0.038	0.824**±0.029	0.838**±0.027	0.839**±0.027	0.801**±0.032
× Alb. index	0.196*±0.088	0.103±0.091	0.027±0.092	0.093±0.091	0.126±0.090
× Yolk height	0.319**±0.082	0.106±0.091	0.333**±0.081	0.350**±0.080	0.225*±0.087
× Yolk weight	0.563**±0.062	0.522**±0.067	0.521**±0.067	0.475**±0.071	0.318**±0.082
× Yolk width	0.426**±0.075	0.368**±0.079	0.494**±0.069	0.241**±0.086	0.383**±0.078
× Yolk index	-0.056±0.091	-0.096±0.091	-0.059±0.091	0.246**±0.086	-0.006±0.092
Shape index × Shell thickness	-0.073±0.091	0.031±0.091	0.054±0.091	-0.048±0.091	-0.080±0.091
× Shell weight	0.012±0.092	-0.002±0.092	0.021±0.092	0.008±0.092	-0.266**±0.085
× Alb. height	0.013±0.092	-0.108±0.090	-0.014±0.092	0.129±0.090	-0.180*±0.089
× Alb. weight	0.064±0.091	-0.125±0.090	0.134±0.090	0.168±0.089	-0.207*±0.088
× Alb. index	0.021±0.092	0.024±0.092	-0.034±0.091	0.012±0.092	-0.123±0.090

(Table No. 30 to continue ....)

Traits	WC r$_p$ ± SE	WPR r$_p$ ± SE	RC r$_p$ ± SE	WC × WPR r$_p$ ± SE	RC × WPR r$_p$ ± SE
Shape index × Yolk height	0.071±0.091	-0.076±0.091	0.010±0.092	-0.086±0.091	-0.296**±0.083
× Yolk weight	0.094±0.091	-0.171±0.089	0.096±0.091	-0.082±0.091	-0.22*±0.087
× Yolk width	0.024±0.092	0.001±0.092	0.265**±0.085	0.002±0.092	-0.119±0.090
× Yolk index	0.043±0.091	-0.048±0.091	-0.167±0.089	-0.050±0.091	-0.213*±0.087
Shell thickness × Shell weight	0.387**±0.078	0.654**±0.052	0.771**±0.037	0.711**±0.045	0.651**±0.053
× Alb. height	0.098±0.091	0.085±0.091	0.193*±0.088	-0.026±0.091	0.152±0.089
× Alb. weight	-0.075±0.091	0.088±0.091	0.301**±0.083	0.181*±0.089	0.261**±0.085
× Alb. index	0.050±0.091	0.034±0.091	0.064±0.091	-0.098±0.091	0.067±0.091
× Yolk height	0.059±0.091	-0.125±0.090	0.227*±0.087	0.17±0.089	0.04±0.091
× Yolk weight	0.113±0.090	0.092±0.091	0.365**±0.079	0.167±0.089	0.153±0.089
× Yolk width	0.109±0.090	0.005±0.092	0.282**±0.084	0.001±0.092	0.253**±0.086
× Yolk index	-0.030±0.092	-0.095±0.091	-0.002±0.092	0.165±0.089	0.108±0.090
Shell weight × Alb. height	0.508**±0.068	0.221*±0.087	0.301**±0.083	0.253**±0.086	0.342**±0.081
× Alb. Weight	0.604**±0.058	0.603**±0.058	0.637**±0.054	0.629**±0.055	0.732**±0.042

(Table No. 30 to continue ....)

