II. REVIEW OF LITERATURE

The nutritive value of finger millet and sorghum in terms of their nutrient composition, anti-nutritive factors, their improved utilization on enzyme supplementation and their utilization along with the influence of oils in poultry rations is briefly reviewed under the following headings.

2.1 Maize
2.2 Ragi - Finger millet (*Eleusina coracana*)
   2.2.1 Area, yield and varieties
   2.2.2 Chemical composition
   2.2.3 Metabolizable energy content
   2.2.4 Antinutritional factors
   2.2.5 Importance of finger millet in poultry rations

2.3 Sorghum (*Sorghum bicolor*)
   2.3.1 Area, yield and varieties
   2.3.2 Chemical composition
   2.3.3 Metabolizable energy content
   2.3.4 Antinutritional factors
   2.3.5 Importance of sorghum in poultry rations

2.4 Role of enzymes in poultry ration
   2.4.1 Purpose of enzymes addition
   2.4.2 Benefits due to enzyme addition
   2.4.3 Enzymes in poultry
   2.5 Oils / Fats in poultry ration
      2.5.1 Soyoil
      2.5.2 Fish oil
2.1 Maize

Maize is a major ingredient in the poultry diet. National Institute of Nutrition, Hyderabad recorded dry matter of 85.10, CP 11.10, ether extract 3.60, crude fat 2.70, total ash 1.50, calcium 0.01 and phosphorus 0.35 (NIN, 2004). ME value of 3389 kcal/kg, 10.4 per cent CP, 3.55 per cent ether extract, 2.24 per cent crude fibre, 2.31 acid insoluble ash per cent, 0.25 per cent calcium and 0.33 per cent phosphorous (Rama Rao et al., 2005).

2.2 Ragi - Finger millet (*Eleusina coracana*)

Ragi belongs to millets, meaning small grain cereal. It is the staple food of the millions of the arid and semi arid tropics of the world. The grains of finger millet being nutritionally superior to rice and wheat, provide cheap proteins, minerals and vitamins to the poorest of the poor where the need for such ingredients is maximum (Seetharam et al., 1986).

Unlike all the cereals, the ragi grain is a utricle and has a hard seed coat and it is very difficult to separate even by mechanical means. The grains are quite small having a diameter of only 1.00 to 1.15 mm and vary in colour from dark brown to nearly white depending on the variety (Kurien et al., 1960).

2.2.1 Area, yield and varieties

The finger millet known as Ragi is developed in Africa from *Eleusine coracana* sub species, viz., Africana and was introduced into India during pre-Aryan times.

English (ragi, birds foot millet, finger millet, worth Indian millet, African millet, kurukkan and coracan millet), India (Bengali, Marua, Gujarati, Bauto, Himalayas, Koda, Kondon and Kodra), Hindi (Manuda, Marua and Ragee), Kannada (Ragi), Malayalam (Muttari), Marathi (Nachni and Nagli), Oriya (Mandiya), Punjabi (Chalodra and Mundal), Sankrit (Raga and Rajika),
According to Shailaja Hittalmani (2003), Tumkur district covers an area of 1,75,115 ha., followed by Bangalore Rural 146944 ha., Kolar 1,31,856 ha., Hassan 1,15,582 ha., Mysore 79,533 ha., Mandya 78,744 ha and Bangalore Urban 48023 ha. The yield is more in Bangalore Rural (2040 kg/ha) followed by Kolar (1733 kg/ha), Hassan (1682 kg/ha), Tumkur (1332 kg/ha) and Mysore (1098 kg/ha). The state level cultivation is 9,41,375 ha.


### 2.2.2 Chemical composition

Deosthale et al. (1970) reported a variation in the profile of amino acid and trace minerals in different cultivars of ragi due to the variations in the ecological conditions. Chemical composition and mineral content of ragi varieties as reported by several researchers in comparison with maize is presented in Table 2.1.

The dry matter of ragi grain varied from 84.40 to 92.75 per cent. The crude protein content ranged from 5.65 to 11.73 per cent, where as ether extract values varied from 1.11 to 4.30 per cent with most of the values being

Tamil (Kapai, Kaver and Kervaragu), Telugu (Chodalu, Ragulu, Soloo and Tamidelu), Tulu (Ragi), U.P. and Bihar (Makra, Nanguli and Rotka) (Seetharam et al., 1986; Srilatha Rani, 1995).
around 1.50 to 2.00 per cent. Ragi being starchy in nature has less fiber ranging from 2.10 to 6.60 per cent with most of the values falling around 4.50 per cent. Nitrogen free extract ranged from 72.00 to 82.69 per cent. The calcium and phosphorus levels in ragi was reported to be around 0.30 to 0.25 per cent, respectively. The total mineral content of different varieties of ragi was around 3.00 per cent.

a) Protein

Many authors reported variable amount of crude protein in ragi samples ranging from 4.71 to 12.30 per cent depending on the variety (Mallanna and Rajashekara, 1969; Mahudeshwaran et al., 1972; Rao et al., 1973; Wankhede et al., 1979; Ravindran, 1991; Rao, 1994; Theerthaprasad, 1994; Kantharaja et al., 1995; Umashankar, 1997; Gideon Glori Doss 2003). They were of the opinion that the protein content in finger millet was comparable to that of maize and the digestibility of protein was not as high as in maize and sorghum. Virupaksha et al. (1975) analysed the protein content of 12 finger millet samples from white and brown grain varieties and found wide variations in protein contents.

As regards the proposition of nutrients in different parts of ragi, there is a wide variation in the protein contents of whole seed flour ranging from 6.77 to 11.03 per cent. On the other hand, protein contents of the endosperm meals vary from 3.49 to 6.33 per cent. The white varieties have a higher protein content than the brown varieties of the finger millet. Solubility fractionation of proteins showed that prolamin and glutamine constituted the major protein fractions. While the white-grain varieties, had higher prolamin and lower glutelin levels than the brown-grain varieties (Srilatha Rani, 1995).

Vadivoo et al. (1978) analysed 36 genotypes of finger millet with varying seed colour and revealed a wide range of protein and calcium
contents. White seeded genotypes had higher protein content, while brown seeded types had a wide range of values. Although, protein content had significant negative association with calcium content, white seeded types had moderate levels of calcium.

Pore and Magar (1979) estimated the nutrient composition of hybrid varieties of finger millet and found that about 70 per cent of the carbohydrates were in the form of starch, and only about two per cent free reducing sugars were present in six grains of *Eleusine coracana* cultivar.

Barbeau and Hilu (1993) analysed eight domesticated cultivars of finger millet to determine their proximate composition, calcium, iron and amino acid content, and reported the content of calcium 376 to 515 mg/100 g and iron 3.72 to 6.8 mg/100 g.

b) Amino acid composition

Lal (1950) using microbiological techniques observed that the amino acid profile (tryptophan, lysine, phenyl alanine, histidine, arginine and threonine) of ragi was quite satisfactory even for maintenance purpose for humans. In different varieties of ragi, the threonine and tryptophan contents were found to range from 2.13 to 3.00 per cent and 1.26 to 1.44 per cent, respectively (Paderson and Eggum, 1983). The protein of finger millet contained higher level of threonine, glutamicacid, valine, methionine, isoleucine, phenylalanine than maize. However, finger millet contained lower levels of proline, cystine, leucine and tryptophan than maize. The reported amino acid composition of ragi in comparison with maize is given in Table 2.2.

Virupaksha et al. (1975) analysed the amino acid composition of finger millet samples from white grain and brown grain varieties and found wide variation in amino acid composition. Solubility fractions of
proteins showed that prolamin and glutelin constituted the major protein fractions. While, the white grain varieties had higher prolamin and lower glutelin levels than the brown grain varieties.

Rao (1994) reported that the Indaf-5 (brown) varieties had protein and iron contents of 12.3 per cent and 12 mg iron per100 g, while in WR (white) variety the values were 8.7 per cent protein and 4.4 mg iron per100 g, respectively. In earlier studies, Lal (1950) using microbiological techniques, observed the amino acid profile (Try, Lys, Phe, His, Arg and Thr) of ragi was quite satisfactory for the maintenance purpose for humans. In different varieties of ragi, the lysine and tryptophan contents were found to range from 2.13 to 3.00 and 1.26 to 1.44 per cent, respectively (Indira and Naik, 1971).

Pore and Magar (1979) determined the composition of essential amino acids in the grains of 6 cultivars of *Eleusine coracana* and found that the lysine content was 3.25 per cent in A-16 and 3.44 per cent in B-11 varieties. About 6 per cent of the protein was in the form of non-protein N.

