II. REVIEW OF LITERATURE

The literature relating to sugarcane press residue including the importance of some major nutrients in poultry production is briefly reviewed under the following headings:

2.1 Alternate Feed Resources for Poultry

2.2 Importance of Various Nutrients in Poultry Diets
   2.2.1 Energy
   2.2.2 Protein
   2.2.3 Minerals
   2.2.4 Nutrient Specification for Various Classes of Poultry
   2.2.5 Performance of Birds on High Fiber Diets
   2.2.6 Other Dietary Factors Influencing the Performance of Birds

2.3 Biotechnological Approaches for Optimizing Birds’ Performance
   2.3.1 NSP Degrading Enzymes
   2.3.2 Lipid Utilizing Agents

2.4 Sugarcane in Agriculture and Industry
   2.4.1 General
   2.4.2 Sugarcane Press Residue (SPR)

2.5 Chemical Composition of SPR

2.6 Effect of SPR Based Diets on Broilers’ Performance
   2.6.1 Growth Rate and Livability
   2.6.2 Feed Consumption and Feed Efficiency
   2.6.3 Carcass Characteristics and Organometry

2.7 Effect of SPR Based Diets on Layers’ Performance
   2.7.1 Egg Production
   2.7.2 Feed Consumption and Feed Efficiency
   2.7.3 Body Weight Change
   2.7.4 Egg Characteristics
   2.7.5 Efficiency of Nutrient Utilization

2.8 SPR as a Feed Ingredient in Other Farm Animals

2.9 Effect of Inclusion of SPR on Utilization of Nutrients
2.10 Effect of Inclusion of SPR on Mineral Status of Birds/Animals
2.11 Economics of SPR Supplementation
2.1 Alternate Feed Resources for Poultry

The spiraling cost of feed ingredients is causing a steep increase in the prices of compounded poultry diets leading to a corresponding raise in production costs with the resultant low marginal profit for the poultry farmer. Hence, it is imperative to resort to other means for alleviating the problem of high feed cost without impairing the performance of the chickens. In this direction, utilization of cheap and locally available non-conventional feed resources, not directly utilized for human food appears to be the most practical and economic approach to this problem (Reddy, 2005).

India, due to its highly variable landscape, rainfall and agro-climate, produce large number and quantities of agro-industrial by-products for livestock feeding. However, only a narrow range of these raw materials are used in poultry feed formulations because of:

1. problem of collection, transportation, processing and storage
2. higher fiber content or low energy value
3. presence of certain anti-nutritional or toxic factors
4. seasonal availability and hence irregular supply
5. variability in nutrient quality

Added to the above constraints, more importantly there is a lack of reliable data on their nutritive quality, feeding value and safe or effective levels of inclusion. Only conventional feed ingredients such as maize, soybean meal, groundnut extractions and fish meal have been evaluated with a fair degree of accuracy and reliability but database is limited for other ingredients. Hence, there is always a urgent need to develop database for conventional feed ingredients on nutrient contents, digestibility/availability of different nutrients and safe/effective level of inclusion and the presentation form of feed for feeding (Mandal et al., 2006).
In last two decades there were occasions when India was facing the shortage of food grains for human beings. During such situations poultry industry is the first to be affected and this led many nutritionists in India to depend on the agro industrial by-products, as a component of poultry rations and as a result several potential sources of feed have come to the light.

The agro-industrial by-products are of primary importance in poultry feeding in view of their availability in quantities sufficient for small farm and commercial use. However, most of them are seldom able to meet the required nutritive value and moreover almost all of these are plagued by the presence of anti-nutritive factors like mycotoxins, phytate, oxalate, tannins and others including high fiber and lignin apart from low nutrient profile (Saxena et al., 2006).

Although their feeding values are known to be poorer than that of conventional feed ingredients, yet when the price of conventional feed ingredients particularly maize is very high, then the compensation in terms of feeding cost may be more than the loss in production while using non-traditional feed ingredients together with biotechnological approaches in formulations.

2.2 Importance of Various Nutrients in Poultry Diets

Among the various nutrients, the role of energy, protein and minerals is of great significance in poultry, because of the exclusive function of each such nutrient. Compounding of poultry diets is being normally done primarily to meet these requirements. Since SPR appears to be a poor source of energy and protein but a good non-traditional source of minerals, it is pertinent to review the literature related to influence of different nutrients on
the performance of birds. The role of crude fiber is also considered because of its anti-nutritive properties.

2.2.1 Energy

Energy, described by Kleiber as the fire of life, is of utmost importance because in the diets containing adequate amounts of all required nutrients, the efficiency of feed utilization nearly depends upon the available energy content of the diet (Leeson and Summers, 2001).

The energy required by the chickens for growth of body tissues, production of egg, carrying out of vital physical activities and maintenance of normal body temperature, is derived from organic compounds viz., carbohydrates, protein and fats in the diets (McDonald et al., 2002).

a) Procedures for measuring metabolizable energy

Various bioassay procedures are available for determination of metabolizable energy (ME) of feed ingredients wherein feed intake and excreta output are measured over a 2 to 5-day test period. In the method of Sibbald and Slinger (1963), the test ingredient is substituted essentially for part of the complete basal diet. However, to avoid mineral and vitamin deficiencies, the components of the diets containing these nutrients are left intact.

Hill and Anderson (1958), assuming that if nitrogen is not retained it will appear as uric acid, proposed a correction value of 8.22 kcal/g nitrogen retained because this is the energy obtained when uric acid is completely oxidized.
Several researchers have also developed prediction equations to estimate the energy content of feed ingredients from their proximate components. Janssen et al. (1979) conducted a series of studies to correlate the chemical composition of different types of feed ingredients to the ME value. By using multiple regression analysis, equations were derived to estimate MEn (kcal/kg dry matter) from chemical composition. A subcommittee of European Federation of the World’s Poultry Science Association (1989) developed a set of equations to estimate the energy value of ingredients. Dale et al. (1990) developed an equation to estimate the TMEn value of dried bakery products, a blend of various by-products produced from the baking industry.

The ME values obtained by predication equations are highly variable. For example, the ME value of grain sorghums is known to be influenced by tannin content. Sibbald (1977) reported TME values of 3300 and 3970 kcal/kg for high and low-tannin grain sorghums, respectively.

Employing high levels of added fat often leads to more MEn than can be accounted for from the summation of ingredients. Several literature (Mateos and Sell, 1981; Mateos et al., 1982; Sell et al., 1983) reported that the high level fat feeding evidently increases the intestinal retention time of feed and so allows for more complete digestion and absorption of the non-lipid constituents.