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Traits	WC $r_p \pm SE$	WPR $r_p \pm SE$	RC $r_p \pm SE$	WC × WPR $r_p \pm SE$	RC × WPR $r_p \pm SE$
Shell weight × Alb. index	0.259***±0.085	0.021±0.092	0.056±0.091	0.027±0.091	0.141±0.090
× Yolk height	0.378***±0.078	0.048±0.091	0.336***±0.081	0.382**±0.078	0.285***±0.084
× Yolk weight	0.549***±0.064	0.431***±0.074	0.500***±0.069	0.44**±0.074	0.457***±0.072
× Yolk width	0.407***±0.076	0.195*±0.088	0.410***±0.076	0.153±0.089	0.488***±0.070
× Yolk index	0.012 ±0.092	-0.059±0.091	-0.0002±0.092	0.301***±0.083	-0.009±0.092
Alb. height × Alb. Weight	0.498***±0.069	0.309***±0.083	0.266***±0.085	0.369***±0.079	0.407***±0.076
× Alb. index	0.888***±0.019	0.874***±0.021	0.925***±0.013	0.913***±0.015	0.944**±0.010
× Yolk height	0.107±0.091	0.093±0.091	0.243***±0.086	0.125±0.090	0.168±0.089
× Yolk weight	0.343***±0.081	0.475***±0.071	0.214*±0.087	0.223*±0.087	0.173±0.089
× Yolk width	0.268***±0.085	0.304***±0.083	0.119±0.090	0.158±0.089	0.210*±0.087
× Yolk index	-0.126±0.090	-0.076±0.091	0.122±0.090	0.063±0.091	0.039±0.091
Alb. Weight × Alb. Index	0.226*±0.087	0.008±0.092	-0.023±0.092	0.088±0.091	0.205*±0.088
× Yolk height	0.241***±0.086	0.068±0.091	0.258***±0.085	0.157±0.089	0.229*±0.087
× Yolk weight	0.397***±0.077	0.394***±0.077	0.238***±0.086	0.2*±0.088	0.135±0.090
× Yolk width	0.303***±0.083	0.296***±0.083	0.217*±0.087	0.03±0.091	0.330***±0.082

(Table No. 30 to continue ....)

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Traits	WC	WPR	RC	WC×WPR	RC×WPR
	$r_p \pm$ SE	$r_p \pm$ SE	$r_p \pm$ SE	$r_p \pm$ SE	$r_p \pm$ SE
Alb. Weight × Yolk index	-0.024±0.092	-0.089±0.091	0.069±0.091	0.151±0.089	0.031±0.091
Alb. Index × Yolk height	-0.062±0.091	0.052±0.091	0.149±0.090	0.003±0.092	0.08±0.091
× Yolk weight	0.140±0.090	0.328**±0.082	0.060±0.091	0.06±0.091	0.035±0.091
× Yolk width	0.117±0.090	0.215*±0.087	-0.003±0.092	0.077±0.091	0.089±0.091
× Yolk index	-0.159±0.089	-0.061±0.091	0.128±0.090	-0.02±0.092	0.025±0.092
Yolk height × Yolk weight	0.562**±0.062	0.382**±0.078	0.414**±0.076	0.632**±0.055	0.359**±0.080
× Yolk width	0.336***±0.081	-0.404***±0.077	0.144±0.090	0.248**±0.086	0.177±0.089
× Yolk index	0.643***±0.053	0.902**±0.017	0.733**±0.042	0.836**±0.027	0.833**±0.028
Yolk weight × Yolk width	0.736***±0.042	0.395***±0.077	0.723**±0.043	0.685**±0.048	0.515***±0.067
× Yolk index	-0.086±0.091	0.084±0.091	-0.158±0.089	0.259***±0.085	0.043±0.091
Yolk width × Yolk index	-0.505***±0.068	-0.758***±0.039	-0.566***±0.062	-0.266***±0.085	-0.396**±0.077

*   Significant at P<0.05.   Alb. - Albumen

**   Significant at P<0.01.

albumen index and yolk index where values were found to be low to very low, non-significant and in both the directions. Similar findings have also been reported in the literature by many workers. Asmundson (1931) and Sapra and Aggarwal (1971) reported positive, significant and very high correlation of egg weight with egg length and egg width but correlation between egg weight and egg width is reported to be more as compared to the correlation between egg weight and egg length. Hutt (1949), Dickerson (1955) and Hicks (1958) reported non-significant and low magnitudes of phenotypic correlation between egg weight and egg shape and in both the directions. Highly significant and positive correlations of egg weight with shell thickness and shell weight observed in the present investigation were similar to the findings of Mahapartra et al. (1982).

Highly significant, positive and very high magnitudes of correlations between egg weight and albumen height as observed in the present study were similar to the findings made by Ishibashi and Takabashi (1968) and Pandey et al. (1984, '87). However, Eisen et al. (1962) and Saeki et al. (1968) observed relatively low magnitudes but highly significant correlation among these traits.

