II. REVIEW OF LITERATURE

The published literature relating to the present study has been reviewed under the following headings:

2.1 Indian Scenario of Rural Poultry Production

2.2 Development of Genotypes Akin to Country Fowl for Scavenging Conditions

2.3 Feeding Standards for Breeder Flock

2.4 Feeding Programs for Breeder Hens
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2.1 Indian Scenario of Rural Poultry Production

Poultry farming in India has transformed itself from backyard venture into a dynamic agro industry at a rapid pace in just over four decades. Whereas, the Industrial poultry production is being progressively concentrated into fewer and fewer hands through self-integrated layer farming or vertically integrated contract broiler farming practices, which are gaining popularity in the developing countries. However, rural poultry production still continues to play its own role.

In India, in 1993, the proportion of “desi” birds to the total chicken population was estimated at around 44 per cent, while its contribution to the total annual egg production was 12 % (Prabakaran, 2003). It is also reported (Farrel, 1992) that almost 75 % of eggs and poultry meat produced in Africa and 50 % of eggs produced in South Asian countries are derived from rural poultry raised on traditional farming systems.

Large number of indigenous domestic fowls is predominating in rural household activities of Bangladesh (Barua and Yoshimura, 1997) raised with little or no inputs and productivity is very low and irregular with an average annual egg production of 35-45 eggs weighing 33-38 gms (Huque et al., 1990). According to Deben and Sarma (2002), nearly 75 % of total poultry population in north eastern region of India is from desi origin and the share of desi fowl in Assam has increased from 87.04 % (1994) to 90.23 % (1997). Similarly, the output of meat from backyard units in Kerala is above 4000 metric tonnes per annum (Jalaludeen, 2002).

The indigenous chicken constitutes more than 50 % of poultry population in Thailand, Indonesia, Philippines and about 85 % in Burma (Sharma et al., 2002). Likewise, rural chicken production is a widely acceptable practice in 52 countries of Africa and it was observed that nearly 85 % of poultry products comes from this sector (Gueye, 1997; Gueye, 1998; Gueye, 2002). Consumers from East Asia and Europe are willing to pay a higher retail price for more tasty egg and chicken meat produced in less confined conditions (Chin, 2003) and they prefer colour-feathered of slow-growing meat type quality chickens.
Village producers keep small flocks of between 5 and 20 birds per household (Bhanja, 2005) and are generally raised on a free range system under which, birds survive as scavengers by feeding on available resources such as worms, household refuse, fruits and vegetable wastes, insects, tender leaves and residues from the harvest etc (Reddy and Qudratullah, 1996). Rudimentary coops or shelters made of bamboo, wood or earth may be provided to give some protection against bad weather and night predators such as reptiles or allowed to rest on the tree branches (Sharma et al., 2002).

These native birds lay about 40-60 eggs annually (Khan, 2002) and this produce is consumed by the family as well as distributed as gifts or occasionally bartered for other commodities (Rita et al., 2008). On the other hand, some are selling these eggs and meat to replenish their day-to-days economy (Mallik, 2005). The entire operation from feeding and management to marketing of eggs/birds is being handled by women (Kitalyi, 1996; Miah, 1996; Desai, 1996; Saha et al., 2005; Sagari, 2008).

Although, India’s backyard poultry population over the last 30 years has been increased only by 16 % from 64 million to 76 million (Ramappa, 2002), it contributes nearly 30 % to the national egg production. Hence the small holder backyard poultry units though not useful for mass production of eggs and poultry meat, still serve as an important source of employment and income apart from bridging the nutritional gap through supply of animal protein for a rural folk (Mohapatra, 2005).

The indigenous fowl enjoys the privilege of superiority over exotic birds (Singh, 2005) due to its following attributes:

- Acceptability of the coloured desi bird by the landless labourers or marginal farmers.
- Use of broodiness for hatching the chicks.
- Capability of self-defense from predators due to its alertness, light body weight, longer shank length, camouflagic characters and aggressiveness.
- Thrive well under adverse environments like poor housing, poor management, poor feeding and have better adaptability to extreme climatic conditions.
Comparatively hardier, resistant to many tropical diseases and need less health care than exotic birds.

Meat from native fowl has significantly higher amino acid contents (arginine and lysine) than meat from exotic birds and is widely preferred especially because of their pigmentation, taste, leanness and suitability for special dishes and often fetching higher prices.

Brown-shelled eggs of native fowl are rich in threonine and valine than farm eggs as well as possess good flavor and fetch premium price.