Factors influencing the MEn value of fat that are not directly associated with fat quality are age of poultry and method of measurement. Renner and Hill (1961), Sibbald and Karmer (1978) and Lessire et al. (1982) reported that an improved utilization of dietary fat occurs after 2 to 6 weeks of age in case of chickens. Such type of improvement, according to Young and Garrett
(1963) and Sell et al. (1986) was evident with long chain saturated fatty acids and fats containing substantial proportions of these fatty acids. A synergism in the absorption of the saturated fatty acids (tallow) related to the added amounts of unsaturated fatty acids (vegetable oil) was also reported (Ketels et al., 1986; Ketels and DeGroote, 1987).

b) Low energy density diets

A series of experiments were conducted by Leeson et al. (1996) to demonstrate the effect of broiler response to variable dietary energy. In the first experiment where the chickens were offered corn-soy diets providing 2700, 2900, 3100 and 3300 kcal ME/kg ad libitum, showed no effect on growth rate and energy intake was constant. In second experiment when the feed intake was restricted, there was reduced growth rate as the energy level decreased from 3300 to 2700 kcal ME/kg. In third experiment, when the broilers offered a choice of diets (3300 kcal diet and either 3100, 2900 or 2700 kcal diet separately), they showed remarkably precise control of intake, such that energy intake was gain constant across all treatments. They also concluded that the broilers possess a good ability to control their feed intake based on desire to normalize energy intake.

Recently, Nagaraju (2006) reported that the broilers consumed a relatively higher amount of feed (3619g/bird) when fed with low nutrient density diet containing 3.5% lesser ME and protein as against the moderate nutrient density diet (3132g/bird) while the body weight gain (2020 and 2055g, respectively) and FCR (1.99 and 2.00 g feed/g weight gain) remained almost similar during 42-day experimental period.

Savory and Gentle (1976a), in studying feeding pattern of quail fed diets diluted with 20% showed that normalization of energy intake had
occurred at 8 to 10 days. In this study with quail, birds were able to normalize their nutrient intake, although growth rate was not maintained suggesting that the diet dilution with fiber in some way influenced energy portioning. However, Savory and Gentle (1976b) measured ME of their diluted quail diets and showed that the fiber per se had no effect on utilization of other feed components.

Since chickens increase their feed consumption as the energy content of the diet reduced, a deficiency of energy can be produced only by using very low energy diets which are usually quite bulky surpassing the capacity of the crop and digestive system (Leeson and Summers, 2001) to hold the ingested feed.

As the energy content of the diet of growing chickens drops below the critical value (2600 kcal/kg), growth is reduced and the amount of fat deposited in carcass decreased. However, as long as the energy content of the diet is adequate for maintenance, no other deficiency systems were observed (Leeson and Summers, 2001).

If the diet is so low in energy that it entails a feed intake which exceeds the physical capacity of the bird, energy intake will then be inadequate to support normal egg production. From the evidence reviewed by (Morris, 1968) it would seem that the lower limit to dietary energy concentration is about 2300 kcal ME/kg. Below this level one can expect reduced rates of the lay if mash diets are fed. The exact limiting value in mash diets is probably determined more by energy per unit volume than energy per unit weight.

As and when sunflower meal was incorporated at higher levels, nutrient and energy densities of the resulting diet may be significantly diluted
and growth being retarded (Senkoylu and Dale, 1999). Fat can be a good way of fortifying the energy density of the diets (Zatari and Sell, 1990).

c) Factors affecting utilization of dietary energy

Feedstuffs containing high amounts of fiber possess relatively low energy values for poultry unless they are also high in fat content (Leeson and Summers, 2001). Variation in available energy and protein content of feedstuffs can be attributed to wide range of anti-nutritive factors such as non-starch polysaccharides (NSP), tannins, protease inhibitors, alkaloids, saponins etc. (Hughes and Choct, 1999).

Of the known anti-nutritive components of poultry feedstuffs, soluble NSP stand out as a major determinant of the available energy and other nutrients for poultry (Hughes et al., 2001). One of the modes of action of soluble NSP is to form a viscous gel in the gut which in turn affects the rates of digestion and absorption of nutrients (Choct, 1999).

Among the bird-related factors influencing energy metabolism, capacity to digest and absorb carbohydrates develops during incubation, providing the newly hatched chick with a relatively mature system for utilization of starch, the main carbohydrates in the diet of poultry (Moran, 1985). On the other hand, the capacity to utilize fat can take 10 days or so to develop in broiler chickens due to lag in lipase secretion by the pancreas (Jin et al., 1998).

2.2.2 Protein

Protein, being the premier nutrient, is always judiciously maintained at certain specified optimum level for different classes of poultry. In general, as the age advances, the level of protein suggested invariably declines (BIS, 1992;
Correspondingly the concentration of energy in the diets is increased with the age of the broilers.

Bedford and Summers (1985) found that as long as the essential amino acids comprised 55 per cent CP, then the level of dietary CP was not a factor affecting the growth and feed intake. Han et al. (1992) observed that the amino nitrogen itself can be a limiting factor in low protein diets.

Edward and Campbell (1991) emphasized the importance of dietary energy in determining the limit response to protein. A small decrease in net energy yield resulting from large dietary inclusions of poor-quality protein is sufficient to explain the impairment of maximum response.

Boorman and Ellis (1996) confirmed that it was impossible to elicit maximum response to the limiting amino acid by feeding large amounts of poor quality protein.

Ferguson et al. (1998) reported that there is a critical dietary CP level below which the birds’ performance will decline. Reducing CP content below 18.8 per cent in the diet fed from 3 to 6 weeks of age would adversely affect performance parameters.