Knox and Godfrey (1934), Eisen and Bohren (1963) and Saeki et al. (1968) observed highly significant and positive correlations of high order between egg weight and albumen weight

which was similar to the findings of the present experiment. The correlation between egg weight and albumen index could not be observed in the available literature. Highly significant and positive correlations of egg weight with yolk height, yolk weight and yolk width as obtained in the present study are in close agreement with the findings of Bornstein and Lipstein (1962), Saeki et al (1968), Diwan Chand (1987) and Pandey et al. (1987). However, Pandey et al. (1984) reported negative correlations of egg weight with yolk weight and positive correlations with yolk height in White Leghorn chicken.

The phenotypic correlations between egg weight and yolk indices were found to be low in magnitude, non-significant, in general, and in both the directions. Mahapatra et al. (1982) reported negative correlation between egg weight and yolk index where as Maan et al. (1983) reported very high and positive genetic correlation between egg weight and yolk index in White Leghorn.

Correlation between egg length and other egg quality traits :

Egg length was found to be positively correlated with all the egg quality traits in all the genetic groups except with the shape index where correlations were in negative directions indicating that egg length may be increased by considering shape index as the selection criterion. Highly significant and negative correlation

between egg length and shape index has also been reported by Tung *et al.* (1968). Highly significant (P<0.05, P<0.01) and positive correlations of egg length with egg width, shell thickness, shell weight as observed in the present study are similar to the findings of Tung *et al.* (1968). Egg length was found to have negative correlation with yolk indices in White Cornish and White Plymouth Rock and positive correlation with Red Cornish, WC x WPR and RC x WPR. The magnitudes of correlation between egg length and the other egg quality traits were observed to be moderate to high except the correlation of egg length with albumen index and yolk index where estimates were low to very low and non significant, in general, in all the genetic groups. The review on correlation of egg length with albumen quality and yolk quality characteristics could not be observed in the literature but the presence of highly significant and positive correlations with high magnitudes in all the genetic groups revealed that albumen weight and yolk weight may be improved simultaneously by considering the egg length as a selection criterion.

Correlation between egg width and other egg quality traits :

Egg width was found to have highly significant (P<0.05, P<0.01) and positive correlations with shape index, shell thickness, shell weight, albumen height, albumen weight, yolk height, yolk weight and yolk width in all the genetic groups except the correlation

between egg width and shell thickness in White Cornish where the correlation was negative, nonsignificant and of very low order. The presence of very high and significant (P<0.01) correlations between egg width and other egg quality traits revealed that by improving the egg width alone the other correlated traits may also be improved. The estimates of correlation between egg width and all these egg quality traits were found to be moderate to high. Similar observations were also reported by Tung *et al.* (1968). Egg width was found to be positively correlated with albumen indices and negatively correlated with yolk indices but magnitudes of correlation were very low, in general.

Correlation between shape index and other egg quality traits :

The coefficient of correlation between shape index and other egg quality traits were found to be either positive or negative and nonsignificant in all the genetic groups except in crosses between RC × WPR where all the estimates were negative and significant (P<0.05, P<0.01). However, the magnitudes of correlation were estimated to be ranged from low to very low. Similar observations were also made by King and Hall (1955) for the correlation between shape index and shell thickness, however, Maan *et al.* (1983) reported very high and positive correlation among these two traits.

Correlation between shell thickness and other egg quality traits :

Shell thickness was found to have highly significant (P<0.01) and positive correlations with shell weight in all the genetic groups. The estimates of correlation among these traits were observed to be very high. Similar findings were also reported in the literature by Marks and Kinney (1964), Tung *et al.* (1968) and Pandey *et al.* (1984, '87). Shell thickness was also observed to have positive correlation with other egg quality traits like yolk weight and yolk width, but correlations with albumen height, albumen weight, albumen index, yolk height and yolk index were in both the directions. However, the estimates of correlation of shell thickness with these traits were very low and non-significant except in Red Cornish where correlations were significant and moderate in magnitude. However, Pandey *et al.* (1987) observed negative correlation of shell thickness with albumen height, albumen index, yolk weight and percent yolk of RIR and positive correlation with yolk index. Kotaiah *et al.* (1975) reported that the correlation between shell thickness and albumen index was non-significant.