The primary and outstanding deficit nutrient in small millets is lysine, an indispensable amino acid essential for protein synthesis. As non-ruminants cannot biosynthesize their own lysine, their diets must contain all of its needs. Failure to supply adequate lysine reduces the growth of young swine and poultry in proportion to its shortage. Rations for non-ruminants should have lysine supplementation (Duane, 1998).

c) **Carbohydrates**

Kurien *et al.* (1960) reported 69.73 per cent of soluble carbohydrates of which starch accounted for 16.2 per cent with 1.2 per cent reducing sugars in finger millet. Pore and Magar (1979) estimated the nutrient composition of hybrid varieties of finger millet and found 70 per cent of the carbohydrate in
the form of starch and only about 2 per cent free reducing sugars were present in six strains of *Eleusina coracana* cultivars.

Wankhede *et al.* (1979) reported the carbohydrate composition of six varieties of finger millet strain cultivars viz., Hamsa, Poorna Indaf 5,6,8,9 and Foxtail millet and found that the millets contained 63 to 70 per cent total carbohydrate of which free sugars were 0.46 to 0.69 per cent, starch 56 to 61 per cent, Cellulose, 0.70 to 1.80 per cent and pentosans, 5.50 to 7.20 per cent. The 70 per cent ethanol extractable sugars were xylose (1.54-4.30%), fructose (8.6-15.0%), glucose (9.9-15%), sucrose (31-35%), maltose (9-11%), raffinose (8.6-12%), maltotriose (5.0-6.1%) and higher oligosaccharides (5-9%). The water soluble gums contained arabinose and xylose as the major sugar components together with the minor amounts of mannose and galactose and varying amounts of glucose. Hemicelluloses A was found to consist mainly of glucans containing arabinose and xylose in smaller amounts. Hemicellulose B contained arabinose and xylose with smaller amount of glucose and galactose.

Kamat and Belavady (1980) reported that the finger millet contained slightly higher levels of total unavailable carbohydrates (18.6%) when compared to wheat (17.3%) and sorghum (14.3%).

Gideon Glori Doss (2003) reported 1.73 and 2.03 per cent sugars in extruded and unextruded finger millet, respectively, and 56.00 and 52.75 per cent available carbohydrate in extruded and unextruded finger millet, respectively.
d) Lipids

Sridhar and Laxminarayana (1994) reported the total lipid content (DM basis) comprising free, bound and structural lipids was 5.2 per cent in *E. coracana*. Linoleic acid, oleic acid and palmitic acids were the chief constituents in all the lipid classes.

e) Minerals

Rao *et al*. (1973) analyzed the mineral content of 15 new ragi varieties and reported fibre content of 3.08 to 5.72 per cent, ash 2.00 to 4.33 per cent and phosphorus 227 to 470 mg/100 g, calcium 203 to 690 mg/100 g and Fe 209 to 93.5 mg/100 g.

Vadivoo *et al*. (1978) analyzed 36 genotypes of finger millet of varying seed colour and revealed a wide range of calcium contents. White seeded types had moderate levels of calcium.

Rao (1994) reported that Indaf-5 (brown) variety had iron content of 12.3 per cent, while in WR (white) variety, the value was 4.4 mg/100g.

f) Vitamins

Vitamin content of ragi (mg/100 g) reported by various researchers

<table>
<thead>
<tr>
<th>Thia</th>
<th>Rib</th>
<th>Nia</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.23</td>
<td>0.06</td>
<td>0.60</td>
<td>Deosthale <em>et al</em>., 1970</td>
</tr>
<tr>
<td>0.52</td>
<td>0.16</td>
<td>0.13</td>
<td>Mahudeswaran and Ayyam Perumai, 1970</td>
</tr>
<tr>
<td>0.42</td>
<td>0.19</td>
<td>1.1</td>
<td>Gopalan <em>et al</em>., 2004</td>
</tr>
</tbody>
</table>

2.2.3 Metabolizable energy

The available literature on ME content of ragi in poultry rations is limited. Hill and Anderson (1958) studied the metabolizable energy values of a variety of grains and grain products for chickens based on the use of glucose as the reference substance and confirmed that nitrogen corrected
metabolizable energy values were a better measure of energy value of feedstuffs for growing chickens.

Sibbald et al. (1960) assessed the influence of various nutrients upon the ME content of poultry rations and observed a decrease in ME values when the calcium content of the diet was increased from 1.0 to 3.0 per cent.

Baghel and Netke (1982) reported the AME and TME of ragi as 3047 and 3280 kcal/kg, respectively. Gopalan et al. (2004,) reported ME value of ragi as 3280 kcal/kg.

Reddy et al. (1995) reported the ME value of 3100 Kcal/kg of Indaf-5 ragi variety used in broilers. The lower ME values of ragi both in broilers and layers has been attributed mainly to the NSP content of ragi, which would cause less availability of nutrients and also to the tannin content of ragi which might inactivate some of the most enzymes such as amylase, protease and lipase leading to poor digestibility or metabolisability of finger millet. A similar energy value of 3071 kcal/kg were reported by Kantharaja et al. (1995) and Nagaraj et al. (1996).

2.2.4 Antinutritional factors

Millets in general inherently carry certain antinutritional factors to keep the predating insects at bay. Ragi does contain antinutritional factors, which might reduce the availability of nutrients thereby reducing the productivity performance of the birds (Abate and Gomez, 1984). Some of these factors present in ragi include tannins, nonstarch polysaccharides (β-glucans), protease inhibitors, oxalates and phytates, each of which might directly or indirectly affect the digestibility of nutrients.

a) Tannins
Tannins are a group of phenolic non-nitrogenous organic constituents, which are chemically classified into two broad categories namely hydrolysable and condensed tannins (McLeod, 1974). Condensed tannins on hydrolysis yield flavans, while the former yield gallic acid.

Tannins have been found to reduce feed intake impair nutrient digestibility and nitrogen retention thus causing growth depression of poultry (Chang and Fuller, 1964; Mohammedian et al., 1986).

Geetha Ramachandra et al. (1977) reported the tannin content of ragi from 0.04 to 3.47 per cent, with most of the values falling around 0.6 per cent. White grain varieties of finger millet had low (0.05%) levels of tannins compared with the brown and dark-brown varieties (0.61%). Highest amount of tannins (3.42-3.47%) was found in two African varieties, IE927 and IE929.

Hulse et al. (1980) and Rao and Deosthale (1988) reported that dark colour varieties contained high levels of tannins while the tannin content of brown varieties of ragi ranged from 0.35 to 2.40 per cent. The white variety ragi hardly contained any tannin. Parida et al. (1989) also reported that the white grain varieties of ragi had very low phenol and tannin levels when compared with brown varieties.

b) **Non-starch polysaccharides [NSPs]**

Generally millets inherently have certain anti-nutritional factors that keep the predating insects at bay. In addition to Tannins and Protease inhibitors, the millets also contain non-starch polysaccharides (betaglucans), phytates, oxalates etc., each of which might directly or indirectly affect the digestibility of nutrients in millets or millets based diets (Abate and Gomez, 1984).
Nonstarch polysaccharides are defined as polymeric carbohydrates, which differ in composition and structure from amylose and amylopectin (Geetha Ramachandra, 1997). NSPs, contain glycosidic bonds other than \( \alpha(1-4) \) and \( \alpha(1-6) \) bonds present in starch. The nature of the bond determines their susceptibility to cleavage by avian digestive enzymes. These NSPs have high molecular weight ranging from 8000 to 9000 million. The NSPs in broiler feed could cause growth depression and decreased in feed conversion efficiency.

The nonstarch polysaccharide (NSPs) content of ragi is as follows.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Total pentosans</th>
<th>Cellulose</th>
<th>Pectins</th>
<th>Total NSPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>5.37</td>
<td>3.12</td>
<td>1.00</td>
<td>9.32</td>
</tr>
<tr>
<td>Sorghum</td>
<td>2.77</td>
<td>4.21</td>
<td>1.66</td>
<td>9.75</td>
</tr>
<tr>
<td>Finger millet</td>
<td>3.31</td>
<td>3.03</td>
<td>1.76</td>
<td>9.40</td>
</tr>
</tbody>
</table>

(Malathi, 2001)

Wankhede et al. (1979) reported pentosan content of ragi as 6.2 to 7.2 per cent, while Malleshi et al. (1986) opined that native millets contained more hexoses than pentosans.

Kamat and Belavady (1980) observed that ragi contained slightly higher levels of total unavailable carbohydrates (18.6%) as compared to wheat (17.3%).

c) Protease inhibitors

The protein inhibitors disrupt the protein digestion by rendering unavailability of the digestive enzymes, trypsin and chymotrypsin and their presence is characterized by compensating hypertrophy of the pancreas.
Shivaraj and Pattabiraman (1981) described the presence of an inhibitor, and it is a single bifunctional protein factor, which is responsible for both amylase inhibitor and trypsin inhibitory activities with two different reactive sites.