2.2.3 Minerals

a) Role of Minerals

Minerals are the inorganic part of feeds or tissue. They fulfill physiological, structural and regulatory functions as mentioned below:

<p>| Role of individual mineral elements and the effects of their deficiency |
|--------------------------|-----------------|------------------|
| <strong>Element</strong> | <strong>Role / functions</strong> | <strong>Deficiency symptoms</strong> |
| Calcium | Bone and egg shell | Growth retardation, decreased |</p>
<table>
<thead>
<tr>
<th>Element</th>
<th>Function</th>
<th>Deficiency Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus</td>
<td>Transmission of nerve impulse, bone, energy metabolism</td>
<td>Feed consumption, rickets, osteomalacia, thin egg shells, rickets, osteomalacia, deprived appetite, poor fertility</td>
</tr>
<tr>
<td>Potassium</td>
<td>Osmoregulation, acid-base balance, nerve and muscle excitation</td>
<td>Retarded growth, weakness</td>
</tr>
<tr>
<td>Sodium</td>
<td>Acid-base balance, osmoregulation</td>
<td>Reduced egg production, poor growth, cannibalism, soft bones, low body weight gains and high mortality</td>
</tr>
<tr>
<td>Chloride</td>
<td>Acid-base balance, osmoregulation, gastric secretion</td>
<td>Alkalosis, poor growth, high mortality, nervous trouble</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Structure of amino acids, vitamins, hormones, chondroitin</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>Bone, activator of enzymes for carbohydrate and lipid metabolism</td>
<td>Nervous irritability and convulsion</td>
</tr>
<tr>
<td>Iron</td>
<td>Haemoglobin, enzymes of electron transport</td>
<td>Anemia, depigmentation of red and block feathers</td>
</tr>
<tr>
<td>Copper</td>
<td>Haemoglobin synthesis, enzyme systems, pigments</td>
<td>Anemia, poor growth, depigmentation, sway back</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Component of vitamin B₁₂</td>
<td></td>
</tr>
<tr>
<td>Iodine</td>
<td>Thyroid hormones</td>
<td>Goiter, drop in production, lacy feathers, weak or dead young ones</td>
</tr>
<tr>
<td>Manganese</td>
<td>Enzyme activation</td>
<td>Perosis, retarded growth, reduced egg production, weak egg shell, skeletal abnormality, atoxia</td>
</tr>
<tr>
<td>Zinc</td>
<td>Enzyme component and activator</td>
<td>Poor growth, depressed appetite</td>
</tr>
<tr>
<td>Selenium</td>
<td>Component of glutathione peroxidase, iodine metabolism, immune function</td>
<td>Myopathy, exudative diathesis, encephalomalacia</td>
</tr>
</tbody>
</table>

(Source: McDonald et al., 2002)
b) **Sources of Minerals**

Most of the feed ingredients that are used as the energy and protein sources in poultry diets invariably also provide minerals in addition to basic organic nutrients. Hence, whenever possible or practicable the mineral requirements should be met by selection or combination of available feedstuffs which supply energy and protein. The amount of different minerals present in commonly used poultry feed ingredients is given below:

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Major minerals, %</th>
<th>Trace minerals, mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca</td>
<td>Pav</td>
</tr>
<tr>
<td>Maize</td>
<td>0.01</td>
<td>0.13</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.05</td>
<td>0.20</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>0.10</td>
<td>0.65</td>
</tr>
<tr>
<td>Rice polish</td>
<td>0.06</td>
<td>0.18</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>0.20</td>
<td>0.33</td>
</tr>
<tr>
<td>Sunflower extr.</td>
<td>0.30</td>
<td>0.75</td>
</tr>
<tr>
<td>Fish meal</td>
<td>6.50</td>
<td>4.00</td>
</tr>
<tr>
<td>Meat meal</td>
<td>8.00</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Source: Leeson and Summers, 2001

The minerals present in commonly used feedstuffs of poultry rations may not be sufficient to meet the requirements for high yielding modern birds. In addition, there is a considerable variability in their availability across various feed ingredients since some of the mineral elements are present in chelated forms, which are largely unavailable for absorption. For example, P from plant sources is only 30 to 45 per cent available (Perney et al., 1993), because much of the P is in the form of phytate (myo-inositol hexaphosphate) and is poorly utilized in poultry. Further, phytate P can complex with several cations such as Ca, Mg, Zn, Fe, K and Cu, as well as amino acids (Ravindran et al., 1998). Hence, the availability of minerals, particularly P in feedstuffs of plant origin is the key issue in poultry nutrition.
Hence, although considerable opportunity exists to provide most of the mineral needs from basal feedstuffs, the flexibility needed in formulating diets often requires concentrated sources of one or more mineral elements sources. The supplementation of inorganic salts is not only expensive but also fails to address the problem of over supplementation, especially in case of P leading to potential environmental pollution in soil and ground water. Specific and exclusive sources of some minerals are given in Table 2.1.

### 2.2.4 Nutrient Specification for Various Classes of Poultry

The requirement of various nutrients for broilers at different age and for laying hens is presented in Table 2.2. The standards show considerable variation in the specifications for all the nutrients. In view of the faster growth observed in the present day broiler genotype and higher egg production rate in layers, the levels recommended by the Governmental agencies (BIS, 1992; NRC, 1994) is lower than the ones followed in the filed particularly for broiler finishers. Current practice is to supply nutrients some what excess of the accepted requirements.

### 2.2.5 Performance of Birds on High Fiber Diets

Crude fiber is known to increase the passage rate in the gut and bringing physicochemical changes in the ingesta due to its hydrophilic property (Southgate, 1973) there by affecting the performance.

Several reports available show the adverse effect of high dietary crude fiber on the digestibility of poultry diets.

Deaton *et al.* (1979) and Mandelkar (1992) found that using high fiber sunflower meal (36% CP and 24% CF) up to 30 per cent in a layer diet significantly decreased feed efficiency while egg production, egg weight and egg shell strength and mortality remained unchanged.
Chaturvedi and Singh (2000) reported that the correlation coefficient between the crude fiber and feed intake on rice bran based diets (9.87, 10.87, 11.48 and 11.57 % CF) has followed the generally accepted concept that on high fiber (low energy) diets, feed intake is relatively higher. They also noticed that the severe deficiency of nutrient (energy) (15.58 to 16.00% CF) lowered feed intake and the degree of reduction in feed intake was governed by the severity of the deficiency.

2.2.6 Other Dietary Factors Influencing Performance of Birds

An important nutritional factor, in addition to the composition of the diet and its caloric value, is the structure of the food, which induces marked changes in behavioral and metabolic parameters. Physical texture and appearance have some effect on the willingness of the birds to approach and consume feed and this is particularly important with young birds.

a) Particle size

Portella et al. (1988) concluded that birds select feed material on the basis of particle size. Further, he observed that the juvenile meat type chick was able to distinguish small differences in food particle size.

The intake of very finely ground or dusty feeds is often a little lower than that of a coarsely ground mash. Reece et al. (1985) reported that the broiler chicks performed better with a mash containing coarse rather than fine particles. Further, the propensity to consume more feed containing coarse vs. fine particles when given the choice is associated with improved performance (Nir et al., 1990).