Correlation between shell weight and other egg quality traits :

Shell weight was found to have significant (P<0.05, P<0.01) and positive correlations with albumen height, albumen

weight, yolk height, yolk weight and yolk width in all the genetic groups. The estimates of correlation were moderate to high, in general, but very high correlation of shell weight with albumen weight suggested that increased albumen weight may be associated with higher shell weight. Pandey *et al* (1987) also reported positive and significant correlation of shell weight with yolk weight and yolk index but magnitudes were of low order.

Shell weight was though found to have positive correlation with albumen indices but magnitudes were of very low and nonsignificant in all the genetic groups except in White Cornish. In contrary to this Pandey *et al.* (1987) reported negative correlation of shell weight with albumen index, however, the magnitudes were very low.

The estimates of correlation between shell weight and yolk indices were found to be very low and non-significant, in general, and in both the directions. However, Pandey *et al.* (1987) reported positive correlation between these two traits and of moderate magnitudes.

Correlation between albumen height and other egg quality traits :

Highly significant (P<0.01) and positive correlations were found to have between albumen height and other egg quality traits in all the genetic groups except the correlations with yolk

height and yolk indices where estimates were very low and non-significant indicating that albumen height had no definite role with the increase or decrease of yolk height and yolk index. That is yolk height is independent to that of albumen height. Contrary to this, the presence of highly significant and positive correlations of albumen height with albumen weight, yolk weight and yolk width may suggest that by increasing the albumen height the correlated traits like albumen weight and yolk weight may be increased. The estimates of correlation between albumen height and albumen indices were obtained to be very high which suggested that eggs had better albumen quality. The findings of the present study are in close agreement with the results of Rauch (1959) and Kotaiah *et al.* (1975) who reported highly significant correlation between albumen height and albumen index. Pandey *et al.* (1984) observed very low and positive correlation of albumen height with yolk height and negative correlation with percent yolk.

Correlation between albumen weight and other egg quality traits :

Albumen weight was found to have significant (P<0.05, P<0.01) and positive correlations with yolk height, yolk width and yolk weight in all the genetic groups except in WPR and WC × WPR crosses where coefficients of correlation between albumen weight and yolk height were non-significant and relatively very low in magnitude. Non-significant, in general, and very low magnitudes of

correlation were observed in both the directions between albumen weight and albumen index, and between albumen weight and albumen index, and between albumen weight and yolk index. However, the studies on correlations between albumen weight and all these yolk quality traits could not be observed in the literature.

Correlation between albumen index and yolk quality traits :

The coefficients of correlation between albumen index and various yolk quality traits were found to be non-significant, in general, except the correlations of albumen index with yolk weight and yolk width in WPR. The magnitudes were found to be very low and in both the direction. However, Henderson (1941) and Rauch (1959) reported significant and positive correlations between albumen index and yolk index. The reports on correlations between albumen index and other yolk quality traits could not be observed in the available literature.

Correlattion between yolk height and other egg quality traits :

Yolk height was found to have highly significant ($P < 0.01$) and positive correlation, in general, with other egg quality traits in all the genetic groups except in RC and RC × WPR cross where correlaions with yolk width were observed to be non-significant. In WPR the correlation between yolk height and yolk width was highly significant but in negative direction. The estimates

of correlation were observed to be moderate to very high indicating that yolk height may be used as selection criterion for the improvement of correlated traits like yolk weight and yolk index. Rauch (1959) and Bornstein and Lipstein (1962) also reported highly significant and very high magnitudes of correlation between yolk height and yolk index. Pandey et al. (1984) reported positive correlation between yolk height and yolk percent, however, the magnitudes were very low. The reports on correlations of yolk height with yolk weight and yolk width could not be observed in the available literature.

Correlation between yolk weight and other egg quality traits :

Highly significant (P<0.01), positive and very high magnitudes of correlation were observed between yolk weight and yolk width in all the genetic groups, however, the estimates of correlation between yolk weight and yolk indices were very low and non-significant, in general, and in both the directions. In WC × WPR cross the correlation was estimated to be positive and highly significant. The reports on correlation between yolk weight and yolk width, and between yolk weight and yolk index could not be observed in the available literatures. However, the highly significant and positive correlation between yolk weight and yolk width as observed

in the present study, suggested that by decreasing the yolk diameter through selection the correlated trait yolk weight may be reduced as very large yolk size is not desirable from human health point of view.

