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Roasting and formaldehyde method to make bypass protein for ruminants and its importance: A review

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ABSTRACT

Protecting highly degradable protein sources like GN cake and mustard cake by formaldehyde treatment gave very good results in terms of increased growth rate and milk production in cattle, buffaloes and goats. Several studies were conducted to prove this point. Higher protein degradability results in wastage of dietary amino acids as urea excreted through urine. With regard to soybean cake, its protein can also be protected through heat treatment, which reduces degradability of soya protein.

Heat treatment of whole soybean also enhances its palatability and the heat also destroys the anti-nutritional factors contained in raw beans. Among the most notable of these factors is the protease inhibitor, which binds the digestive enzymes, trypsin and chymotrypsin, rendering it unavailable to the host animal. Thus, properly processed soybean is an excellent feed ingredient which can be incorporated in the ration for high yielding cattle, buffaloes and for growing calves. Roasting of soybean is the most common heat treatment given to this proteinous feed and the roasted soybean can be incorporated even in the complete feed blocks, to act as a concentrated source of energy and protein, for high yielding dairy cows producing 15 to 20 kg of milk / day.

Formaldehyde treatment of cakes (GN cake, mustard cake and soybean cake) effectively reduces their protein degradability and feeding of such treated cakes improved performance of animals in terms of growth and milk production. The treated cake has no effect on the health of animals or the milk quality. The method is also low cost and feasible, the technology has gone commercial in India.

Key words: Bypass protein, Degradability, Formaldehyde, Growth, Health, Roasting

In recent years, there has been a considerable interest in the technological interventions for enhanced livestock productivity in the Indian sub-continent, because of the increased demand for livestock products for human consumption. Appropriate technological methods such as physical, chemical or combinations of both, for the proteinous feeds and their by-products can be used before their inclusion in the rations of livestock for improving productivity. Among the processing methods, dry roasting and extrusion cooking technologies can be used to improve digestibility and utilization of proteinous and other feeds in ruminants. Heat treatment can also destroy anti-nutritional factors inherently present in some of the proteinous feeds.

Highly degradable proteinous oil cakes when ingested by ruminants, result in large scale ammonia production, much of it gets wasted as urea excreted through urine. Even the animal has to spend energy to convert ammonia into urea in liver. To increase the efficiency of protein utilization from the highly degradable cakes, these proteins need to be protected from excessive ruminal degradation and can be used as bypass protein, so that the amino acids from these protein feeds are absorbed intact from the intestines of the animal for tissue protein synthesis as well as for the process of gluconeogenesis in liver.

Apart from heat treatment, chemical treatments are also used for the protection of proteins. Among the chemical treatment, the formalin treatment has been the most effective and feasible technology for making bypass protein.

Heat treatment of feeds

Dry processing like roasting is accomplished by passing the grains/ proteinous feeds through flame by heating them to more than 100°C at various exposure times, resulting in some expansion which produces a palatable product. The moisture content of the product is also reduced. One of the major aims of dry roasting is to increase the energy availability. In addition, it inactivates enzymes and inhibiting factor, thereby improving the nutritive value of the feeds. Mathison (1996) reviewed the importance of processing in enhancing nutritive value of several grains as energy sources in cattle.

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Cereal grains and proteinous feeds were subjected to various heat-treatments such as roasting, flaking, rolling, extrusion etc. for increasing the efficiency of utilization, and thereby improving the animal performance. Several studies indicated that the flame roasting of barley, corn, oats and wheat had little effect on the nutrient utilization by non-ruminants, but significantly decreased the effective ruminal degradation of dry matter and crude protein (McNiven *et al*. 1994). It was suggested that heat treatment by roasting might be beneficial, resulting in a slow release of nutrients in the rumen and allowing more DM and CP to escape rumen degradation, to be digested in the small intestine.