In general, small numbers of chickens and small ruminants serve as safety kits for financially starved rural families and are sold during emergencies to get cash-in-hand.

Thus, country fowls are maintained with very low land, less labour and capital inputs and can therefore be kept by even the poorest social strata of the rural population. However, because of the low productivity, indigenous fowl production has been denigrated or even ridiculed and it is frequently considered by farmers as an insignificant secondary occupation when compared with other agricultural and allied activities. Nevertheless, the sustainability of this type of production system under the harsh village conditions has been largely demonstrated (Bessei, 1996).

It is important to note that just 25% of the country’s population living in urban or semi-urban areas consumes 100 eggs and 1.2 kg meat per person per annum, while in contrast, the consumption is merely 15 eggs and 0.15 kg meat in villages (Sharma and Chatterjee, 2006). The availability of eggs at affordable prices in rural areas is possible by developing germplasms for efficient rural poultry production and this approach can prove to be successful in developing countries, as it is low capital and less labour intensive.

2.2 Development of Genotypes Akin to Country Fowl for Scavenging Conditions

The Red Indian Jungle fowl is proudly claimed to be the genetic foundation of today’s best layer breeds of the world. While the Indian Game Bird (Aseel)
historically had a high place in social life of the country being patronized by both the aristocracy as well as by the humble farmers (Krishna Rao, 2002).

In the past three decades, a large population of exotic layers and broilers has been introduced in the country leading to large-scale multiplication and gradual depletion of indigenous chicken germplasm. Therefore, a network programme was started by Govt. of India involving SAUs and ICAR institutes to achieve self-reliance and produce superior genetic stocks of layers and broilers by utilizing local indigenous germplasm for improvement of specific traits viz., adaptability, immune competence, carcass quality traits etc.

Most of the research attempts are contemplated in the area of breeding and development of imitated phenocopies of indigenous type of birds from exotic blendage. Such developed birds were made available for rural households who reared them at negligible maintenance cost (Lokanth and Murthy, 2002).

Work on development of coloured birds with higher production potential was initiated in eighties. The University of Agricultural Sciences, Bangalore released the first improved coloured bird suitable for backyard rearing ‘Giriraja’ in 1989. Giriraja is a pioneer bird and blazed to strengthen the economy of the rural poor by producing good number of eggs (75-180/yr) as well as good quantity/quality meat (3-6 kg body weight) under rural conditions (Reddy and Rajendiran, 2002).

Subsequently, several varieties viz., Vanaraja by Project Directorate on Poultry (GOI), Nandanum by Tamilnadu University of Veterinary and Animal Sciences, Kroiler by Keggs Poultry Farms etc. were also released. Though these varieties have become popular to some extent among farmers and tribes, but are more prone to predation because of heavy size and low flight capacity (Viroji Rao, 2006).

Taking queue from the success of meat type backyard poultry, several research institutes have developed coloured egg type chicken suitable for backyard rearing. Gramapriya, Krishipriya, Krishna-j, CARI Shyama are a few, which fall in above category with variegated plumage, good egg production potential but yet with smaller body size (Rai et al., 2005; Krishna Rao, 2005; Dev Roy, 2006).
Few private breeding farms introduced Kalyani-DK, Kalyani-SPK, Kalyani-KD and other marketed varieties into markets selling as desi fowl. Similarly, Central Avian Research Institute has produced Hitkari and Upkari varieties of middle body weight for scavenger raising (Khan, 2005).

Abundant scope for evolution of genetically engineered superior new strains of poultry for weaker sections is in offering which is bound to succeed and will be a major revolution in the Poultry sector of India (Sanjeev and Choudhary, 2006; Saxena, 2006). In this direction, genetically improved Black and White Nicobari strains were developed for backyard farming in Bay Islands. In fact, the Nishibari and Nicorock birds of these islands produce 160-170 eggs and 130-140 eggs per year, respectively under backyard rearing (Rai, et al., 2005).

Since crossbred chicken introduced in the backyard are comparatively good producers, it is better to provide some quantum of balanced feed rather than leaving them entirely on scavenging. Such a measure would facilitate to exploit their production potential to a great extent. Accordingly, productivity of these birds has been improved by providing balanced feed @ 25-30 g/bird/day (Jalaludeen, 2002). Nevertheless, the nutritional requirements of these genetically superior stocks have to be precisely and accurately defined to meet their needs for maintaining highest levels of growth and production (Nagra, 2005).