Correlation between yolk width and yolk index :

Yolk width was found to have highly significant (P < 0.01) and negative correlation with yolk index in all the genetic groups and magnitudes were moderate to high which suggested that yolk index may be increased or decreased by decreasing or increasing the yolk width but higher yolk index is the indication of good yolk quality. However, the reports on correlation between these two traits could not be observed in the available literature.

Fertility and Hatchability :

Fertility :

The fertility and hatchability percentage were studied during the months of winter. Fertility percentage of various pure and cross bred chickens have been presented in Table-31. It revealed the presence of very high fertility percentage in all the genetic groups ranging from 87.35 to 93.50. In purebreds the fertility percentage found to be quite higher as compared to the crossbreeds ranging from 91.25 in RC to 93.50 in WC and in crossbreeds it is ranged from

Table - 31 Fertility and hatchability percentage of different genetic groups of chicken.

Genetic groups	Number of eggs set	Total no. of fertile eggs	Total no. of chicks hatched	% fertility	% hatchability on total no. of eggs set	% hatchability on fertile eggs basis
WC	200	187	143	93.5	71.50	76.47
WPR	173	158	129	91.33	74.56	81.64
RC	160	146	108	91.25	67.50	73.97
WC X WPR	166	145	115	87.35	69.27	79.31
RC X WPR	208	187	144	89.90	69.23	77.00

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87.35 to 89.90. The higher fertility percentage of purebreds, in comparison to the crossbreeds as observed in the present study is also reported by many workers (Colotiva and Morandici, 1966; Basu, 1969; Husain, 1972; Sapra et al, 1972 and Singh, 1978). Sapra et al. (1972) reported that the lower fertility in crossbreds is attributed due to incompatibility of two pure breeds involved in crosses. The percentage of fertility in WPR was estimated to be 91.33 which is lower in comparison to WC. Lower percentage of fertility in WPR as compared to WC is also reported by Chhabra and Sapra (1972). Among the crosses the fertility percentage was found to be ranged from 87.35 in WC × WPR to 89.90 in RC × WPR. Very high percentage of fertility as observed in the present study was in accordance with the findings of many workers. Colotiva and Morandici (1966), Husain (1972), Yadev & Sengar (1983) and Sharma (1984) reported very high percentage of fertility in WPR ranging from 89.38 to 98.60 while Reddy et al. (1965) and Sapra et al. (1972) reported the lower percentage of fertility in WPR as compared to the present findings. In WC the fertility percentage reported by Ramappa and Gowda (1973) is in agreement with findings of present study. Very low percentage (75.01) of fertility in WC as compared to the present findings reported by Sapra et al. (1972). Sharma (1984) reported 89.60% fertility in RC. Very high fertility percentage of WC

× WPR crosses reported by Colotiva and Morandici (1966) and Ramappa and Gowda (1973) is in agreement with the findings of present investigation. Whereas Yadev and Sengar (1983) reported quite lower percentage (64.84) of fertility. Sharma (1984) reported higher percentage (85.18) of fertility in RC × WPR which is in accordance with the findings of the present experiment.

Hatchability : .

The hatchability percentage on the basis of total number of eggs set and on the basis of fertile eggs set of various pure and crossbred chickens is presented in Table 31. In purebreds the hatchability percentage on the basis of total number of eggs set was found to be quite higher in comparison to crossbreds except in RC. The hatchability percentage of RC was estimated to be 67.50 which is lower by 4.0 and 7.06% as compared to WC and WPR respectively. The hatchability percentage in WC × WPR and RC × WPR was found to be 69.27 and 69.23 respectively.

In purebreds, the hatchability parentage on fertile eggs basis was observed to be lower as compared to crossbreds except in WPR indicating the superiority of crossbreds over purebreds for this trait. The hatchability percentage in purebreds was found to be ranged from 73.97 in RC to 81.64 in WPR. In WC the hatchability percentage was shown to be 76.47. The hatchability percentage in

crossbreds observed to be ranged from 77.00 in RC × WPR to 79.31 in WC × WPR. Significant breed differences for hatchability has been reported by many workers (Mahadevan, 1954; Kawahara, 1961; Gleichauf, 1963; Reddy *et al.*, 1965 and Sapra *et al*, 1972). The superiority of crossbreds over purebreds for hatchability on fertile eggs basis has been reported by many workers (Byerly *et al.*, 1934; Warren, 1942; Knox *et al.*, 1943; Dickerson *et al*, 1950; Hutt & Cole, 1952; Nordskog and Glaostley, 1954; Hussain, 1963; Colotiva and Morandici, 1966; Hussain, 1972 and Sapra *et al*, 1972). However, Kushner *et al*, (1952), Fomin (1952), Basu (1969) and Singh (1978) did not observe any appreciable difference in hatchability percentage between pure and crossbred chickens.