Chandrashekara et al. (1982) reported that millets had considerable varietal differences in the proteinase inhibitor activity and that the finger millet had more antitryptic activity than antichymotryptic activity. However, Ravindran (1991) reported that the chymotrypsin inhibitory unit values obtained for different finger millets were comparable.

Shivaraj et al. (1992) isolated two inhibitors from ragi by affinity technique and designated them as chymotrypsin inhibitor (CTI) and trypsin alpha amylase inhibitor (TAI).

2.2.5 Finger millet in poultry ration

Abate and Gomez (1984) substituted finger millet with maize at 0, 20, 40 or 60 per cent in both broiler starter and finisher diets. The birds on finger millet had decreasing weight gain with increasing level of the millet, particularly in the starter phase and was not evident during later stages of the chick growth. The difference in the body weight gain between the control and the treatments was however not significant.

Mohamedian et al. (1986) reported that the feed intake, though not significantly different among the three rations used, was maximum in the maize based diet, minimum in sorghum and intermediate in finger millet.

Asha Rajini et al. (1986) conducted a feeding trial to study the possibility of replacing maize with other cheaper and easily available coarser grains such as jowar, finger millet and pearl millet replacing maize in the control diet up to 37.5 per cent of diet and found that there was significant
improvement in weight gain of broilers when maize was completely replaced by either of the millet at eight weeks of age, but however without any change in feed intake or feed efficiency. These findings were also confirmed by Kantharaja et al. (1995).

Purushothaman and Thirumalai (1995) compared the performance of layer chicks by including sorghum or finger millet or a mixture of these millets at the expense of maize. They found that the feed consumption was statistically higher in all the dietary groups except in the finger millet group where the feed intake was significantly low which could be due to reduced palatability of finger millet based diets.

Purushothaman and Thirumalai (1995b) studied the growth rate, feed intake and feed conversion efficiency in 8 to 12 week old layer pullets fed grower diets with 30 per cent maize, or with maize replaced by sorghum, bajra, finger millet, or a 1:1:1 mixture of these and noted that the growth, weight gain, feed intake and feed conversion efficiency were similar, except for bajra, where weight gain decreased and feed conversion efficiency got adversely affected.

Yeong and Syed Ali (1976) replaced maize with 15, 30, 45 or 60 per cent finger millet in the diets fed to commercial broiler chickens and recorded no significant difference in feed intake, body weight gain or feed efficiency through a four weeks trial period.

Ramarao et al. (2002) broilers fed on diet containing pearl millet, finger millet or sorghum as principal source of energy had significantly lower weight gain and poor feed conversion efficiency compared to the maize fed group till 5 weeks of age. However these differences did not exist when feeding of cereal diets continued up to 7 weeks of age in coloured broilers.
Gizzard and intestinal weights were significantly higher in broilers fed finger millet diet compared to maize diet.

Raju et al. (2003) reported that the feed consumption was significantly high and low in maize and unground ragi fed groups, respectively and also they reported that the feed conversion efficiency was significantly greater with sorghum and was lower with unground ragi. Feed conversion efficiency was significantly lower in the groups fed ragi, irrespective of enzyme supplementation and the differences among other cereal fed groups and the control were non-significant.

Raju et al. (2003) observed better metabolizability of dry matter in sorghum group (69.23%) as against that of maize (50.87%) and ragi ground (51.88%) groups. Raju et al. (2003) recorded the performance of broilers fed bajra and jower in terms of body weight (1193 and 1164 g), feed efficiency (2.26 and 2.26) and dry matter metabolizability (63.3 and 66.0%) was similar to maize (1217g, 2.09 and 65% respectively), irrespective of difference in energy levels. Ragi adversely affected the body weight (1054g and feed efficiency 2.47). Slaughter yields were similar in all the groups but weight of abdominal fat was significantly more in jowar group (1.57 vs 0.77% in control). Weights of gizzard and giblets and length of small intestine were significantly more in ragi. These results indicate the utility of bajra and jowar as effective alternatives to maize, while ragi in whole form was not suitable for inclusion in broiler diets.

Elangovan et al. (2004) concluded that diet containing finger millet or poor quality of grain can be improved by adding commercial feed enzyme preparation.
Raju (2004) reported that the dry matter metabolizability was significantly higher in maize group compared to those of jowar and ragi groups. Further, they reported that enzyme supplementation showed no influence on dry matter metabolizability. The Ready-to-cook yield for different dietary groups of bajra, ragi and jowar were comparable for all the groups. The weight of gizzard (P<0.01) and giblets (P<0.05) were significantly higher in the groups fed ragi compared to sorghum and bajra.

Rama Rao et al. (2004) reported that graded levels of finger millet can be used to replace maize in broilers on weight basis without affecting growth and feed efficiency.

Rama Rao et al. (2004) observed significant increase in weight of gizzard in broilers on incorporation of ragi at 75 to 100 percent cereals in the diet.

Mandal et al. (2006) conducted a 7-week 3x2 factorial experiment with day old broiler chicks to study the efficacy of addition of commercial feed enzyme preparation at the rate of 50 grams per quintal to diets contains either maize, sorghum, finger millet as sole cereal source or a combination of maize, sorghum, finger millet and pearl millet in equal proportions on performance, nutrient utilization, carcass traits and feed costs of production. The body weight and feed efficiency were significantly lower in finger millet based diet, which significantly improved upon enzyme addition. However, addition of enzyme to other cereal diets did not improve the performance of broilers. The carcass traits remained unaltered by various dietary treatments. Feed costs of broiler production was significantly higher in finger millet based diets.

Tyagi et al. (2004) recommended that finger millet can be used at a lower level in broiler diet replacing not more than 25 per cent of maize. The study revealed that the test cereals depressed growth in starting phase (14.5,
29.4, 45 and 60.6%) when used at higher level but had no or little growth depressive effect during finisher phase (16.5, 33.5, 51 and 68.7%).

Mandal et al. (2006) reported increase in feed conversion ratio in the combination of maize and finger millet diet supplemented with enzyme preparation.

Rama Rao et al. (2005) reported that at 21 days of age the body weight gain (390 g) was significantly depressed with inclusion of finger millet at the lowest level of inclusion in diet (25% of maize) when compared to body weight gain (441 g) in 100 per cent maize fed group.

Rama Rao et al. (2005) reported that body weight gain (1560 g) at 42 days of age in 25 per cent finger millet fed group was similar to 100 per cent maize fed group (1661 g) and also observed that broilers fed 50 per cent or above levels of finger millets weighed significantly lower than maize reference group. The feed efficiency in the starter phase was non-significantly affected with maize up to 25 per cent replacement of finger millet and at 50 per cent and above levels of finger millet, the feed efficiency was significantly decreased.

Salunkhe et al. (2005) studied the effect of using sorghum and ragi replacing maize at 70, 85 and 100 per cent level in isonitrogenous and iso-caloric diets in broilers respectively had maize either reduced the retention of nutrients significantly or had no significant influence on it. Use of these cereals instead of maize at 70 and 85 per cent level reduced the per cent retention of all the nutrients significantly (P<0.05), while further inclusion of coarse cereals instead of maize at 100 per cent level, showed higher ether
extract retention, however, retention of other nutrients was reduced significantly.

Tyagi et al. (2005) reported that a combination of maize, pearl millet and sorghum at the rate of 33 per cent each or maize, pearl millet, sorghum and finger millet at the rate of 25 per cent each in diet of broilers could support the optimum growth and feed conversion efficiency without affecting nutrient utilization and meat yield.

2.3 Sorghum (Sorghum vulgarie)

Sorghum (Sorghum vulgarie) has food value for human consumption particularly by rural people. It is also called as Jowar. Sorghum is fifth in importance among the world’s cereals. Compared to maize, sorghum is reported to have higher levels of crude protein (10-13%), lysine, methionine, fiber, ether extract, ash and phosphorous and almost twice as much calcium (Gualtieri and Rapaccini, 1990). The ME content of sorghum ranges from 2617 to 3886 kcal/kg depending on tannin concentration (Douglas et al., 1988).

2.3.1 Area, yield and varieties

The sorghum crop is cultivated in 17.81 lakh hectares with an average yield of 920 kg/ha in Karnataka and this is the third important crop cultivated in India with an annual production of 118.78 lakh tonnes (FAO, 2002).

World level top sorghum producers are United States (9.8 Mt), India (8.0 Mt), Nigeria (8.0 Mt), Mexico (6.3 Mt), Sudan (4.2 Mt), Argentina (2.9 Mt), China (2.6 Mt), Ethiopia (1.8 Mt), Australia (1.7 Mt), Brazil (1.5 Mt) (FAO, 2005).