2.3 Feeding Standards for Breeder Flock

Feeding standards are the statements of the amounts of nutrients required by animal/bird, expressed in quantities of nutrients or in dietary proportions. They may be given separately for each function of the animal or as overall figures for the combined functions (Reddy, 2004).

The nutrient requirements of poultry tend to change from one generation to the next because of the applied speed of genetic selection and thus, the national feeding standards fail to keep up with the changes. The multiplicity of feeding standards, the tendency for them to be frequently revised and the increasing use of computers besides the relevance of newer feed resources in ration formulation are factors that have encouraged users to be more flexible in their selection of feeding standards (McDonald et al., 2002). Such nutrient specifications are therefore intended for
guidelines in diet formulation when general growth and development is the goal of the rearing program.

Several factors influence nutrient requirements like bird type, breed and strain, sex, age, productive state of the bird, energy concentration, digestibility of nutrients, management, environmental temperature, antinutritional factors and toxins in feed, deficiencies or excesses of nutrients, nutrient interrelationships and interactions. The requirements for egg type breeders and broiler breeders are different because of the differences in feed intake, body weight and probably digestibility. Thus, optimizing and updating nutrient requirements of poultry birds is a continuous process because of improved performance, variations in nutrient availability, interaction of different nutrients at sites of absorption and metabolism (Mandal et al., 2006).

Nutrient requirements of hens for breeding purposes as described by BIS (1984) as well as NRC (1994) are given in Table 2.1. While the typical recommended (Reddy and Rajendiran, 2002) nutrients’ profile of diets for Giriraja breeder flock is presented in Table 2.2. Nutrient specifications for egg type breeders on as fed basis (88% dry matter) as described by Ramasubba Reddy (2006) are given in Table 2.3.

The nutrient requirements of light breeds have been extensively documented and recommended for various age groups and production phases. But however, scanty information (Deo et al., 2004ab; Elangovan et al., 2004; Mandal et al., 2005) is available on nutritional requirements of native chickens or strains for sustainable low input rural poultry production. The requirements of different nutrients for synthetic breeds may differ from that of Leghorn type breeds (Elangovan et al., 2004).

2.4 Feeding Programs for Breeder Hens

2.4.1 Feed restriction for female breeders

The goal of any restriction program of feeding is to ensure optimum weight-for-age at sexual maturity. A major concern with restriction programs is maintenance of flock uniformity. Feed restriction should be relaxed if birds are subjected to any stresses such as beak trimming, vaccination, general disease challenges or substantial reduction in environmental temperature.
The modern breeder female is a genetic compromise between two very different selection criteria. This parent must have the genetics for rapid and efficient growth and yet exhibit a high rate of egg production to supply the next generation of chicks (Renema and Robinson, 2004). The negative relationship between growth and reproductive fitness has been recognized for over 30 years in the chicken (Maloney et al., 1967; Jaap and Muir, 1968) as well as in turkeys (Nestor et al., 1980).

The *ad-libitum* feeding programmes in pullets and during sexual maturation can lead to a lifetime obesity, discomfort, poor vigour and poor control over ovarian follicle production and release. Thus, the routine feed restriction of broiler/layer breeders from an early age is considered as essential for the well being of the birds (Katanbaf et al., 1989a) and for the production of eggs and chicks (Katanbaf et al., 1989b). But however, continual changes in the genetic composition of stocks by the primary breeders (Robinson et al., 1993) and strain specific management effects may yet limit the potential application of a defined, ideal, welfare-friendly growth curve of feed restriction method.

Body weight in broiler breeder hens has been reported to be negatively correlated with duration of fertility and fertile egg production (Bilgili and Renden, 1985). Robinson et al. (1998) exposed breeder pullets of four commercial strains to either *ad-libitum* or restricted feeding programmes from photostimulation and two of the strains had an accelerated sexual maturation with *ad-libitum* feeding, while the onset of lay was not affected in the other two strains.

Time of introduction of restricted feeding needs to be flexible and according to the growth potential of the strain of birds. Restriction after 24 weeks of age in case of broiler breeders along with more severe feed restriction results in delayed maturity and loss of chicks per breeder (Wilson et al., 1989).

Feed restricted birds are not free from hunger; they have the welfare benefit of reduced incidences of metabolic disorders and mortality (Whitehead, 2002). Under current conditions, the negative relationship between excess nutrient intake and reproduction will have to be altered by management strategies, including feeding and lighting programmes (Renema and Robinson, 2004).