Leghorn type cockerels are less susceptible to diet particle size than the broiler type cockerels. Nir et al. (1990) showed that the preference for particle
size vary with age. The disappearance of large particle from the feed is most pronounced as birds become older.

Nir et al. (1994) also reported that the particle size uniformity has a positive effects on performance.

As birds age, their preference for larger particles increases. In choice situations, the refusal of the fine grind was obvious at all ages and was more pronounced as birds got older (Nir and Ptichi, 2001).

When fed a diet in mash form, the weight of the gizzard and its contents are positively related to the size of the feed particle, whereas the pH of its contents is negatively related (Nir et al., 1994; Nir et al., 1995).

Nir and Ptichi (2001) opined that the passage rate of smaller particles through the gizzard of young chicks is faster than that of large particles, resulting in marked atrophy of stomachs (proventriculus and gizzard) and the hypertrophy of the small intestine, and lower pH of the intestinal chyme. The later could be result in excessive bacterial fermentation, producing volatile fatty acids.

b) Density

The physical form of a diet has a substantial influence on the resulting physical density and on growth. Although the dietary energy concentration is normally expressed as energy per unit weight there is some evidence to suggest that energy per unit volume may be a value in defining the energy content of a diet, particularly at the lower end of the scale. Martz et al. (1957) observed that neither energy concentration nor physical density alone was satisfactory for measuring the adequacy of a diet for rapid chick growth and they preferred to use an energy /volume measurement.
Sibbald et al. (1960) also observed that for young chicks nutrient concentration expressed as a gravimetric basis was not as satisfactory as nutrient concentration expressed on a volumetric basis.

c) Palatability

Apart from particle size, the other major dietary factors which affects the feed intake and growth rate is palatability of the diet. The acceptability of the feed is a less important factor with poultry than with other classes of farm livestock, probably because the senses of taste and smell are not developed in birds.

The sense of the taste and smell in birds is less developed than mammalian species (Lindenmaier and Kare, 1959), but this is compensated by mechanoreceptors located in the beak. Mechanoreceptors have been described in chicken beaks (Roumy and Leitner, 1973).

Feed refusal is generally attributed to the presence of mycotoxins in the diets. However, quite often the diet’s texture is responsible for this phenomenon. The past-ingestive nutritional effects of the feed are memorized and coupled with sensorial cues to build feed identification.

As stated earlier, high amount of fines in the diets cause an agglomeration of pasty material on the beak, reduce feed intake, increase water consumption and waste feed in the water trough.

2.3 Biotechnological Approaches for Optimizing Birds’ Performance

Biotechnology is a wide discipline incorporating applied biosciences and technology and involving practical application of microorganisms or their sub-cellular components to the manufacturing and service industry. It is an exciting field offering tremendous scope for more control over biochemical
activities with in the body and also helping dietary nature or the nutritive quality of feedstuffs and feeds.

Application of biotechnological tools in the feed industry such as usage of exogenous feed enzymes has been found to be logical, especially when the diet comprises of unconventional feedstuffs. The concept of using feed enzymes in poultry is well accepted and found economical (Reddy, 2005).

2.3.1 NSP Degrading Enzymes

Poultry, being a simple stomach creature, has a very limited ability to cope up with toxic and anti-nutritive substances if present in any significant amount in their diet. Crude fiber and non-starch polysaccharides are the most important anti-nutrients in the poultry feeds which hamper productivity either through exerting direct effects in the system or by way of lowering digestion and/or absorption of dietary nutrients in birds. These negative effects get further aggravated by inclusion of non-conventional feed ingredients as they are rich in these components in addition to gum and mucilages. Enzymes possessing cellulolytic and hemicellulolytic activity have been found useful in hydrolyzing such components in feeds.

Choct et al. (1995) stated that suitable enzyme combination strategies for different feed ingredients might result in an increase in feed intake, stimulation of growth, improvement of feed conversion and would overcome the problem of wet litter, all of which ultimately would culminate in the cost effectiveness of diets. Enzyme supplementation not only enhances bird performance and feed conversion, but also lessens the environmental problems (Yi et al., 1996).
Rajeshwara Rao and Devegowda (1996) reported that supplementation of enzymes to diets based on SFE and DORB improved the performance of broilers which was attributed to improved nutrient digestibility.

However, Chennegowda et al. (2001) showed a marginal (non-significant) improvement in weight gain by 3.6 to 4.2 per cent in the groups fed 20 % sunflower extraction with commercial enzyme preparations (xylanase and pectinase or xylanase and cellulase) which was attributed to improved digestibility of NSPs by enzyme supplementation only at sufficient levels of substrate (20% SFE) as feed enzymes have higher Km.

In layers, Sharma and Katoch (1993) observed a numerical increase in egg production when a fiber degrading enzyme was supplemented in a diet of 26 weeks old birds. Similar observations were also made by Jayanna and Devegowda (1993) and Mohandas and Devegowda (1993).

Zang Sumin et al. (1996) reported that addition of 0.5% compounded enzyme to the basal diets significantly (p<0.01) decreased the feed intake in layers. The improvement in the feed efficiency due to addition of single or compound enzyme was also reported by Francesh et al. (1995).

Ponnuvel et al. (2001) observed that the per cent hen-day and hen-housed egg production, egg weight and feed efficiency were statistically comparable among groups fed standard layer diet and high fiber diets supplemented with cellulase at different levels (0.06, 0.12 and 0.18%). However, numerically better egg production and feed efficiency were noticed when high fiber diet supplemented with cellulase. Further, they also noticed that the average daily feed intake was significantly lower in all the enzyme supplemented diets and standard layer diet fed groups when compared with unsupplemented high fiber ration fed group.
Exogenous enzymes in feed endows animals with additional metabolic arsenal to fight undigestible feed components as well as ANFs. Use of specific enzymes like xylanase, pectinase and cellulase could breakdown plant fiber releasing energy as well as increasing the protein digestibility due to better accessibility of protein when the fiber gets broken down (Saxena et al., 2006).

2.3.2 Lipid Utilizing Agents

In addition to simple nature of stomach, birds also have low level of natural lipase production during early ages. Hence, young birds do not utilize and absorb fat effectively.

Sell et al. (1986) reported that fat retention improved with age in poult's, regardless of fat source or fat level. In their study, fat retention ranged from 66.4 to 83.7% and from 90.8 to 96.5% at 2 and 8wk age, respectively.