Various varieties are hybrids CSH-1 (7.04), CSH-5 (9.16), CSH-6 (9.44), CSH-9 (8.31), CSH-13 (11.76), CSH-14 (8.84), CSH-16 (10.85). Sweet sorghum SPH-821 (9.33), SPH-840 (8.87), SSV-84 (12.67), MLSH-14 (7.79) and Varieties SPV-462 (7.84), SPV-1231 (9.32), SPV-1328 (10.4),

2.3.2 Chemical composition

Several authors have reported chemical composition of sorghum on dry matter basis (Table 2.3).

Mean proximate analysis components of maize and sorghum hybrid grain samples (% dry-matter basis) are:

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Chemical composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Protein</td>
</tr>
<tr>
<td>ASA3042 X KS115</td>
<td>13.5</td>
</tr>
<tr>
<td>A Wheatland x KS115</td>
<td>12.9</td>
</tr>
<tr>
<td>ASA3042 X Eastin-1</td>
<td>14.1</td>
</tr>
<tr>
<td>A Wheatland x KS115</td>
<td>13.3</td>
</tr>
<tr>
<td>ASA3042 X RT x 435</td>
<td>13.2</td>
</tr>
<tr>
<td>A Wheatland x RT x 435</td>
<td>12.1</td>
</tr>
<tr>
<td>ASA3042 X RT x 2737</td>
<td>12.7</td>
</tr>
<tr>
<td>A Wheatland x RT x 2737</td>
<td>12.3</td>
</tr>
<tr>
<td>Maize</td>
<td>10.2</td>
</tr>
</tbody>
</table>

(Travis et al., 2006)

The crude protein content ranged from 7.07 to 11.85 per cent, where as ether extract values varied from 1.11 to 6.70 per cent with most of the values being around 2.26 to 2.97 per cent. Sorghum being starchy in nature has less fibre ranging from 1.60 to 3.60 per cent. Nitrogen free extract ranged from 71.08 to as high as 85.34 per cent. The calcium and phosphorous levels in sorghum was reported to be around 0.03 and 0.31 per cent, respectively. The total mineral content of sorghum was around 2.00 per cent.

a) Protein

Protein content of sorghum is more variable than that of maize and can range from 7.07 to 11.85 per cent. In most cultivars, the kernal contains 12 per cent, which is one to two percentage point higher than maize. The protein
contains no gluten. Prolamine makes up about 59 per cent of the total protein in normal sorghum. The protein content of the grain is invariably correlated with its waist and storing content (Carpenter and Clegg, 1956; Reddy and Vaidya, 1973).

Aravind Bhat (1991) reported that the crude protein content of sorghum varies from 9.17 to 10.82 per cent with M-35 variety showing the highest, while MSH-51 had the least protein content, which has more or less similar to the findings of Reddy and Vaidya (1973), Ibrahim et al. (1988), Gopalan et al. (1989) and Kank et al. (1991).

Many authors reported variable amount of protein ranging from 8.91 to 11.85 per cent, (Carpenter and Clegg, 1956; Reddy and Vaidya, 1973; Aravind Bhat, 1991). They were of the opinion that the protein content in sorghum was more than that of maize.

b) **Amino acids**

The protein and amino-acids composition is much like that of maize protein. Lysine is the first limiting amino acid, followed by threonine tryptophan and some other amino acids are a little higher than in maize. The amino acid composition of sorghum as reported by several researchers is presented in Table 2.4.

The data on amino acids availability from sorghum and maize to chicks as reported by Stephenson et al. (1967) and Degussa (2001) is given in Table 2.5.

Sorghum apart from contributing energy also provides protein up to 22 per cent, but certain varieties have found with high lysine content and low
threonine through in most of the varieties, amino acid composition was more or less similar to maize (Featherston et al., 1975 and Okoh et al., 1982).

c) Carbohydrates

As an energy source, carbohydrate forms a major constituent in sorghum of which starch amounts to 60 to 65 per cent, sugar 1 to 2 per cent (Carpenter and Clegg, 1956), Hemicellulose 5.84 to 6.60 per cent (Moir and Connor, 1977). Chemically, the starch is made up of 70 to 80 per cent branched amylopectins and 20 to 30 per cent amylose.

Gopalan et al. (2004) reported mineral and trace element contents of sorghum (mg/100g) as described below.

<table>
<thead>
<tr>
<th>Ca</th>
<th>P</th>
<th>Mg</th>
<th>Sod</th>
<th>Pot</th>
<th>Cu</th>
<th>Mn</th>
<th>Mo</th>
<th>Zn</th>
<th>Cr</th>
<th>S</th>
<th>Cl</th>
<th>Iron</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>222</td>
<td>171</td>
<td>7.3</td>
<td>131</td>
<td>0.46</td>
<td>0.78</td>
<td>0.039</td>
<td>1.6</td>
<td>0.008</td>
<td>54</td>
<td>44</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Laxmi Tulasi et al. (2004) reported the mineral content of different sorghum cultivars as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CSV 15</th>
<th>CSH 16</th>
<th>PSV 16</th>
<th>S 35</th>
<th>Local</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium (%)</td>
<td>0.051</td>
<td>0.047</td>
<td>0.050</td>
<td>0.052</td>
<td>0.036</td>
</tr>
<tr>
<td>Phosphorus (%)</td>
<td>0.226</td>
<td>0.270</td>
<td>0.260</td>
<td>0.304</td>
<td>0.200</td>
</tr>
</tbody>
</table>

Aravind Bhat (1991) reported total ash content of 1.35 to 2.09 per cent, which is in accordance with results reported by Ibrahim et al. (1986), Gopalan et al. (1989) and Kank et al. (1991).

The sorghum’s ash content ranges from 1.50 to 2.80 per cent. As in most cereals potassium and phosphorus are the major minerals. The calcium and zinc levels tend to be low. Sorghum has been reported to be a good source of more than 20 micronutrients.
e) **Vitamins**

When compared to maize, sorghum contains higher levels of B vitamins, pantothenic acid, niacin, thiamine, biotin, riboflavin and pyridoxine are located in the germ portion of sorghum. Gopalan *et al.* (2004).

**Vitamin content of sorghum (mg/100 gm)**

<table>
<thead>
<tr>
<th>Thia</th>
<th>Rib</th>
<th>Nia</th>
<th>B 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.37</td>
<td>0.13</td>
<td>3.1</td>
<td>0.21</td>
</tr>
</tbody>
</table>

(Gopalan *et al.*, 2004).

### 2.3.3 Metabolizable energy content of the sorghum

The metabolizable energy content of sorghum has been evaluated by various researchers and the factors responsible for variation in ME in majority of the cases appears to be tannin content.

The reported ME values and true metabolizable energy of sorghum are presented in Table 2.7.

The ME values reported by most of the authors ranged from 1.58 to 3.60 kcal/g, with most of the values falling around 3.1 to 3.3 kcal/g, where as true metabolizable energy (TME) values is around 3.3 kcal/g.

Fuller *et al.* (1966) evaluated 22 sorghum hybrids for their nutrient composition and found the tannin, content in the range from 0.2 to 2.0 per cent with ME varying from 2617 to 3516 kcal/kg.

Sibbald (1976a) estimated TME value of two sorghum varieties as 3380 kcal/kg for low tannin and 3870 kcal/kg for high tannin in SPV 462 and CSV 15 varieties respectively.

Sinha *et al.* (1980) reported that the metabolizable energy content of feed ingredients showed maize to rank the highest (3440 kcal/g).
Yamazaki and Kaku (1988) determined TME values of two sorghum varieties as 3880 and 3990 kcal/kg.

The ME of sorghum varieties as reported by Bolten and Blair (1974) ranged from 3.070 to 3.225 kcal/g. These ME values were similar to the values reported by Newton (1982), Hubbel Charles (1984), Basavaraj Reddy (1984), Veloso et al. (1985), Doughlas et al. (1988), but values are lower than those reported by Grossu et al. (1981), Hulan and Proudfoot (1982), Veloso et al. (1985) and Halley et al. (1986).

Aravind Bhat (1991) observed significant (P<0.05) difference in ME of the test diets and non-significant (P<0.05) differences among the sorghum varieties. However, M-35 variety (3226 kcal/kg) had a highest ME value with a difference of 150 kcal/kg from the rest of varieties.

2.3.4 Antinutritional factors

a) Tannin

The tannin content sorghum varieties as reported by several research workers is presented in Table 2.8.

Tannin is found to reduce feed intake, nutrient digestibility and nitrogen retention (Elkin et al., 1978). Such effects were manifested by growth depression as observed in broilers fed high tannin sorghum (Armstrong et al., 1974; Mohammedian, 1986; Nagra et al., 1990).

Elkin et al. (1978) reported that tannins cause alternations of the organic matrix of bone and attributed 48 per cent leg abnormalities due to
tannins in sorghum based diets. On the contrary, Mitaru et al. (1985) found no correlation between incidence of such disorders and tannin content.

b) Non-starch polysaccharides

Several authors reported NSPs content of Sorghum as presented in following table (Nyman et al., 1984; Classen, 1996; Choct, 1997; Malathi, 2001).