2.4.2 Beak trimming in laying hens
Egg laying strains of chickens are routinely beak trimmed to reduce injuries and deaths due to feather pecking and cannibalism (Mench, 1992; Cunningham and Mauldin, 1996; Hester and Shea-Moore, 2003; Cheng, 2006). Outbreaks of feather pecking and cannibalism can occur among hens in any type of housing system and represent a serious welfare and production problems (Kathle and Kolstad, 1996; Blokhuis and Wiepkema, 1998). Beak trimming can also be viewed as a painful mutilation that adversely affects feeding behavior (Gentle, 1986).

Beak trimming of birds at 4 weeks of age or older had more long-term deleterious effects on behaviour than when done at younger ages (Duncan et al., 1989; Lee and Craig, 1991; Gentle et al., 1997). Neuroma formation and persistence of these neuromas in beak stumps were prevalent in birds whose beaks were trimmed at 5 weeks of age (Gentle, 1986), but neuromas did not persist in younger birds whose beaks were subjected to mild trimming at 10 day of age or earlier (Dubbeldam et al., 1995; Lunam et al., 1996; Gentle et al., 1997).

Andrade and Carson (1975) compared 1 day, 6 days, 6, 8, 12 and 16 weeks old beak trimming of White Leghorn birds to beak intact controls. Results indicated that those birds trimmed at 6 or 8 weeks of age showed significant beak re-growth requiring a second trim at 20 weeks of age. White Leghorns trimmed at 12 or 16 weeks of age had smaller egg size as well as body weights. Whereas trimming at 1st day of age delayed sexual maturity but at 6th day did not affect egg production traits. The authors concluded that beak trimming should be done prior to 12 weeks of age to prevent a detrimental effect on egg production traits. Furthermore, they also recommended under the conditions of their study that, 6 days of age was the best time to beak trim when compared to all other ages.

Likewise, White Leghorns beak trimmed at 6 days vs. 11 weeks of age had similar egg production, feed consumption, mortality and net egg incomes. But feather scores were improved for the birds trimmed at 11 week of age as compared to 6 days (Anderson and Davis, 1997).

2.4.3 Energy requirements and its influence on the performance of layers
Defining a bird’s needs for energy is somewhat more complex than specifying needs for most other nutrients. Chickens have a remarkable ability to monitor their energy intake and adjust feed intake as diet energy concentration changes. In most situations, variable management conditions influence energy needs and so it is important to relate all other nutrients to energy level (Leeson and Summers, 2005).

Payne (1967) described the classical feed intake (106-127 g/d) of brown egg layers fed diets with varying energy concentrations (2860-3450 kcal ME/kg). Results showed lower levels of feed intake in higher energy level diets.

Some reports indicated that there was no significant effect of low and high energy diets on egg production, but however, better feed efficiency was observed at high energy levels compared to low energy levels (Mac Intyre and Aitken, 1957; Peterson et al., 1960; Hegwang and Vavich, 1962; Morris and Fox, 1963; Lillie and Denton, 1965). Contrary to these results, some workers observed significant effect of different levels of energy on egg production, feed consumption and feed efficiency (Hill et al., 1956; Harms et al., 1957; Brown, 1965; Robert et al., 1976; Mohan et al., 1977; Venkata Reddy et al., 1980).

Brown et al. (1968) observed no significant differences in egg production and egg weight with different diets containing 2476, 2590, 2659 and 2868 kcal of ME/kg. But, Daghir (1973) studied the effect of different levels of energy (2610, 2665, 2720, 2775 and 2890 kcal of ME/kg) on the performance of the laying hens and reported significant differences in egg production, feed consumption and feed efficiency.

Similarly, Palpox (1974) formulated diets with different levels of energy (2576, 2682, 2788, 2894 and 3000 kcal ME/kg) and when fed to the White Leghorn pullets, significantly higher body weight, egg weight as well as egg production were evident at higher energy levels.

Singh and Talapatra (1974) fed White Leghorn birds’ diets with 1516, 2013, 2509 and 2961 kcal ME/kg and observed no significant difference in overall egg production percentage. Whereas, Sugandi et al. (1975) conducted an experiment to know the effect of different levels of dietary energy (2650, 2850 and 3030 kcal ME/kg) on egg production and observed significant decrease in egg production at
higher level of energy than lower ones and they also concluded that 2850 kcal ME/kg diet was sufficient for optimum egg production.

Likewise, Olomu and Offiong (1983) fed diets with different levels of energy (2400, 2600 and 2800 kcal ME/kg) to the layers and suggested that 16 % protein and ME of 2400 kcal/kg was adequate for optimum production. Same levels of energy as well as protein were also recommended by Jalaludeen and Ramakrishnan (1989).