Korgdhal and Sell (1989) found that dietary fat (animal or vegetable origin) was not effectively utilized until the time that lipase activity reached maximum levels between 40 to 56 days of age. Similarly, Wiseman et al. (1991) also observed a marked reduction in overall AME of fats linearly with increasing free fatty acids; the effect was more pronounced with young birds.

Noy and Sklan (1995) reported that net duodenal secretion of amylase, trypsin, and lipase were low at 4 days of age and increased 100, 50 and 20-fold, respectively. Leeson and Attech (1995) also concluded that turkey poult’s, similar to chicks, have an age-related depression in fat utilization that is undoubtedly related to the saturated fatty acids found predominately in animal fats.
Al-Marzooqui and Leeson (2000) found that the supplemental lipase enzymes (Pancreatin® and Pancreatic®) increased (p<0.01) the diet ME and apparent fat digestibility. However, both enzymes caused lower feed intake and lower body weight gain (p<0.01) of male broilers chicks and such a trend was not noticed in feeding crude porcine pancreas. Further, they also observed that the ME values of the diets were greater as the enzyme levels increased.

Recently, Meng et al. (2004) reported that the dietary supplementation of bacterial lipase improved fat use as the young birds have insufficient secretion of endogenous lipase.

In addition to age related effect, fat utilization is also correlated with less efficient bile salts in very young chicks (Serafin and Nesheim, 1970). Several studies have shown that supplementing the diet with bile salts improves the utilization of dietary fat by chicks (Polin and Hussein, 1982; Attech and Leeson, 1985).

Since the synthetic bile salts are expensive, the cheaper alternative emulsifying agents or detergents that have the ability to transform a hydrophobic surface into a hydrophilic surface were tried by several researchers. For example, Jones et al. (1992) showed that the addition of emulsifier increased digestibility of tallow (p<0.01). However, Al-Marzooqui and Leeson (2000) did not observe any improvement in fat utilization upon supplementing a detergent mixture of 95% sorbitan monstearate and 5% polyoxyethylene sorbitan monstearate (Tween-80). Furthermore, other researchers (Agur et al., 1974; Polin et al., 1980) reported that the addition of lecithin, an emulsifier, increased the digestibility of fats containing long chain saturated fatty acids.
Lecithin, an excellent source of phospholipids has the ability to promote fat absorption in the digestive system as the birds’ cannot synthesize this component and thereby increases energy efficiency of feed. Soybeans are the most common source for commercial lecithin. Soy oil has the greatest lecithin and phospholipids content. Lecithin contains about 50% phospholipids and 25-30% unrefined soy oil (Meng et al., 2004).

In general, enzymes such as pentosanases and beta-glucanases hydrolyze the non-starch polysaccharides. A recognized benefit of enzyme usage is a better litter quality which itself is indicative of better poultry health and lysophospholipids can improve digestion and absorption of nutrients (Reddy, 2006). Further, the lysophospholipids are powerful surfactants and can improve the mixing of digesta and facilitate the enzyme access to nutrients in the GIT.

2.4 Sugarcane in Agriculture and Industry
2.4.1 General

Sugarcane is one of the most important commercial crops that plays a key role in the Indian economy. Indian sugar industry with 480 sugar factories located at rural areas throughout the country is a prime catalyst in economically strengthening the potential agro-industrial rural sector (Hunsigi, 2001).

The cultivation of sugarcane crop generates huge quantities of varied by-products viz., sugarcane tops, filter cake/ press residue, bagasse and molasses as renewable resources. However, only limited fractions of total
produce are utilized as feed for livestock and much of sugarcane by-products is wasted.

The by-product availability in India and the World (1997-98) is given below:

<table>
<thead>
<tr>
<th>By-product</th>
<th>Yield (as % of sugarcane)</th>
<th>Availability in million tons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>India</td>
</tr>
<tr>
<td>Bagasse</td>
<td>30</td>
<td>52</td>
</tr>
<tr>
<td>Filter cake</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Molasses</td>
<td>4</td>
<td>6.9</td>
</tr>
<tr>
<td>Cane tops</td>
<td>7</td>
<td>75</td>
</tr>
</tbody>
</table>

(Hunsigi, 2001)

The efficient utilization of these agro-industrial by-products assume significance due to a chronic shortage of feedstuffs for animal feeding. The sugarcane press residue that accounts for 3% of sugarcane is one such by-product but most of it being wasted.

2.4.2 Sugarcane Press Residue (SPR)

Sugarcane Press Residue (SPR), also known as filter cake, is a by-product of sugar industry obtained during the process of precipitation of cane juice. It is a soft, spongy, amorphous dark brown material containing sugars, fiber, coagulated colloids including wax, apart from containing albuminoids, organic salts, etc., and is a rich source of organic carbon and minerals with good proportion of N, P, Ca, Fe and Mn (Singh and Solomon, 1995).

The quantity of SPR obtained in any sugar factory depends on the extent of impurities (non-sugars) present in cane juice and the process of clarification adopted. In carbonation process, a large quantity of milk of lime
used is neutralized by passing carbon dioxide and the precipitate formed is mostly calcium carbonate. In sulphitation process, the little quantity of milk of lime is used which is neutralized by sulfur dioxide gas and the precipitate formed is mainly calcium sulphite. The weight of the carbonation press cake (on wet basis) is about 8 to 10% of the cane crushed while the sulphitation press cake is about 3 to 4 % (Hunsigi, 2001).

The current production of SPR in India amounts to be more than 3.6 million tons annually (Singh and Solomon, 1995) which is roughly 23% of world’s production. The SPR is normally considered as a waste and only fraction of this is used as a soil conditioner or as an ameliorating agent as manure for enhancing soil productivity. A large quantity of it remains unrecycled or partly utilized due to lack of proper technology and thus causing environmental pollution as well.

Ranjhan (2001) reported that the organic matter content in the SPR is about 64 percent of dry weight and is a rich source of calcium and further recommended that it can be used for feeding ruminants in combination with other ingredients.

2.4 Chemical Composition of SPR

The chemical composition of any feedstuff is subjected to variation with respect to variety, stage of maturity and agro-climatic conditions under which it is grown, besides the methods of analysis (Lodhi et al., 1976).