Effect of altering protein degradation and essential amino acid availability: Heat treatment of proteinous feeds may enhance the efficiency with which that protein is utilized by ruminants. Heating creates cross-linkage between and among peptide chains and with carbohydrates, thereby lowering solubility (Reddy and Morril 1993). Heat treatment above the optimal temperature may change the protein so that it is neither fermented in the rumen nor digested in the small intestine. The enhanced protein efficiency due to heat treatment largely results from decrease in ruminal protein degradation and concurrent increase in the quantities of crude protein and amino acids (AA) entering and disappearing from the small intestine (Plegge *et al*. 1985). However, excessive heating can render a fraction of the protein indigestible (VanSoest 1982) and consequently, decrease its value. Roasting suggested to decrease the ruminal degradability of proteins, partly by blocking reactive sites for proteolytic enzymes and partly by reducing protein solubility (Hsu *et al*. 1993).

The roasting of soybean meal increased the amount of soy protein escaping microbial degradation in the rumen. Reduction of protein degradation occurs because of Maillard type reaction between sugar aldehyde group and free amino groups (Dhiman *et al*. 1997). Roasting of soybean and soybean meal resulted in the lowest in situ degradation rates of protein 0.037 and 0.029 per hour, respectively (Faldet *et al*. 1991).

Synchronization of the rates of supply of N and energy yielding substrates in the rumen improved the microbial synthesis and protein flow from the rumen to the duodenum. Heat processing (roasting) of soybean and corn increased the starch gelatinization and reduced the N solubility in the rumen, resulting in improved microbial synthesis, improvement in the body weight gain and efficiency of utilization in calves (Sinclair *et al*. 1993 Abdelgadir *et al*. 1996). Dry roasting of faba beans was effective in shifting the CP degradation from the rumen to the intestine, thus, reducing the unnecessary N loss in the rumen (Yu *et al*. 1998).

The roasting of soybean improved digestibility of ruminally undegraded amino acids in roosters (Aldrich *et al*. 1997) and steers (Aldrich *et al*. 1995). Roasting of cottonseed increased the flow of total amino acids to the intestine (Pena *et al*. 1986). Heating of soybean meal resulted in decreased availability of amino acids post-ruminally. Even though intestinal supply of most amino acids was enhanced by modest application of heat, protein value could be compromised by a lack of increase in the supply or availability of lysine due to its greater susceptibility to heat damage by Maillard reaction (Demjanec *et al*. 1995). Eweedah *et al*. (1997) also reported that the quantity of amino acids escaping the degradation in the rumen increased with heat treatment.

Dry roasting decreased the lysine content in cottonseed oil cake and soybean oil cake but increased threonine, glutamic acid and glycine. Whereas, phenylalanine and lysine in cottonseed oil cake and soybean oil cake were less resistant to microbial degradation in the rumen after heating, arginine and glutamic acid were more resistant than the other amino acids (Schroeder *et al*. 1995). Hence, for each cereal or proteinous feedstuff, optimum temperature employed and time of exposure while roasting have to be worked out before employing their processing technology.

Effect of heat treatment on reduction of antinutritional factors: Several proteinous feeds were subjected to dry heat processing methods, i.e., roasting to reduce or to inactivate anti-nutritional factors, which are inherently present in the feeds as these are heat labile in nature. Heat can alter the conformation of protein (denaturation), causing the inactivation of proteinous anti-nutritional factors (i.e. trypsin inhibitors, lectins, etc.), because these proteins require their structural integrity in order to exert the effects (Vander Poel 1990).

Roasting reduced the cyanide content of expeller processed *kosum* (*Scheichera oleosa*) cake (Prasad *et al*. 2001); rich content in castor (*Ricinus communis*) oil beans (Okorie *et al*. 1985); toxic effect of wild coffee (*Cassina occidentalis*) beans (Suliman and Shommein 1986) and phytic acid content in cereals. Roasting completely reduced the canavanine content of jack bean (*Cannavalis ensiformis*) seeds but strongly damaged protein fractions (Viroben and Michelaureli Vargas 1997). A study conducted to reduce anti-nutritional factors in tropical legume seeds indicated that roasting greatly reduced or lowered haemagglutinating and trypsin inhibitor activities, phytic acid, oxalate and tannic acid contents (Apata and Ologhobo 1997). Roasting soybeans inactivated trypsin inhibitors up to 95 % and completely reduced haemagglutinnins (Ramamani *et al*. 1996) and highest reduction in thioglucoside content was reported (Aletor and Ojo 1989).