In an attempt to study inter relationship between different levels of protein (16.5 and 18 per cent) and metabolisable energy (2550 and 2700 kcal/kg) in White Ply mouth Rock breeders, Nandagopala (1991) noticed better efficiency in low protein (16.5 %) and low energy (2550 kcal/kg) diets.

Anitha et al. (1992) studied the effect of different levels of energy (2300, 2500 and 2700 kcal ME/kg) on commercial layers and observed that a combination of 16 % protein with 2300 kcal ME/kg diet appeared to be adequate for optimum egg production. Qudratullah and Eshwarai (1992) conducted an experiment on a pure strain of White Leghorn breeders housed in cages and were fed with diets containing 16, 18 and 20 per cent protein each at ME of 2500, 2700 and 2900 kcal/kg. They observed significantly higher egg production at 18 % protein with 2500 kcal ME/kg.

Sikka et al. (1994) studied on the protein and energy requirements of Satlej strain of White Leghorn layers. They fed them with 14, 16, and 18 % protein and ME of 2500, 2700 and 2900 kcal/kg. From the experimental results, they concluded that 16 % protein and ME of 2700 kcal/kg combination was the most favorable combination for optimum production. Fanimo (1996) in an experiment with hens fed diets containing ME 2250, 2450, and 2650 kcal/kg found a significant decrease in feed intake, hen day egg production and egg weight with highest energy based diets.

Parsons et al. (1994) showed the adjustment over time of 0 to 6 days that occurs with layers when they are suddenly confronted with change in diet energy. Changing from low (2850 kcal ME/kg) to high (3075 kcal ME/kg) energy concentration causes a transitory 3 to 4 % increase in energy intake, while moving from high to low energy, causes a rather 10 % decline in energy intake. Kote (1999) fed varied levels of energy (2400, 2500, 2600, 2700 and 2800 kcal ME /kg) with
isonitrogenous (CP-18 %) diets to new synthetic line of birds and suggested 2400-2500 kcal ME/kg for optimum production.

There are differences in growth rate of commercial pullets throughout the 18 week growth period. At 4 weeks of age, there would be a 14 per cent difference in body weight between the lightest and heaviest strain, while at 18 weeks, this difference could be 10 % and this differential growth rate is reflected in nutrient needs (Leeson and Summers, 2005).

Whereas, the age of sexual maturity in laying hens is decreasing by almost one day each year, yet ‘mature’ size has changed little over the last ten years. In growing the pullet therefore, it is becoming increasingly difficult to achieve desired weight-for-age and that the energy seems most often to be the limiting nutrient. When the growing pullets (0-18 wks) were offered a range of dietary energy levels (2650-3150 kcal ME/kg), growth rate and energy intake was maximized with higher energy concentrations (Leeson and Summers, 2005).

Some of the experiments conducted by Leeson and Summers (2005) showed that the brown egg pullet seems more responsive to diet energy than does the white egg pullet. As energy level increased from 2750 to 3030 kcal ME/kg at a fixed protein level, a reduction in growth rate was sometimes seen because protein and amino acid intakes were limited. Brown egg pullets seem to change their feed intake very little under these conditions and consequently there was an improvement in growth rate.

In another study (Leeson and Summers, 2005), pullets were fed diets at 2750 and 3000 kcal ME/kg. Over the 126 days growing period, brown egg pullets consumed 6 % more energy when fed the high energy diet (20.6 vs. 19.4 Mcal). Contrary to this increased energy intake, white egg pullets consumed about 18 Mcal ME regardless of energy level in the diet.

2.4.4 Influence of different levels of dietary protein, calcium and phosphorus on performance of layers

Malik and Quisenberry (1963) has reported that the birds receiving isocaloric diet with 18 % protein laid significantly more eggs of heavier weight than those receiving 15 % protein.
Reid et al. (1965) conducted an experiment on laying hens fed 13, 15, 17, 19 % dietary protein with methionine 1.77, 1.81, 1.88, 1.89 % and lysine 4.08, 4.64, 4.94, 5.26 % levels, respectively, of isocaloric diets (2860 kcal/kg). The results indicated that 13 % protein did not support optimum egg production. But however, there was no significant difference in overall egg production of birds fed 15, 17 and 19 % protein diets and they suggested that 15 % dietary protein was needed for adequate egg production.