The chemical composition of SPR is highly variable depending on the quality of cane crushed and the process followed for clarification of cane juice (Yadav, 1995).
The chemical composition (%) of sugarcane press residue obtained in the sugar mills of different countries are as follows:

<table>
<thead>
<tr>
<th>Countries</th>
<th>Ash</th>
<th>Organic matter</th>
<th>Lipids</th>
<th>Protein</th>
<th>CaO</th>
<th>MgO</th>
<th>P₂O₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>26.7</td>
<td>73.3</td>
<td>6.6-13.7</td>
<td>8.4-14.6</td>
<td>6.2-7.7</td>
<td>-</td>
<td>5.3-6.3</td>
</tr>
<tr>
<td>Brazil</td>
<td>14.9-22.3</td>
<td>77.7-85.1</td>
<td>-</td>
<td>-</td>
<td>4.8-5.5</td>
<td>0.2-0.6</td>
<td>0.7-1.0</td>
</tr>
<tr>
<td>South Africa</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.1-3.1</td>
<td>0.6-0.8</td>
<td>1.7-1.3</td>
</tr>
<tr>
<td>Mauritius</td>
<td>12.0</td>
<td>87.3</td>
<td>9.4-16.5</td>
<td>11.4-12.0</td>
<td>2.8-3.6</td>
<td>0.6</td>
<td>1.8-2.0</td>
</tr>
<tr>
<td>Jamaica</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8.8</td>
<td>3.8</td>
<td>1.1</td>
<td>2.8</td>
</tr>
<tr>
<td>Trinidad</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7.1</td>
<td>3.2</td>
<td>0.6</td>
<td>2.9</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>16.2</td>
<td>83.7</td>
<td>11.2</td>
<td>13.7</td>
<td>3.0</td>
<td>0.5</td>
<td>2.8</td>
</tr>
<tr>
<td>Philippines</td>
<td>14.9-31.0</td>
<td>-</td>
<td>10.7-16.9</td>
<td>-</td>
<td>1.4-2.5</td>
<td>0.3-06</td>
<td>-</td>
</tr>
<tr>
<td>Santo Domingo</td>
<td>-</td>
<td>27.4-74.0</td>
<td>-</td>
<td>-</td>
<td>1.2-3.9</td>
<td>0.6-1.2</td>
<td>0.7-2.5</td>
</tr>
<tr>
<td>Taiwan</td>
<td>9.0-20.0</td>
<td>-</td>
<td>5.0-14.0</td>
<td>5.0-15.0</td>
<td>1.0-14.0</td>
<td>0.5-1.5</td>
<td>1.0-3.0</td>
</tr>
</tbody>
</table>

¹Singh and Solomon (1995)  

ICIDCA, 1988

Gupta and Ahuja (1998) reported that the SPR contained organic matter—80.0, crude protein—6.0 and ether extract—4.7 % and the fiber fractions viz, neutral detergent finer, acid detergent fiber, hemi cellulose and cellulose were 66.5, 51.3, 15.2, and 24.7%, respectively. The AIA and lignin contents were found to be 11.4 and 17.2 %, respectively.

Reddy et al. (2003) revealed that the sun dried SPR comprised (%) of CP-9.69, EE–11.37, CF–17.67, TA–13.42 and NFE–47.85. The mineral profile of SPR was of Calcium–2.40, phosphorus–1.20, magnesium–1.28, potassium–1.81, sulfur–2.62% and Iron–2042, manganese–228, Zinc–36.5, copper–22.6 and cobalt–236.7 ppm. The acid insoluble ash and lignin contents of same sample were found to be 4.04 and 15.97 %, respectively (Suresh, 2004; Suresh, 2006). Where as Suma (2005) reported that the sun dried SPR contained CP-12.67, EE– 7.5,
CF–17.5, TA-24.62 and NFE-37.71%. She also reported that SPR contains 4.52% Ca and 1.25% P.

The content of amino acids (% on air dry basis) that have been identified in the gross protein portion of the press residue obtained in the Cuban sugar mills has been reported as: Aspartic acid-4.4, threonine-2.8, glutamic acid-3.7, methionine-0.5, isoleucine- 2.1, alanine-5.8, valine- 3.5, leucine-3.6, tyrosin-0.6, phenylalanine–1.3, tryptophan-1.2, histidine-2.2, lysine-2.1 and arginine–0.9 (ICIDCA, 1988).

2.4 Effect of SPR Based Diets on Broilers’ Performance

Only a scanty information is available regarding the utilization of SPR in animal feeding. A study conducted in commercial broilers where in SPR was included up to 4% level as a source of minerals in their diets is briefly mentioned hereunder:

2.4.1 Growth Rate and Livability

Budeppa (2004) demonstrated that the inclusion of SPR at 1, 2, 3 and 4% in either the soy based or fish based broiler diets at the expense of sunflower extractions, rice polish and relevant mineral contributing salts affected the growth rate significantly during 3rd and 6th week of age as well as during starter phase (0- 21days) and cumulatively (0-42 days). The trial also indicated that the cumulative weight gains (1777, 1721, 1713, 1568 and 1664 g/bird) were tended to decrease gradually in accordance with the inclusion level of SPR (0, 1, 2, 3 and 4 %, respectively) in fish based diets. However, such a trend was not evident with the soy based diets (1851, 1749, 1699, 1731 and 1840 g/bird, respectively). He concluded that there was a non significant (P>0.05) inconsistent decline in body weight gain of broilers as the level of SPR increased in test diets irrespective of protein sources (Budeppa, 2004). He
further reported that the inclusion of SPR up to 4% either in fish based or soy based diets has no significant effect on livability of birds (80.0 to 96.7%) (Budeppa, 2004).

2.4.2 Feed Consumption and Feed Efficiency

Budeppa (2004) noticed that there was an inconsistent and significant (p<0.05) difference in feed consumption among different dietary treatments during starter phase (0-21 days) with the values being 912, 981, 1099, 983 and 919 g/bird in fish based diets and 973, 900, 872, 956 and 937 g/bird in soy based diets at 0, 1, 2, 3 and 4% SPR inclusion levels, respectively, whereas values during grower phase (22-42 days) as well as cumulatively were similar (p>0.05) among different groups with the cumulative values ranging from 3266 (soy:2%SPR) to 3722 g/bird (fish:3%SPR).

Budeppa (2004) reported that the inclusion of SPR has significantly (p<0.05) affected the feed conversion ratio during both starter (0-21 days) and finisher phases (22-42 days) as well as cumulatively with the cumulative FCR values 1.85, 2.04, 2.17, 2.04 and 1.99 for fish based diets and 1.70, 1.93, 1.92, 2.06 and 1.89 for soy based diets that were incorporated with 0, 1, 2, 3 and 4% SPR, respectively indicating that the FCR tended to be affected with the inclusion of SPR.