<table>
<thead>
<tr>
<th>Arabinoxylans</th>
<th>Pectin</th>
<th>Cellulase</th>
<th>β-glucans</th>
<th>Total NSPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.97</td>
<td>1.17</td>
<td>3.99</td>
<td>-</td>
<td>9.00</td>
</tr>
<tr>
<td>1.90</td>
<td>1.50</td>
<td>2.10</td>
<td>-</td>
<td>5.60</td>
</tr>
<tr>
<td>2.10</td>
<td>0.15</td>
<td>2.20</td>
<td>0.2</td>
<td>4.80</td>
</tr>
<tr>
<td>2.77</td>
<td>1.66</td>
<td>4.21</td>
<td>-</td>
<td>9.75</td>
</tr>
</tbody>
</table>

2.3.5 Importance of sorghum in poultry rations

Many authors conducted experiments by replacing maize with Sorghum and reported the results in broilers (Table 2.9).

Earlier workers noticed the feed efficiency with maize diets to be superior to that with wheat and sorghum (Keppens, 1969).

Jensen (1964) reported that grilled birds fed on the grain sorghum diet had the poorest flavour and that the smell grades were significantly lower in the case of birds fed on sorghum than those fed on any other cereal.

Petersen (1969) fed diets containing 40 per cent corn, sorghum having the same ratio of ME to digestible protein found the body weight gain was equal in both the groups.

Syed et al. (1975) replaced maize by sorghum at 25, 50, 75 and 100 per cent in 0-8 weeks of commercial hybrid broiler rations and found that 100 per cent replacement gave non-significant differences in weight gain and feed efficiency, but xanthophyll deficiency was observed.
Yeong Ali (1976) reported no significant difference in weight gain and efficiency of feed utilization by direct substitution of maize with sorghum.

Cunha and Moraes (1978) and Trinade et al. (1978) reported poor efficiency of feed and protein utilization in broiler chicken fed sorghum based diets.

Sinha et al. (1980) studied the comparative efficiency of utilization of maize, pearl millet (bajra), sorghum, wheat and rice polish in broiler chicks and found that feed efficiency with the different diets was significantly different (P<0.01), with the pearl millet group (2.09) having the best efficiency followed by those of maize (2.35), rice polish (2.56), sorghum (3.05) and wheat groups (3.29) in that order.

Hulan and Proudfoot (1982) reported non significant effect on the weight gain and feed conversion efficiency when the sorghum containing diets were made isocaloric. In this study, maize was replaced by sorghum at 25, 50 and 75 per cent in Cobb broiler chicks (0-42 days) and found that weight gain, feed conversion were non-significant at 75 per cent replacement.

Thakur et al. (1984) replaced 50 and 100 per cent maize by sorghum in diets of crossbred broiler chicks (0-8 weeks) and reported that CSH-6 cultivar can replace maize up to 50 per cent with non-significant difference in body weight, feed intake and feed efficiency.

Cao et al. (1985) replaced maize by sorghum at 25, 50, 75 and 100 per cent in broiler ration and found non-significant difference weight gain and feed efficiency at 100 per cent replacement of maize.

Thakur et al. (1985) replaced maize by sorghum at 50 and 100 per cent in Hubbard broiler chicks of 0-8 weeks duration and reported that SPV-346 cultivar can replace maize by 100 per cent with non-significant difference in
weight gain, feed intake and feed efficiency. Further, they reported significantly lower body weight gain and feed efficiency at 60 per cent and above levels of replacement of maize by sorghum (Var Countri-2201) in broilers. On the contrary, Cao et al. (1985) observed non-significant difference in weight gain and feed efficiency when maize was replaced 100 per cent by high tannin variety sorghum in broilers of 0-42 days of age.

Asha Rajini et al. (1986) conducted a feeding trial to study the possibility of replacing maize with other cheaper and easily available coarser grains such as jowar, finger millet and pearl millet replacing maize in the control diet up to 37.5 per cent of diet and found that there was significant improvement in weight gain of broilers when maize was completely replaced by either of the millets at eight weeks of age, but however without any change in feed intake or feed efficiency. These findings were also confirmed by Kantharaja et al. (1995). Further, they replaced maize with sorghum at 25 and 100 per cent in broiler chicks ration did not affect weight gain and feed efficiency at 100 per cent replacement.

Mohamedian et al. (1986) reported that birds fed sorghum diet showed significantly (P<0.01) lower weight gain (1.45 kg) than those kept on either finger millet (1.67 kg) or maize (1.72 kg) diets. Feed intake, though not significantly different among the three rations used, was maximum in the maize based diet, minimum in sorghum and intermediate in finger millet.

Ananda Kumar et al. (1993) found significant reduction in body weight in broilers fed high levels of jowar. On the contrary, Aravind Bhat (1991) and Krishnappa et al. (1992) found no significant reduction in feed efficiency and obtained better body weight gain in broilers fed diets containing chemically treated jowar replacing maize.
Purushothaman and Thirumalai (1995) compared the performance of layer chicks by including sorghum or finger millet or a mixture of these millets at the expense of maize. They found that the feed consumption was statistically (P<0.05) similar in all the dietary groups except in the finger millet group.

Dixit and Baghel (1997) reported that the intake of feed was significantly (P<0.05) higher (3.73 kg) in 80 per cent sorghum substituted group, while lowest feed consumption (3.334 kg) was observed in 100 per cent sorghum group. They also reported that the body weight gain of broilers was higher in groups fed with 40 per cent replacement of sorghum than that of control. Further, the substitution of maize with sorghum at 60, 80 or 100 per cent although reduced the weight gain in broilers but variation among groups was non-significant.

Reddy and Rao (2000) conducted experiments on chicks and layers and indicated that good quality sorghum could be used at fairly higher levels as a principle source of energy in chick and layer diets. They further recommended that the discolored and small grain sorghum when available, can be used upto 100 g/kg in commercial poultry feeds. They also reported that the ready-to-cook yield was similar as that of maize based diets by replacing sorghum fed birds, but increased gizzard, giblets recorded in finger millet diets. Raju et al. (2003) reported bajra and jowar as effective alternatives to maize while ragi in whole form was not suitable for inclusion in broiler diet.

Raju et al. (2004) reported that ready-to-cook carcass yield for different dietary groups of bajra, ragi and jowar were comparable for all the groups and further, weight of gizzard (P<0.01) and giblet (P<0.05) were significantly higher in the group fed ragi compared to sorghum and bajra.
Ayodeji (2005) reported that maize-sorghum brewers dried grains (SBDG) can act as an energy substitute for maize at inclusion levels of about 25 per cent in broiler starter diets without adverse effect on carcass characteristics and muscle development in broiler chicks.

Salunkhe et al. (2005) studied the effect of sorghum and ragi replacing maize at 70, 85 and 100 per cent level isonitrogenous and isocaloric, respectively. Inclusion of these instead of maize either reduced the retention of nutrients significantly ($P \leq 0.05$) or had no significant influence on it. Use of these cereals instead of maize at 70 and 85 per cent level reduced the per cent retention of all the nutrients significantly ($P < 0.05$), while further inclusion of coarse cereals instead of maize at 100 per cent level, showed higher ether extract retention, however, retention of other nutrients was reduced significantly.

Sannamani et al. (2005) conducted an experiment to study the effect of different varieties of sorghum grains with varying concentrations of tannins fed sorghum (1.86% tannin, yellow sorghum with 0.57% tannin and white sorghum with 0.32% tannin) replacing maize at 50, 75 and 100 per cent level. The study revealed that the carcass characteristics (eviscerated and ready to cook yield) and organ weights (heart, liver, gizzard and pancreas) were statistically similar ($P \geq 0.05$) in all dietary treatments except for gizzard weight (% of live weight), which was significantly ($P < 0.01$) higher in red sorghum diet ($2.69 \pm 0.11$) as against that of control diet ($2.15 \pm 0.07$). Further, organoleptic evaluation of meat from broilers meat different dietary groups revealed non-significant differences for sensory attributes. Travis et al. (2006) reported that KS-115 hybrids produced grain with exceptionally high seed weight and increased fat content appeared to be beneficial to sorghum based poultry diets, resulting in increased bird performance that is comparable with that of maize.
Tyagi et al. (2005) reported having the combination of 33 per cent each of sorghum, pearl millet, finger millet and pearl millet with maize resulted in similar body weight gain, feed intake and feed conversion ratio and it was inferred that a combination of maize, pearl millet and sorghum at 33 per cent each or maize, pearl millet, sorghum and finger millet at 25 per cent each in diet of broilers could support the optimum growth and feed conversion ratio without affecting nutrient utilization and meat yield.