Heat processing was effective in removing or inactivating polyphenols in cowpea (Laurena *et al*. 1987). Heat processing also destroys the enzymes like lipoxigenase, urease, lipases and phytases (Eweedah *et al*. 1997).

The roasting of proteinous feeds is a promising technological process, since it is simple and economical. But the optimal conditions required for roasting of various feeds has to be worked out in order to apply this technology to various proteinous feeds before their inclusion in the rations of animals. Roasting soybeans inactivated trypsin inhibitors up to 95% and completely reduced haemagglutinnins (Ramamani *et al*. 1996) and highest reduction in thioglucoside content was reported (Aletor and Ojo 1989). Pluyer *et al*. (1987) reported that in naturally contaminated groundnuts, oven drying and micro oven roasting were effective in destroying 48 to 61% AFB_1 and 32 to 40 % of aflatoxin B_1.

Formaldehyde treatment of proteinous feeds

Nitchman *et al*. (1943) found that proteins form hard complex with formaldehyde (HCHO) and the complex prevents the proteolytic enzymes to act on proteins under ruminal pH. This effect is nullified (reversible) in acidic pH of abomasum. The proteins thus protected from the attack of ruminal proteases are then digested in abomasum and duodenum much in the same way as proteins are digested in the non-ruminant stomach or duodenum. The action of HCHO is as follows:

(i) Formation of methylol groups on terminal amino groups of protein chain and epsilon amino group or lysine.

(ii) Condensation of these groups with primary amide group of asparagine and glutamine, and guanindyl group of arginine. The condensation results in the formation of intermolecular and intramolecular methylene bridges. These bridges are broken down in the acidic medium of abomasum with liberation of formaldehyde (Frankel-Convat and Oleott 1948).

Antoniewicz *et al*. (1992) reported that the FT reactions with protein may be an addition or condensation type in which non-ionic bands are formed between the active side chain groups of amino acids like S–H, –OH.NH_3 etc. and the carbonyl (–C=O) group of FT. Secondary cross-linking by methylene bridges may also be possible. Most of these reactions are reversible under the action of diluted acid solution and do not affect amino acid composition or post-abomasal protein digestibility.

Formaldehyde is available in several forms and concentrations. The form most often used in feeds is formalin, a solution containing approximately 40% formaldehyde. The level of formaldehyde to be applied varies according to the type of feed and its protein content. Treatment with higher dose of formaldehyde can have an adverse effect in causing overprotection of the cake, which makes protein indigestible even in lower tract and can hardly supply any RDN for rumen microbial growth. Thus, the level of HCHO is very important and should be optimum due to its criticality.

Ruminal protein degradation

In rumen, the ingested proteins are extensively degraded by microbial proteases to polypeptides, peptides and amino acids, which are again deaminated to liberate ammonia and volatile fatty acids. The rate and extent of dietary protein degradation in the rumen varies between proteins from different sources. It also depends on the level of proteolytic activity in rumen which is governed by the time protein spends in rumen (retention time) as well as on rumen pH and microbial species present. The other factors which govern the protein degradation in the rumen are: type of diet (Nolan 1993), tertiary structure of the proteins (Leng and Nolan 1984), protein stability (Chalupa 1975, Tamminga 1979), level of feeding (Ganev *et al*. 1979) and feed processing and storage (Satter 1986). Various *in vitro* and *in vivo* methods were suggested to estimate ruminal protein degradability.