Insufficient dietary calcium causes decreased egg production (Mehring, 1965; Scott et al., 1971). Excess calcium diets have been reported to reduce feed consumption (Hurneitz and Barnstein, 1966 and Roland et al., 1985) along with decreased egg production (Hurneitz and Barnstein, 1966; Moran et al., 1970).

Sadagopan et al. (1971) found that an increase in protein level improved the egg production and suggested that, for optimum egg production the hens require 18-20 % protein in diets under Indian conditions.

Lower protein levels in the diet of laying hens may not support optimum egg production (Singh and Talapatra, 1974) and feed efficiency (Thatte et al., 1981). On the other hand, the high level of protein in the diet showed higher production (Sadagopan et al., 1971; Kling and Hawes, 1990).

But Mohan et al. (1977) fed layers with different levels of dietary protein (11, 13, 15 and 17 %) and varying levels of energy (2550, 2650, 2750 and 2850 kcal ME/kg) and suggested that 15 % dietary protein and 2650 kcal ME/kg in diet for optimum performance.

Reichmann and Cannor (1977) studied the effect of different levels of Ca (2.4 to 5.69 %) and phosphorus (0.45 to 1.42%) on layers and found that no significant differences between different treatments on egg number, feed consumption, FCR and body weights.

Sexena et al. (1986) observed that in commercial layers different levels of energy (2800, 2900 and 3000 kcal ME/kg) with different protein contents (15, 17 and 19%) had no significant effect on egg production, feed consumption, feed efficiency
and egg weight and suggested the optimum protein and energy requirement for layers in winter to be 15 % and 2800 kcal ME/kg, respectively.

Hartel (1989) conducted an experiment in layers fed diets containing 2750 kcal ME/kg and 17.5 % CP with combination of six calcium levels (2.0, 2.5, 3.0, 3.5, 4.0 and 4.5 %) as well as seven phosphorus levels (0.32, 0.42, 0.52, 0.62, 0.72, 0.82 and 1.62 %) and concluded that the minimal requirements of calcium and phosphorus for the laying hens were 2.5 and 0.32 %, respectively.

Leeson et al. (1993) in an experiment conducted with 0.4, 0.35, 0.30 and 0.25 % nonphytin phosphorus (NPP) at 3.5 % Ca in brown egg type layers had found no significant effect of different P levels on production performance of the hens.

While evaluating four varieties of ragi by replacing the maize either at 12.5 and 25 % in the total diet of young (33 weeks) and old (58 weeks) WLH hens, Umashankar (1998) observed that older hens were found to be the poor converters of dietary protein (28.4 %) when compared to younger hens (33.7 %).

By feeding different levels of protein (15, 16.5, 18 and 19.5 %) and constant energy (2600 kcal ME/kg) to the new synthetic line of birds, Dayananda (1998) suggested 15 % protein for optimum production. Likewise, Rao et al. (2002) recommended a ME of 2400 kcal/kg and 16 % CP for optimum performance of Vanaraja chicks during their juvenile phase.

2.4.5 Effect of different levels of dietary energy and protein on egg characteristics

Studies indicated that different levels of energy concentration had no effect on quality of the egg (Mac Intyre and Aitken, 1957; Combs and Helbacka, 1960; March and Biely, 1963).

Lillie and Denton (1967) recommended 16-18 % protein in layer diets for better egg weights. Smaller eggs were evident from a limitation of energy intake (Payne, 1967). Whereas, Nivas and Sunde (1969) observed that 16.8 % protein was sufficient for optimum egg weights.
Sadagopan et al. (1971, 1972) studied the different levels of energy as well as protein in layers and reported that Haugh unit score, albumen index and shell thickness were not affected either by protein or energy. Similarly, different levels of energy in the layer diets had shown no significant effect on egg weight, shell thickness (Sugandi et al., 1975), specific gravity and Haugh unit score (Robert et al., 1976).

Gowda et al. (1976) found an improved egg weight at 15% protein level than at 13% level and they also found that an increase in energy content from 2400 to 2750 kcal/kg had no effect on egg weights. Similarly, Singh et al. (1980) observed increased egg weights with an increase in protein level (18 – 20%) in the diets of White Leghorn hens.

In another experiment, Jalaludeen and Ramakrishnan (1989) observed that shell thickness was superior with 2600 kcal ME/kg than with 2500 kcal ME/kg, but differences in shell thickness among 2400, 2600, and 2700 kcal ME/kg were found to be statistically similar. Several other reports indicated that increasing levels of energy in the layer diets (Sexena et al., 1986; Keshavarz and Nakazima, 1993; Summers and Leeson, 1993; Adeyemo and Longe, 1996) had no significant effect on egg weights.