Mandal et al. (2006) conducted an experiment in day old broilers (n=180) using maize – sorghum based diets containing either soybean meal or partly replaced with solvent extracted rape seed meal or sunflower seed meal at 5 and 10 per cent level. Replacement of maize by 50 per cent sorghum did not affect body weight gain.

Travis et al. (2006) recorded that the sorghum hybrid KS 115 with exceptionally high seed weight and increased fat content appear to be beneficial in increased broiler performance that is comparable with that of maize.

A feeding trial was conducted on 360 one day old broiler chicks from 0-6 weeks of age to assess the effect of processed high tannin red sorghum in the diet of broiler chickens on nutrient utilization. The tannin content was reduced from 23-16 g/kg in reconstituted red sorghum. The treatments were maize – soya based standard broiler diet (control) and either raw red sorghum at 25, 50, 75 and 100 per cent or reconstituted red sorghum at 25, 50, 75 and 100 per cent replacing 25, 50, 75 and 100 per cent of maize from the control diet. They recorded that high tannin red sorghum resulted in about 30 per cent reduction in its tannin concentration. Feeding of reconstituted sorghum based diets to broiler chicken did not exert any appreciable influence on nutrient utilization, blood biochemicals and gross pathological changes. The birds fed
on raw red sorghum exhibited higher immuno-responsiveness in comparison to their reconstituted counterparts. (Kumar et al., 2007)

Subramanian and Metta (2007) suggested that sorghum can replace maize in poultry feed to a great extent in view of the similarity in the composition in the grain. The results on egg production and broiler weight were similar in two experiments, when sorghum or maize was fed as a source of energy.

2.4 Role of enzymes in poultry ration

Enzymes are proteins, made of long chains of amino acids with a highly complex molecular structure, catalyzing all metabolic processes in plants, animals and microorganisms without being engaged themselves. Currently 2477 different enzymes are grouped into 6 main classes based on type of reactions they catalyze. All the enzymes act at specific reaction conditions, temperature, pH or humidity, substrate concentration as well as in the presence of activators and inhibitors (Snaw and Pade, 1996).

2.4.1 Purpose of enzymes addition

1) To increase the bio-availability of polysaccharides and proteins.
2) To partially hydrolyze various carbohydrates (beta-sugars and pentosons) that are present in cereal grains, which may inhibit nutrient absorption and transportation.
3) To hydrolyze extensively the fibrous material not usually degraded by the natural enzymes formed in animals to provide additional sugars for growth.
4) To help in augmenting the host enzyme system.

An alternate explanation has been proposed by Hesselman and Aman (1986). They proposed that the beta-glucans and arabinoxylans which form the endosperm wall of cereals, act to restrict access of enzymes to nutrients.
They postulated that the disruption of intact walls and the release of entrapped nutrients is the major factor responsible for the improvement of nutritive value ascribed to exogenous enzymes. Chesson (1993) has postulated that a single enzyme should be effective if the beneficial effects of enzymes are attributable solely to viscosity reduction. The reason is that since viscosity is partially a function of chain length as it is only necessary to break the chain in a few sites to substantially reduce or destroy its gel-forming capacity (Marquardt et al., 1996).

It has been hypothesized by numerous researchers that the principal mode of action of most enzymes is the destruction of gel-form polysaccharides leached from cereal cell walls in amounts which depresses performance (Annison and Choct, 1991; Bedford, 1992; Chesson, 1993).

Enzymes for long time have been identified as nature’s teeth to breakdown complex molecules failed to be utilised by biological system. This concept has been fully exploited in poultry in degrading complex NSP and proteins.

2.4.2 Benefits due to enzyme addition

- Reduced viscosity in the diet and digesta
- Enhanced digestion and absorption of nutrients especially fat and protein
- Improved AME value of the diet
- Increased feed intake, weight gain, and feed–gain ratio
- Decreased size of gastrointestinal tract
- Altered population ratio of microorganisms in gastrointestinal tract
- Reduced water intake
- Reduced water content of excreta
- Reduced production of ammonia from excreta
- Reduced output of excreta, including reduced N and P
- Reduced output of bile salts in digesta

Annison and Choct (1991)

The recent advances in biotechnology has facilitated the commercial production of enzymes making them available cheaply in large quantity. They are now being extensively used in many industrial processes like in detergent and paper products, leather and textile processing, beverage and feed industry. Presence of these factors not only increase the digesta viscosity but decreases digestibility and inturn uptake of nutrients. Enzyme supplementation is one of the novel solutions to overcome the adverse effects of anti nutritional factors (Annison and Choct, 1991).

2.4.3 Enzymes in poultry ration

Enzymes of the digestive tract of birds produced in situ help in the digestion of dietary proteins, carbohydrates and lipids while polysaccharides of plant origin in the diet are only partly digested by chickens, host enzymes. Birds lack fibre degrading enzymes that would degrade the complex molecules like cellulose, hemicelluloses and pectins etc and as such, supplementing poultry diets with fibre degrading enzymes would facilitate degradation of these polymers thereby making available the nutrients which would otherwise be excreted. Irrespective of the feed ingredients (cereals) used, the effect of supplementation of enzymes holds good for small millets, since the information relating to it is very scanty.

Majority of the feed ingredients used in poultry diets are also industrial byproducts like sunflower extracts, DORB etc which contain high amounts of NSP’s. The digestibility of NSP’s is very low in poultry and also large amount of NSP’s are wasted. Research has shown that supplementation of
enzymes in poultry feed is useful in improving the feeding value of low energy feed ingredients to poultry and to eliminate anti nutritional factors.

The supplementation of fibre degrading enzyme in high-fiber or low-energy broiler diets @0.5g/kg of diet resulted in a significant improvement in body weight gain, feed efficiency and breast muscle weight in broiler birds (Muramatsu et al., 1992). They opined that the enzyme supplementation would benefit growth performance in chicken through enhanced dietary ME values, which were primarily brought about by an increased digestibility of NDF especially when dietary energy was a limiting factor for the growth.

Aravind Bhat (1991) and Anand Kumar (1993) observed no improvements in growth performance of broilers fed higher levels of sorghum diet (60%) with amylase or cellulase or combination of both.

Supplementation of cereal-based diets for poultry with enzyme preparations may notably improve the performance and reduce the viscosity of digesta and excreta. However, the overall effect depends on the level of anti-nutritive non-starch polysaccharides (NSPs) in diets, the age of birds and the quantum of extraneous enzymes (Jeroch et al., 1995).

Umashankar (1997) studied the influence of biocellulase and betaglucanase in diets with different levels of ragi grain varieties in layer diets and revealed that the enzyme betaglucanase and biocellulase supplementation to be of no consequence.

The effect of enzymes in improving the apparent metabolizable energy (AME) in poultry fed corn-soy based diets has been demonstrated in few recent studies in broilers. Overall, the addition of enzymes to broiler diets based on corn-soy increased in the AME by 0.52 to 11.9 per cent.
Elangovan et al. (2004) conducted a 4x2 factorial experiment for period of 7 weeks on 240-d-old broiler chicks to study the efficacy of commercial feed enzyme preparation added at the rate of 50 g/100 kg in four experimental diets containing either maize, sorghum, finger millet as sole cereal source or a combinations of maize, sorghum, finer millet and pearl in equal proportions on performance, nutrient utilization, carcass traits and feed cost of production. The body weight gain and feed efficiency were significantly lower in finger millet based diets which were improved upon enzyme addition. However, addition of enzyme in diets based on other cereals did not improve the performance of broilers. The enzyme addition significantly improved the dry matter and gross energy metabolizability with higher nitrogen retention from diet containing finger millet. The carcass traits remained unaltered by various dietary treatments. Feed cost of broiler production was higher in finger millet based diet. It is concluded that diet containing finger millet, a poor quality grain, can be improved by adding commercial feed enzyme preparation.

Raju et al. (2004) did not notice any significant improvement in body weight at 5\textsuperscript{th} week of age of broilers on supplementation of multi-enzyme mix (amylase, cellulose, lipase and phytase) to sorghum and ragi based diets.

Enzyme supplementation in broiler diets did not influence (P>0.05) the weight gain at 21 day of age, but at 42 day of age, weight gain was depressed sufficient with enzyme supplementation. The feed efficiency was significantly improved at 21 days of age with enzyme supplementation, but such beneficial effects were not seen at 42 days of age (Raju et al. (2004).

Mandal et al. (2006) recorded improved body weight gain during starting phase and feed conversion efficiency at any growth phase in finger millet based diet containing 10 per cent maize-soy-sorghum (SSM). The
sorghum-maize-10 per cent SSM diet also showed marginal improvement in growth and feed conversion ratio during starter and finisher phases. Cost production however reduced in sorghum+maize+10 per cent SSM diet only. They also observed that enzyme supplementation was beneficial in improving utilization of sunflower seed meal in maize-finger millet or maize-sorghum based broiler diet.