2.4.3 Carcass Characteristics and Organometry

Budeppa (2004) reported that the dressing percentage (71.31 to 72.93), meat to bone ratio (2.91 to 3.27) and relative weights (g/100g live weight) of giblet organs viz. liver (2.19 to 2.39), heart (0.38 to 0.48) and gizzard (2.16 to 2.42) remained statistically similar among the groups fed diets with either 0, 1, 2, 3 or 4% SPR either soy or fish based protein source. However, with regards
to protein source as main factor, he noticed a significant difference in relative weight of heart (soy- 0.42 and fish-0.45%).

In general, it was opined that SPR can be a valuable non-conventional feedstuff for broilers and it might prove still better than being observed in the above study, if energy and protein in the diets are optimally appropriated (since non-isonitrogenous and non-isocaloric diets used in that trial) beyond the level of 4 % that has been tested.

2.5 Effect of SPR Based Diets on Layers’ Performance

In layers also, the literature is quite limited. An experiment conducted in layers where in SPR was included up to 15% level at the expense of DORB and mineral contributing salts in their diets is briefly reviewed hereunder:

2.5.1 Egg Production

Suma (2005) reported that the 84-day average egg production was 93.33, 91.25, 87.14 and 90.71 % in birds fed 0, 5, 10 and 15 % SPR included soy-based diets, respectively and the values in fish based diets were 91.13, 92.08, 92.38 and 83.93 %, respectively. The corresponding egg production values were 92.33, 91.67, 89.76 and 87.32% irrespective of the protein source, a non-significant decrease as the level of SPR inclusion increased.

2.5.2 Feed Consumption and Feed Efficiency

Suma (2005) reported an inconsistent trend in feed consumption values (g/hen/day) of 119.1, 118.1, 117.4 and 120.3 in soy diets and 120.6, 121.7, 121.7 and 119.9 in fish based diets at 0,5,10 and 15% SPR inclusion, respectively. She also reported that the corresponding feed consumption values were 119.9, 119.9, 119.6 and 121.7 g/hen/day irrespective of the protein source.
Suma (2005) demonstrated that the 84-day cumulative feed efficiencies in 5, 10 and 15 % SPR based soy diets (1.56, 1.65 and 1.62 respectively) were poorer when compared to soy control group (1.53) while it was not consistent with the level of SPR inclusion (1.59, 1.58, and 1.74, respectively) in fish based diets against the fish control (1.61). Further, considering SPR and protein source as main factors, the average values were found to be 1.57, 1.57, 1.61 and 1.68 in 0, 5, 10 and 15% SPR included diets, respectively while the soy based diets (1.59) showed better FCR when compared to fish based diets (1.63). Similar trend was persistent when the feed efficiency was expressed in terms of egg mass (2.33 to 2.75 g/g).

2.5.3 Body Weight Change

Suma (2005) noticed a general loss in body weight in all the groups at the end of 84-days with the values ranging from as low as 10.05 to as high as 118.5g in the birds fed on diets containing 0, 5, 10 and 15% SPR incorporated soy or fish based diets excepting only soy control group (0 % SPR) which showed slight gain in body weight (4.45g).

2.5.4 Egg Characteristics

Suma (2005) observed that the inclusion of SPR at 0, 5,10 and 15 % does not affect the egg weight with the non-significant values of 54.39, 53.90, 52.84, and 53.66 g, respectively at the end of 84 days experimental period. However, a numerically increased egg weight in the group fed diet containing 15 % SPR was noticed when compared to 10% SPR on different (28th, 56th and 84th day) days (Suma, 2005).

Contrarily, the birds fed with 10% SPR showed numerically better percent shape index (77.10) when compared to 5% (76.97) and 15% SPR dietary groups (76.78) barring the source of protein i.e., either soybean meal
or fish meal. She also noticed a non-significantly higher egg weight in birds fed soy based diets while a better shape index prevailed in birds fed fish based diets.

Suma (2005) observed a significantly \( (p<0.05) \) lowest yolk index values of 0.355 (15% SPR) and 0.368 (10% SPR) in fish based diets against the corresponding highest values on 0.390 and 0.401 on 28\textsuperscript{th} and 56\textsuperscript{th} day of experiment, respectively and concluded that a particular type of protein source has got significant influence on the yolk index rather than the SPR level. However, the yolk colour remained unaffected with the values ranging from 6.75 to 6.94 during the 84-day experimental period Suma (2005).

Suma (2005) reported that the shell quality was not affected by the inclusion of SPR up to 15% in either soy or fish based diets. She also noticed an increasing trend in shell thickness values during initial stages (0.365, 0.368, 0.373 and 0.374 mm on 28\textsuperscript{th} day) but a reducing trend was observed on 56\textsuperscript{th} day (0.319, 0.316, 0.305 and 0.305mm) and 84\textsuperscript{th} day (0.297, 0.295, 0.279 and 0.294mm) of experiment with incremental level of SPR at 0, 5, 10 and 15%, respectively.

Suma (2005) noticed an non-significant increase in albumen index values as the SPR level in diets increased from 0 to 15\% during the 84-day experiment excepting on terminal day (84\textsuperscript{th} day) with the significant different values of 0.033 and 0.053 in 0 and 10\% SPR included soy based diets. However, such trend was not noticed when albumen height expressed in relation with egg weight i.e., Haugh unit score with the mean values ranging from 49.17 to 59.34 during the entire experiment.
Based on the different egg characteristics parameters studied, Suma (2005) concluded that the inclusion of SPR up to 15% either in soy or fish based diets did not affect the quality of egg including its weight.

In general, there was no difference in egg production performance as well as egg characteristics between test and control diets when the layers were fed diets containing several non-conventional feedstuffs such as dried poultry manure, rice polishing, cassava leaf meal, rubber seed cake and ragi (Ravindran, 1995)

2.6 SPR as a feed Ingredient in Other Farm Animals

Experiments conducted in Mauritius, one of the main sugarcane producing countries, have suggested direct utilization of dried SPR as animal feed. Parish (1962) observed that air-dried SPR along with molasses and green cane tops (in the ratio of 38:14:48) had an apparent digestibility of about 33 per cent in experimental sheep.