Heterosis of fertility and hatchability :

The heterosis percent of fertility and hatchability is presented in Table-32. Heterosis for fertility and hatchibility on the basis of total number of eggs set were observed to be negative while heterosis on fertile eggs basis was found to be positive for WC × WPR and negative in RC × WPR. Galjpern and Vinogaadova (1969) observed both negative and positive heterosis for fertility in the crosses between Cornish and White Plymouth Rock and negative heterosis in their reciprocal crosses. However, they reported positive heterosis in direct cross and negative heterosis in reciprocal cross for hatchability percentage. Similar observations were also made by

Table - 32 Percent heterosis of fertility and hatchability in crossbreds chickens.

Crosses	Fertility	Hatchability on fertile egg	Hatchability on total egg
WC X WPR	-0.054	0.003	-0.051
RC X WPR	-0.015	-0.010	-0.025

Sinickin (1969). Heterosis percent for hatchability was also noted by Agrawal *et al* (1978) in the crosses of WPR and WC and their strain crosses.

As compared to the available literature the findings of the present study were similar for all the egg quality traits including egg weight. However, the percentage of shell weight was more than the estimates reported in the literature. The percentage of fertility and hatchability though fall within the range as reported in the literature but were in the higher side.

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Chapter-5

Summary & Conclusions

(vi) Percent shell weight

(vi) Yolk width

(vii) Yolk index

(viii) Yolk weight

(ix) Percent yolk
weight

4. Fertility percentage7

5. Hatchability percentage

The experiment was undertaken with the following objectives :

1. To estimate the mean, standard error and coefficient of variation percentage of fertility, hatchability, egg weight and egg quality traits under study in different genetic groups.

2. To study the effect of different genetic groups on fertility, hatchability, egg weight and egg quality traits.

3. To evaluate the percentage of heterosis for various traits under study chicken.

4. To estimate the coefficient of phenotypic correlations among Various traits under study.

5. To study. the effect of egg weight on egg quality traits in chicken.

Six males and 42 females were taken from each genetic group and maintained separately in deep litter system with a mating ratio of 1 male : 7 females. To study the genetic effect on egg quality traits, a total of 120 eggs were collected at random from each of 5 genetic groups at 36 weeks of age. To examine the effect of egg weight on egg quality traits all these eggs were divided into 5 different groups with a difference of 3 g from each.

Significant ($P<0.05$, $P<0.01$) differences were observed between the genetic groups for egg weight and all the egg quality traits except albumen index. The average egg weight of purebreds at 36 weeks of age ranged from 53.70 (WC) to 55.47g (WPR) and in crosses from 55.85 (WC× WPR) to 55.98g (RC× WPR). The increament in egg weight over the egg of 24 weeks of age ranged from 18.22 to 20.38%. The average length and width of the eggs ranged from 5.515 to 5.649 cm and 4.109 to 4.189 cm respectively. The average shape indices ranged from 73.595 in WC to 74.909 in RC × WPR. The average shell thickness obtained to be ranged from 0.324 to 0.332 mm. The average heights of albumen and Yolk were observed to be ranged from 5.753 to 6.081 mm and 15.758 to 16.189 mm respectively. The average albumen and yolk indices were found to be ranged from 7.453 to 7.928 and 38.509 to 40.212 respectively. The average weight of albumen and yolk ranged from 31.423 to 32.719 g and 16.093 to 17.142 g respectively. The average percentage of albumen and yolk observed to be ranged from 57.844 to 58.691 and

33.044 to 33.819 respectively. The average shell weight and shell percentage observed to be ranged from 6.100 to 6.135 g and 11.160 to 11.316% respectively.