Jeroch et al. (1991) investigated the effect of beta-glucanase containing enzyme preparation Avizyme R with a barley-based broiler finisher feed and recorded that the carcass composition and meat quality were similar in the treatment groups.

Rajeshwara Rao and Devegowda (1996) reported an improved digestibility of neutral detergent fiber and acid detergent fiber with the supplementation of enzyme complex containing diets.

Richter et al. (1994) analysed the effect of enzyme mixture (cellulases, hemi cellulase and glucanase) in broiler diets of barley, rye or triticale and found that in diets with triticale, growth was not improved by enzyme supplementation. Different body fractions and crude nutrients in edible carcass were not influenced by enzyme supplementation.

2.5 Oils / Fats in poultry ration

The terms “fat” and “oil” refer to triglycerides of several profiles of fatty acids. The fat constitute the main energy source for animals and they have the highest caloric value among all the nutrients. Besides supplying energy, the addition of fat to animal diets improves the absorption of fat-soluble vitamins, decreases pulverulence, increases diet palatability, and the efficiency of utilization of the consumed energy. Furthermore, it reduces the rate of food passage through the gastrointestinal tract, which allows a better
absorption of all nutrients present in the diet (Dam et al., 1959; Carew and Hill, 1964; Summers and Leeson, 1979).

The energy value of oils and fats depend on the length of the carbonic chain, the number of double bonds, the presence or absence of ester bonds (triglycerides or free fatty acids), the specific arrangements of the saturated and unsaturated fatty acids on the glycerol backbone, the composition of the free fatty acid, the composition of the diet, the quantity and the type of the triglycerides supplemented in the diet, the intestinal flora, the sex and the age of the birds.

2.5.1 Soya oil

The raw soybean oil has on its composition several substances considered as impurities that must be removed using several processes (filtration, hydration and degum). These substances are solid residues from the extraction process, and they are phospholipids, gums, metallic complexes, free fatty acids, peroxides, polymers, secondary products from oxidation and pigments (Beauregard et al., 1996). Composition of the raw soybean oil is given below:

<table>
<thead>
<tr>
<th>Components</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triglycerides</td>
<td>95 – 97 %</td>
</tr>
<tr>
<td>Free fatty acids</td>
<td>0.3 – 1.1 %</td>
</tr>
<tr>
<td>Phospholipids</td>
<td>1.5 – 25 %</td>
</tr>
<tr>
<td>Metals</td>
<td>30 – 150 ppm</td>
</tr>
<tr>
<td>Chlorophyll</td>
<td>50 – 1200 ppb</td>
</tr>
<tr>
<td>Tocopherols</td>
<td>0.06 – 0.15 %</td>
</tr>
<tr>
<td>Sterols</td>
<td>0.3 – 0.5 %</td>
</tr>
<tr>
<td>Hydrates of carbon</td>
<td>0.01 – 0.02 %</td>
</tr>
</tbody>
</table>

Beauregard et al. (1996)

a) Degummed Soybean oil

The degummed soybean oil is a product obtained from the raw oil after degumming, which involves centrifugation of the soya oil to separate it into
the two following parts: degummed oil and unsaponifiable matters (Compêndio Brasileiro de Alimentação Animal, 2000).

Scaife et al. (1994) fed female broilers with diets containing different sources of lipids (beef tallow, soybean oil, canola oil, marine fish oil or a mixture of these oils) and observed that live weight was significantly higher when soybean oil was used. Birds fed with canola oil also showed higher intake resulting in higher weight. Broilers fed beef tallow had the poorest conversion rate.

The extra caloric effect of added soybean oil improved the body weight gain, food utilization and metabolizable energy. Two diets were formulated to contain 12.1 Mj/kg, one with no added fat and the second with 30 g/kg soybean oil. Improved body weight gain by 6.9 per cent (P<0.05) was evident. Two other diets were formulated to contain 13.0 Mj/kg, one with 30 and one with 60 g/kg added soybean oil bringing the total fat in the high energy, high fat diet to 84 g/kg. Addition of oil in this case improved weight gain by only 3.4 per cent (P≥0.05). Addition of soybean oil increased the apparent digestibility of total dietary fat and reduced that of starch (Nitsan et al., 1997).

The soybean is by far the most important oilseed crop in the world and is grown for a number of industrial and agricultural uses. As an animal feed, it is traditionally the extracted oil seed cake that is most widely employed as a high protein meal. However, recently there has been considerable interest in the use of the unextracted seed (full fat soya, FFSB) which combines the protein of the cake with high dietary energy values associated with the oil content to produce a raw material that is of some considerable value in poultry nutrition.
Vieira et al. (2006) evaluated broiler rations containing 0, 4 and 8 per cent of soybean oil and acidulated soybean oil soap stock, and observed similar weight gain between the different lipid sources and improved feed conversion in birds fed with soybean oil in comparison to the birds fed with acidulated soybean oil soap stock. They also observed a reduction in feed intake of birds fed with acidulated soybean oil soap stock when the inclusion level was increased from 4 to 8 per cent, whereas no reduction in feed intake was observed in birds fed with soybean oil.

Lara and Baião (2005) fed male broilers with different lipid sources (degummed soybean oil, poultry fat, acidulated soybean oil soap stock, a mixture of poultry fat/soybean oil and other mixture of soybean oil/acidulated soybean oil soap stock) and observed better weight gain and feed intake in birds fed with soybean oil in relation to the birds fed with acidulated soybean oil soap stock. The different lipid sources had no influence on the levels of moisture, ether extract, and protein of the breast, thigh and whole carcasses.

Each of the four diets, containing 6 per cent fish oil (FO), 4 per cent FO + 2 per cent linseed oil (LO), 2 per cent FO + 2 per cent LO + 2 per cent sunflower oil and 6 per cent soyoil were allocated to replicates of 20 chicks each (Ozpinar et al. 2003). The meat samples were taken on days 21 and 42 of fattening, and fatty acid composition of meat samples were analysed at the end of the study. The levels of poly unsaturated fatty acids, especially EPA and DHA were increased, thereby, n-6-fatty acid levels in meat samples were decreased and n-3 level was increased by adding fish oil to the diet.

Onu et al. (2004) conducted an experiment in Anak broiler chicks to investigate the growth response of broiler fed diets containing different energy sources. Maize as the control and the major source of energy as diet 1, while diets 2 and 3 contained millet and sorghum as the major source of
energy. The chicks were randomly allotted to the three diets in completely randomized designed. Each treatment consisted of three replicates. The experiment lasted for 28 days. The mean daily feed intake, body weight gain and feed conversion ratio values showed significant differences (P<0.05) between treatments. Birds fed millet based diet performed better (P<0.05) than the other groups in terms of body weight gain and feed conversion ratio. There was no significant (P>0.05) difference in body weight and feed conversion ratio of birds fed maize or sorghum based diets. The results of the experiment showed that the millet could be used as the principle energy source in broiler diets with improved performance. The results also indicated that the adequately ground, low tannin sorghum could equally replace maize in broiler diets without any deleterious effect.

Mandal et al. (2006) recorded eviscerated carcass yield, weight of the liver, heart and gizzard were non-significant in broilers fed diets with maize, sorghum and finger millet.

Raju et al. (2005) conducted an experiment by adding sunflower oil (SFO) at 30 or 60 g/kg or 3 vegetable oils namely, SFO, soybean (SBO) or groundnut (GNO) at 30 g/kg to isocaloric and isonitrogenous broiler chicken diets which were evaluated for possible counteractive effects against aflatoxin (AF) (0.3 μg b1/g diet) from 0-42 day of age. Body weight, food intake and serum concentration of protein were lower in AF group than in control, whereas in the SFO and SBO supplemented groups, they were comparable with those of the control.

Inclusion of soyoil in diet had no significant effect on feed intake in chicks. Lowest abdominal fat was observed in chicks fed with a diet containing 7.5 per cent soyoil with NRC recommendation protein level (Tabeidian et al., 2005).
Barbour *et al.* (2006) reported that corn plus soy diets supplemented with 10, 20 or 30 g/kg of soybean oil in isocaloric (2965 kcal/kg) and isonitrogenous (21.7%) diets resulted in increase of 175 and 120 g in body weight gain and ready-to-cook yield carcass weight of 97 and 91 g at 44 days, respectively. They suggested that improvement in production parameters can be achieved in broilers fed a low ME diet through the addition of moderate levels of soybean oil.

b) **Acidulated soybean oil soap stock**

Wiseman *et al.* (1991) worked with diets for broilers supplemented with three different sources of lipids (tallow, soybean oil and palm oil) and their respective acid oils, with different levels of free fatty acids. The reduction in metabolizable energy values of the fats with higher contents of free fatty acids tend to be more pronounced with greater inclusion levels of lipids. Besides, reduction is also greater with greater saturation levels. The increase in free fatty acid levels reduces progressively the ME values of the energy source, and such effect is more pronounced in young birds.