Summers and Leeson (1994) concluded that body weight is the main factor controlling early egg size. Although there is some evidence to indicate that nutrients such as protein, methionine and linoleic acid can influence egg size throughout the laying cycle, these nutrients have only moderate effects on early egg size. This is probably related to the pullet producing at maximum capacity at least up to the time of peak egg mass.

Adeyemo and Longe (1996) conducted an experiment on layers using 4 isonitrogenous diets with varying levels of energy (2400, 2500, 2600 and 2700 kcal ME/kg) and reported that the egg weight and shell thickness did not differ significantly due to varying dietary energy levels.

Fanimo (1996) in an experiment on Black Harco hens with diets containing 2200, 2450 and 2650 kcal ME/kg had reported that highest energy level decreased the egg weight but no significant effect was observed on shell thickness and Haugh unit score.
2.5 Effect of Energy, Protein and other Nutrients on Immunity Status

Dietary composition impacts immune function of the chicken. As research in the area of nutritional immunology has increased, it is becoming apparent that nutrient needs for immunity do not coincide with those for growth or skeletal tissue accretion (Mandal et al., 2006). Click (1977) in a review, reported the development and functions of the chicken’s humoral immune system and also indicated a limitation in understanding of avian immune system and environmental factors. This led to research in chickens to evaluate the humoral immune system (Click et al., 1981) and cellular immune system (Click et al., 1983) in the presence of a calorie-protein deficiency.

Proper functioning of the immune system depends upon the availability of nutrients, the precursors for cell growth and activity. The nutrients which have immuno-modulating effect include protein and energy (Prahraj et al., 1999); Methionine (Swain and Johri, 2000); vitamin A (Friedman and Sklan, 1997); vitamin E and Se (Hooda et al., 2005); vitamin E (Pardue et al., 1985); sodium (Pimental and Cook, 1987); and trace elements like zinc, iron, copper and manganese (Fletcher et al., 1988; Dardenne, 2002). Whereas, Latshaw (1991) indicated lower requirements of amino acids for maximum growth compared to the immunity. Similarly, higher dietary Methionine levels were required for immunity than for weight gain (Rao et al., 2003).

2.6 Impact of Dam Nutrition in terms of Protein, Energy, Calcium and Phosphorus on Progeny Performance

2.6.1 Protein

Breeder hen nutrition impacts progeny viability and early growth. Proudfoot et al. (1985) fed broiler breeder diets containing 15 or 17% crude protein and evaluated body weight, feed conversion, and profitability of progeny up to Day 41 post-hatching. Day 41 feed conversion was the only parameter affected and was best in progeny from hens fed the low protein diet. It was rationalized that this improvement in feed conversion occurred because progeny from hens fed the low crude protein diet had numerically lower mortality.
Lopez and Leeson (1994) fed boiler breeder diets varying in crude protein (9, 11, 13, and 15%) and found that female progeny chicks, but not male progeny chicks, from breeders fed 15% dietary crude protein had increased hatch weight relative to egg weight. The highest body weight in female broilers was noted in progeny from breeders fed 15% crude protein 24 hours post-hatch, but not at days 7, 21, 35, or 49 posthatching. Although reducing dietary crude protein reduced egg weight, differences in progeny at day 49 in terms of live performance and carcass traits did not occur. Breeders in the former trial were placed on experimental treatments at week 58. Because no detrimental progeny effects were observed, it is concluded that protein can be decreased in mature broiler breeders without negative consequences in progeny.

Lopez and Leeson (1995a) fed 18 week old broiler breeder with diets containing 10, 12, 14, and 16% crude protein and found that eggs laid from hens fed the 10 and 12% crude protein diets were smaller and resulted in depressed chick weight at hatch. Subsequent research by same workers (Lopez and Leeson, 1995b) evaluated progeny live performance and carcass traits from 30 and 52 week-old breeders fed the former crude protein levels and found no detrimental effect in progeny up to day 48. These studies support the conclusion that dietary crude protein levels for breeders may be lowered below levels thought to support good egg weight without compromising overall progeny performance.