Egg weight at 36 weeks of age was found to have significant (P<0.01) effect on all the egg quality traits except yolk index. The heavier egg weight groups had higher egg length, egg width, shape index and shell thickness. The heavier egg weight groups were also observed to have higher albumen height, albumen index, yolk height and yolk width but there was no significant difference for yolk index. The absolute weight and percentage of albumen and egg shell were estimated to be more in heavier egg weight groups. Yolk weight was though found to be increased significantly (P<0.01) with the increase in egg weight but its percentage decreased inversely.

Heterosis percent was found to be positive for egg weight, egg length, egg width, shell weight, albumen weight, yolk weight and yolk width in both the crosses (WC × WPR and RC × WPR). Heterosis percent was negative for shape index and shell thickness in WC × WPR and for albumen height, albumen index, yolk height and yolk index in RC × WPR.

The estimates of phenotypic correlation between egg weight and all the egg quality traits were highly significant (P<0.01), positive and very high except the correlation with shape index, albumen index and yolk index where estimates were low to very low, nonsignificant ,in general, and in both the directions. Highly significant and positive correlations were also observed among the various egg quality traits, except the correlation between egg length and shape index and between yolk width and yolk index where magnitudes were though high and significant (P<0.01) but negative in direction. The correlations of shape index, shell thickness and albumen index with other egg quality traits are either positive or negative and nonsignificant, in general, with low to very low in magnitudes.

The average fertility and hatchability on fertile egg basis were obseved to be quite high. The average fertility in pure and crossbred chicken were observed to be ranged from 91.25 to 93.5 and 87.35 to 89.90% respectively. The average hatchability on fertile egg basis in pure and crossbred chickens was shown to be ranged from 73.97 to 81.64 and 77.00 to 79.31% respectively.

The heterosis percent of fertility and hatchability were found to be very low and negative, in general.
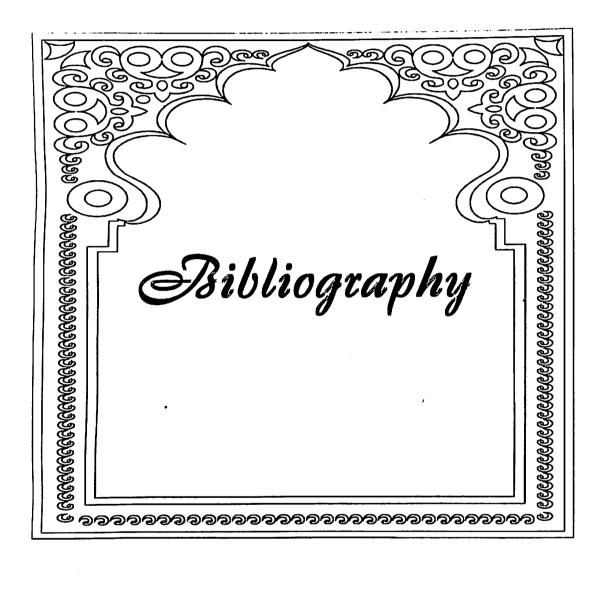
CONCLUSIONS

1. The genetic groups were found to have significant effect on egg weight and egg quality traits. The crossbreds were observed to be superior as they laid heavier eggs than the purebreds.

2. Crossbreds were also found to be superior over purepreds except WPR for most of the egg quality traits. Nonsignificant differences were observed between the crosses for egg weight and most of the egg quality traits like egg width, shell thickness, albumen height, albumen index, yolk width, albumen weight, yolk weight and shell weight. WC × WPR was superior over RC × WPR for egg length, yolk height and yolk index where as RC × WPR was superior for shape index.

3. The egg weight was found to have significant effect on egg quality traits and heavier egg weight groups had higher estimates for all the egg quality traits except yolk index and yolk percentage.

4. The heterosis percent were observed to be positive, in general, and estimates were higher in WC × WPR crosses than the RC × WPR.

5. The estimates of phenotypic correlations between egg quality traits were shown to be highly significant and positive, in general, in all the genetic groups.

6. All the genetic groups observed to have higher fertility and hatchability percentage but purebreds were superior over crossbreds for fertility and hatchability on the basis of total number of eggs set. Where as crossbreds were, in general, observed to have higher hatchability percentage on the basis of fertile eggs set. However, WPR had higher hatchability percentage among all the genetic groups.

RECOMMENDATION

Due to high rate of fertility and hatchability and better egg quality of WPR, it is therefore, recommended that this breed may be used as female line for broiler production.

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