The use of refined soybean oil, raw soybean oil or acidulated soybean oil soap stock showed an increase in the levels of linoleic fatty acid on the carcass of birds fed with refined soybean oil and raw soybean oil in relation to the acidulated soybean oil (Martin *et al.*, 2003).

Mehmet *et al.* (2005) conducted an experiment in broilers and recorded daily weight gain and feed intake which were significantly higher in the Beaf tallow (BT) compared to soybean oil (SO) and poultry grease (PG) fed groups.

Tabeidian *et al.* (2005) conducted an experiment in broilers by including soybean oil in the diet and they have recorded no significant effect on feed intake in broilers fed diet containing NRC protein level. In 7-21 days
broiler chicks feeding a diet with 2.5 per cent soybean oil (SO) and a protein level of 1 per cent more than NRC recommendation resulted in lowest feed conversion ratio. Feeding different levels of soybean oil and protein had no effect on carcass weight. Lowest abdominal fat was observed in broilers fed with a diet containing 7.5 per cent soybean oil (SO) with NRC recommended protein level.

Two experiments were conducted to study the performance and carcass quality of broilers in response to varying composition of a diet low in ME, through the supplementation of graded levels of soybean oil. In an initial study, isocaloric (2,965 kcal/kg) and isonitrogenous (21.7%) corn-soybean diets were supplemented with 10, 20, or 30 g/kg of soybean oil. In a second experiment, diets containing ME levels of 2,940 and 3,040 kcal/kg were supplemented with soybean oil levels of 20 or 40 g/kg. In both experiments, supplementation of up to 30 or 40 g of oil/kg of diet resulted in increases of 175 and 120 g BW gain and 97 and 91 g in ready-to-cook carcass weight respectively at 49 days. There was a significant linear decrease in percentage deposition of abdominal fat pad only in diets containing 2,965 or 2,940 kcal of ME/kg with no significant changes in ready-to-cook carcass and whole breast or pectoralis major muscle yields and ready-to-cook carcass composition. The study indicated that improvements in production parameters can be achieved in broiler chickens fed a low ME diet through the addition of moderate levels of soybean oil (Barbour et al., 2006).

An experiment was carried out on 150 Ross 308 female chickens, fed diets containing increasing amounts of mono-, di-, tri butyric acid glycerides 0.2, 0.35, 0.5, 1.0 per cent levels, with soybean oil as the energy supplement, treated birds showed significantly higher live weight at slaughtering with a better feed conversion rate. The carcass characteristics were not influenced, but the small intestine wall showed slightly modified shorter villi, longer
microvilli and larger crypts depth in jejunum, with lowest concentration of the supplement (0.2%). It was concluded that butyric acid glycerides were efficient feed supplement to broiler diets, deserving particular attention as a possible alternative to antimicrobial drugs, which have been banned in Europe (Antongiovanni et al., 2007).

2.5.2 Fish oil

Fish oil is produced by the compression of whole fishes and sub-products of fishery industry. This kind of oil contains high percentages of long-chain polyunsaturated fatty acids, which accounts for the oxidative instability and the transference of characteristic fish flavor to the meat of animals fed with fish oil. In general, fish oils are rich sources of omega-3 fatty acids and poor sources of omega-6, and the contents of linoleic acid are also low (<2%).

Withdrawal of fish oil at 4th week of age resulted in favorable organoleptic evaluation. A more favorable evaluation was obtained if yellow grease was substituted in place of fish oil for the last 4 weeks. The organoleptic scores were highly significantly correlated with the content of 20:5 03, 22:5ω3 and 22:6 3 but it was less significantly correlated with the content of 20:4 ω3. An inverse relationship existed between the content of the ω3 with that of the ω6 fatty acids (Miller and Robisch, 1969).

Some authors reported the unpleasant flavor of fish in the meat of broilers fed with 1.5 to 2.5 per cent of fish oil (Hardin et al., 1964; Miller and Robisch, 1969). Phetteplace and Watkins (1990) evaluated different sources of poultry fat and fish oil (Menhaden) in broiler feeding. Birds fed with diets containing more fish oil have deposited more quantities of unsaturated fatty acids in the abdominal fat, as well as more n-3 fatty acids.
In recent studies the fatty acid composition of broiler carcass has been customized for high concentration of essential polyunsaturated fatty acids (PUFA; especially n-3 fatty acids), through supplementing diets with fish oil (Ackman et al., 1988; Hulan et al., 1984; Chanmugam et al., 1992). Results from these studies indicate that the degree of influence of a dietary fat on carcass fatty acid composition depends on its origin.

When fed to chicken, fish oil (marine origin), rich in eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), results in a high degree of enhancement for these fatty acids in the carcass (Hulan et al., 1984 and Ackman et al., 1988).

Chanmugam et al. (1992) also demonstrated that the content of n-3 fatty acids in the thigh of broilers might be increased by the addition of linseed oil or fish oil in the diet (Menhaden). Therefore, it has been suggested that the inclusion of low dietary levels of fish oil together with another source of linoleic fatty acid to obtain an acceptable product with increased ratio between n-3:n-6 fatty acids.

Scaife et al. (1994) have utilized beef tallow, soybean oil, colza oil, oil of marine fish or mixtures of these oils in female broiler diets. The relation n-6:n-3 was significantly increased with the inclusion of soybean oil and decreased with the inclusion of marine fish oil.

Lower levels of dietary fish oil were more efficacious in improving broiler performance than higher levels, and fish oil provided from fish meal was not as efficacious as oil per se, possibly due to nonlipid components of the meal (Korver et al., 1998).

The influence of fish oil (highly unsaturated) and beef tallow (highly saturated) with vitamin E (100 IU/kg) supplementation on the antioxidant
status of male broiler chicken was investigated. Chicks were fed a control diet with no added fat, 40 g/kg each of fish oil and beef tallow diets, respectively, from 11 to 42 days of age. Tocopherol concentration and the rate of lipid peroxidation, thiobarbituric acid reactive substance (TBARS) in liver, fatty acid composition of the liver lipids, blood serum total antioxidant status (TAS), and reduced glutathione (GSH) content were determined. Vitamin E supplementation of the diet increased liver α-tocopherol content in chicks regardless of the type of dietary fat. Fish oil diet resulted in higher liver TBARS value while beef tallow diet showed lower values compared to the control diet. Vitamin E supplementation reduced liver TBARS as well as serum GSH, and raised serum TAS for all diets. Serum GSH was the same for vitamin E supplemented diets regardless of the fat supplement. Fish oil diets resulted in a significant increase in hepatic lipid n-3 PUFA content. A significant positive correlation was found between liver TBARS and n-3 PUFA content. No relationships were established, however, between liver TBARS and n-6 PUFA or saturated fatty acids. The results suggest that feeding oils rich in n-3 PUFA increases tissue concentration of these fatty acids, consequently increasing tissue lipid peroxidation and reducing the antioxidative status of broiler chickens. Supplementing high levels of vitamin E with such oils may increase tissue oxidative stability. Serum TAS or GSH may be used as a measure of antioxidative status in chickens (Husvéd et al., 2000).

Inclusion of increasing amounts of fish oil in the diet improved performance, decreased indices of the inflammatory response and either improved or did not change indices of the specific immune response of growing chicks (Korver et al., 1998).

Dietary inclusion of eight per cent of sunflower oil, fish oil or tallow resulted in lower deposition of corporal fat in birds was concluded that
feeding broilers with sources of n-3 and n-6 produced less carcass fat, and also improved feed conversion. The results are interesting both from an economical point of view and from the point of view of the health of consumers (Newman et al., 2002).

A factorial design was used to study the effect of dietary fish oil (1.25% and 2.5%), all-rac-α-tocopheryl acetate (70 and 140 mg/kg), and Zn supplementation (0 and 200 mg/kg) on the composition and consumer acceptability of chicken meat stored at -20°C for 5 months. Supplementation of the diet with all-rac-α-tocopheryl acetate increased the α-tocopherol content in meat. The fatty acid composition of the meat was affected only by the amount of fish oil. Diets supplied with 2.5 per cent fish oil produced meat with an eicosapentaenoic and docosahexaenoic acid content double that of diets supplied with 1.25 per cent fish oil. Zn supplementation did not affect the content of this mineral in the meat. Moreover, the consumer acceptability of meat samples showed no significant differences among dietary treatments after 5 months of storage at -20°C or with respect to a freshly cooked commercial sample used as a blind control (Bou et al., 2004).

It was found that high-density lipoproteins (HDL) level in blood of females are aspartate aminotransferase (AST) in males were higher in the group fed with 4 per cent fish oil compared to the control group (P<0.01). The highest gross margin in the treatment groups was observed in the group fed 2 per cent fish oil (Alparslan and Özdogan, 2006).