### 2.6.2 Protein and energy

Aitken et al. (1969) fed breeder hens two dietary treatments differing in protein and energy contents (low density, 14.6% CP and 2,490 kcal ME/kg; high density, 17.5% CP and 2,880 kcal ME/kg). Both low and high-density diets were fed ad libitum. As expected, progeny from hens fed the high-density diet had heavier weight. Also, these progeny chicks from the hens fed the high-density diet had improved growth rate at 42 and 63 days post-hatching. Interestingly, protein and energy intakes of hens were similar because higher feed consumption was noted in hens fed the low density feed.

Pearson and Herron (1981) fed broiler breeder with diets varying in energy (1.88, 1.73, or 1.52 MJ AME/bird/day) and with protein allowances of 19.4 to 27.2 g
CP/bird/day from weeks 21 to 64. Progeny were hatched from breeders at weeks 36, 51, and 52 and differences in growth rate, feed conversion, and mortality did not occur. It was concluded that amino acid levels in the hen's diets were sufficient to produce viable progeny.

Proudfoot and Hulan (1986) fed breeder pullets, two diets differing in protein and energy (13.1% CP and 12.2 MJ ME/kg of diet versus 16.0% CP and 11.3 MJ ME/kg of diet) from 15 to 20 weeks. In addition, the breeder hen diets contained different levels of protein (15.0 or 11.0% of diet) and energy (11.1 and 11.5 MJ ME/kg of diet) from weeks 20 to 60. Dietary treatments fed to pullets or hens had no impact on progeny performance.

Spratt and Leeson (1987a) fed broiler breeders 150g of diets per day that provided 19 or 25 g CP and 325, 385, and 450 kcal ME. Breeder dietary treatments were initiated at week 19 and progeny performance was evaluated from hatches at weeks 29, 32, 36, and 40. In all hatches, male progeny chicks, but not female chicks, from hens fed the 450 kcal energy diet had improved days 1 and 20 body weight over chicks from hens fed the 325 kcal energy diet. Progeny chicks were only reared to day 41 in the hatch from week 29 and differences in male body weight as affected by energy did not occur at days 34 and 41. Moreover, hen dietary protein had no effect on progeny male or female performance except to increase male broiler carcass protein at day 41 when hens were fed the high protein diet. High (450 kcal) dietary energy, however, increased carcass protein and decreased carcass fat in male, but not female broilers at day 41 as compared to male broilers from hens fed the low (325 kcal) energy diet. They postulated that male chick growth, rather than female chick growth, is benefited by their dams consuming higher energy, because their growth is more rapid than females. It has also been shown (Spratt and Leeson, 1987b) that hens consuming high energy diets have larger yolks relative to egg weight and an increased yolk weight provides more energy and protein to the chick post hatch.

Attia et al. (1995) fed broiler breeder hens (weeks 21 to 61) 88, 94, and 100% of a primary breeder company's recommended energy levels and noted no improvements in progeny body weight at hatch. More recent work (Brake et al., 2003), evaluated crude protein and energy levels in broiler breeders on Day 21 progeny body weight in four hatches from 27, 28, 33 and 39 week old breeders.
Increasing protein and energy density resulted in male progeny having improved body weight in three of the four hatches and female progeny having improved body weight in one out of the four hatches.

2.6.3 Calcium and phosphorus

Hen’s mineral status, as affected by it’s dietary mineral levels, is correlated with the transfer of minerals to the egg for embryo utilization (Richards and Steele, 1987).

Restricting dietary calcium in a hen's diet has been shown to reduce hatch weight of chicks (Buckner et al., 1925). Although few reports have addressed the impact of calcium needs of the chick as affected by maternal levels, it is not thought that levels near those typically fed to optimize egg production will impact chick early growth.

Singsen et al. (1962) and Taylor (1965) indicated that dietary phosphorus in a hen's diet had minimal effects on egg weight. Subsequent research by Hartel (1990) supported the former results, but El Boushy (1979) found that increasing hen phosphorus increases egg weight.

Harms et al. (1964) reported that the addition of 3.5 g of dietary phosphorus/kg of diet from defluorinated phosphate to hen diets containing 3.4 and 3.9 g/kg total phosphorus did not impact percentage ash, calcium level, or phosphorus level of eggs or chick tibias at hatch and 2 weeks post hatch.

In contrast to earlier work, Triyuwanta et al. (1992) demonstrated that altering hen dietary phosphorus levels (2.0, 6.0, and 10.0 g available phosphorus/kg of diet) had no impact on progeny chick body weight at hatch or at two or seven weeks post hatch. However, increasing hen phosphorus increased egg phosphorus resulting in improved progeny ossification (tibia maximal force, elastic force, and ash content) at hatch, but not at 7 weeks post hatch.