Staub and Drane (1965) observed that the experimental cows fed a diet incorporated with SPR/molasses/fish meal (in the ratio of 50:35:15) showed better response to milk yield and cost of production as compared to those fed control diets.

Efforts have been made at the Institute of Animal Science, Cuba, to incorporate pressmud in animal feed along with preheated straw or cellulosic residues from cane cleaning centre (Singh and Solomon, 1995).

A trial conducted at this Institute where SPR was evaluated at 1, 2 and 3% of concentrate mixtures which were offered to meet 50% dry matter requirement of lambs, Suresh (2004) demonstrated that the dry matter intake,
average daily body weight gain and feed conversion ratio were uniform among different treatment groups including that of the control (0% SPR) group. He concluded that the stall fed sheep can tolerate the inclusion of SPR up to 3% in concentrate mixtures.

2.7 Effect of Inclusion of SPR on Utilization of Nutrients

From a metabolism trial involving 4 laying hens per treatment, Suma (2005) concluded that the percent metabolizability of various proximate principles viz., dry matter (52.71 to 55.46), organic matter (58.91 to 63.29), ether extract (69.01 to 75.14), crude fiber (63.18 to 71.35) and NFE (52.47 to 57.93) with exception of crude protein (70.10 to 73.72) varied significantly (p<0.05) without showing any definitive trend among different groups fed diets prepared by incorporating SPR at 0, 5, 10 and 15% with either soy or fish meal as protein source.

Similarly, the retention of calcium by layer birds under different dietary treatments ranged significantly (p<0.05) from 90.43 to 92.31 % while phosphorous retention values ranged non-significantly from 61.33 to 63.99% (Suma, 2005). Further, it was concluded that although there was a significant variation in the metabolizability values of various nutrients and calcium retention, birds did tolerate SPR inclusion up to 15% in their diets. Thus, the results indicated that SPR can be incorporated in layers’ rations effectively as a source of organic and inorganic nutrients (Suma, 2005).

In sheep, Suresh (2004) found that the digestibility coefficients of proximate principles and fiber fractions were similar among diets prepared with 0, 1, 2 and 3% SPR and so was the balance of nitrogen and calcium.
In general, Basavaraja Reddy (1984) reported that the dry matter metabolizability values ranged from 85 to 95 per cent for cereals such as maize, jowar, broken rice and bajra, while the range was from 50 to 70 per cent for protein sources such as groundnut cake and fish meal and 15 to 30 per cent for by-products such as wheat bran and rice bran. He further reported that the DMM of the diet was inversely related to the amount of crude fiber and inorganic matter in the diets.

Han et al. (1976) using total collection method, suggested that dry matter metabolizability of individual feedstuffs is a significant measuring index for assessing the quality of the feeds or feedstuffs. Although Hartel et al. (1977) explained that almost at the same time the digestibility coefficient of individual nutrients differed between feedstuffs.

2.8 Effect of Inclusion of SPR on Mineral Status of Birds/Animals

Bone ash contents viz., tibial ash and toe ash are shown to be the good indicators of Ca and P status of birds and toe ash is reasonably accurate in determining the extent of P availability from diet of poultry (Potter, 1988).

Budeppa (2004) noticed that a non-significant increase in tibial ash content (30.63, 31.25, 32.69 %) with increased level of SPR inclusion (0, 1, 2 and 3%) with an exception of unreasonably lower value at 4% inclusion (29.52%), irrespective of protein source. He also noticed a similar trend with toe ash content (18.77, 19.36, 20.17, 22.10 and 19.81%, respectively).

Similarly, in an attempt to incorporate dried yeast sludge (DYS) in broiler diets, Senthilkumar et al. (1997) reported a significantly higher tibial ash content in the 5% DYS included diets (39.24%) when compared to that of basal (34.50%) and 10% DYS dietary groups (33.68%). They also noticed that
the level of calcium (29.98 to 31.50%) and phosphorous (12.38 to 14.00%) were nearly same in all the treatments.

The serum calcium and plasma inorganic phosphorous levels among the broiler birds fed diets containing 0, 1, 2, 3 and 4% SPR were well within the normal physiological range suggesting that the bone mineralization was quite effective by dietary SPR supplementation (Budeppa, 2004). In his study, serum calcium ranged from 9.8 to 11.2 mg/dl on 21st day and from 8.5 to 11.4 mg/dl on 42nd day and plasma inorganic phosphorous ranged from 6.67 to 8.70 mg/dl on 21st day and 6.69 to 8.30 mg/dl on 42nd day of experiment.

Similarly in laying hens, Suma (2005) observed that the average serum calcium and plasma inorganic phosphorous concentration values ranged non-significantly (p>0.05) from 13.85 to 25.58 and 3.82 to 6.37 mg/dl, respectively among groups fed with either soy or fish based diets incorporated with SPR at 0, 5, 10 and 15% levels. However, elevated and significantly different values of plasma phosphorous (5.03 to 9.32 mg/dl) were observed on 56th day of experiment (Suma, 2005).

In sheep, Suresh (2004) reported that the calcium, magnesium and phosphorous status in blood of SPR based groups were comparable to those of control (serum Ca: 8.20 to 11.36 mg/dl, serum Mg: 1.43 to 3.40 mg/dl and plasma iP: 5.04 to 9.62 mg/dl) at different stages of experimental period.

### 2.9 Economics of SPR Supplementation

Budeppa (2004) observed that as the SPR level increases, the cost of both soy and fish based starter and finisher diets got reduced while the mean net returns from groups fed diets with increasing levels of SPR showed an inconsistent decreasing trend.
Suma (2005) noticed that the cost of the soy and fish based diets reduced by 25 and 23 paise per kg, respectively as the SPR level increased from 0 to 15 %, which was partly due to the progressive decreasing cost of mineral salt at the expense of SPR as mineral source. However, the cumulative net returns per bird decreased from Rs. 7.88 to 6.76 with incremental level of SPR from 5 to 15%, respectively irrespective of protein source.

Similarly, Ravindran (1995) reported that the cost to produce a dozen eggs was decreased by feeding layers with diet containing several non-conventional feedstuffs such as dried poultry manure, rice polishing, cassava leaf meal, ipil ipil leaf meal, rubber seed cake and ragi and attributed the benefit to the price structure of such feedstuffs.

In general, Reddy (2005) reported that the reduction in feed cost by incorporating locally available unconventional feed ingredients may appear advantageous but the resulting loss in performance may have negative effects on economics.