Degradation of dietary protein: Dietary proteins are degraded by potent bacterial as well as protozoal proteases located on their surfaces with the production of peptides and amino acids followed by deamination of amino acids or amino acid degradation (Tamminga 1979). Apart from feed proteins, the proteins of rumen bacteria and protozoa are also degraded after their death. Rumen protozoa have relatively higher digestibility (87 %) than bacteria. Lower digestibility of bacteria is ascribed to the lower digestibility of bacterial cell wall and the fact the 20 % of N is present as nucleic acid, which after absorption are excreted through urine as purine derivatives. The reason concerning the degradation of dietary protein and subsequently that of amino acids is not well understood. One school of thought indicates that the intact peptides are taken up from the medium. These peptides are further degraded to amino acids, which are then utilized to resynthesize the microbial protein. If the amino acids are in excess of immediate requirement, these are removed in various ways, including deamination and catabolism intracellularly, presumably to provide ATP or excreted into the medium (Erfle *et al*. 1977). Ammonia formed by amino acid catabolism is also excreted into the medium. Ammonia concentration in the rumen is a function of the relative rates of entry and removal of NH_3. Ammonia enters the medium from several sources including fermentation of feeds, lysed cell fragments, endogenous proteins, miscellaneous soluble N compounds (such as endogenous urea, nucleic acid, uric acid and nitrate) and protozoal excretion. Ammonia N is removed from rumen fluid in several ways – by incorporation into microbial matter which then passes out of rumen; by absorption through rumen wall, and in fluid flowing to the lower tract (Nolan 1993). The portion of ammonia produced in rumen, which is not incorporated into microorganism is absorbed through the wall of the reticulo-rumen and the major part of which is lost through urine, after being converted to urea in liver.

Effect of feeding, roasted and formaldehyde treated cakes on growth and nutrient utilization of ruminants

A lot of work has been done to record the effect of formaldehyde treatment of groundnut cake (GNC) on growth rate and nutrient utilization in ruminants. Only few studies have been conducted to record the effect of FT on mustard cake (MC) and soybean cake.

Soybean cake meal (SBM): Peter *et al*. (1971) observed that feeding of SBM treated with HCHO increased weight gain and feed conversion efficiency, without affecting wool growth in sheep. There was a significant increase in growth rate of lambs fed HCHO treated SBM (Alawa and Hemingway 1986). Spears *et al*. (1980) reported increased growth rate and feed conversion efficiency in cattle fed SBM treated with HCHO at different levels varying from 0.4 to 0.9 % of DM.

However, Hadyipanayiotou (1992) reported no significant effect of FT of SBM (at the level of 0.5% of CP and 0.12% of DM, respectively) on growth rate and feed conversion efficiency in calves, kids and lambs. Schmidt *et al*. (1974) observed reduced growth in steer fed FT (4% of CP) SBM. In first 2 cases, the levels of HCHO used were too low to give in optimum protection of proteins, and thereby, lowering the intestinal availability of proteins, while in the later case the level was too high and caused overprotection. An increased growth and feed conversion efficiency was reported on feeding HCHO treated SBM by Weiss (1990), Deniz *et al*. (1993) and Bhagwat and Srivastava (1993) in calves with the level of HCHO varying from 0.9 to 1.0 % of CP.

Calves consuming the starters containing soybeans processed at 171°C consumed more feed, gained faster, had lower fecal scores and less mortality (Abdelgadir *et al*.1984). Nitrogen retention was similar when calves consumed any of the heat-treated soybean diets, but was less for the raw soybean diet.

Nitrogen digestibilities of the rations were not significantly different; however, nitrogen retention for the roasted soybean ration was higher than that of raw or microwave-heated soybean rations (Prasad and Morril 1976). Nitrogen solubility of the roasted soybeans was lower than that of the raw soybeans. There were no significant differences in the digestibilities of dry matter, ether extract or nitrogen free extract among the 3 rations of raw, roasted and microwave heated soybean. Digestibility of crude fibre was lower for the roasted ration than for the other rations (raw and microwave heated soybean). The decreased N-solubility of the roasted soybean protein may have been a factor for increased protein utilization of this ration. Prasad and Morril (1976) thus concluded that utilization of soybeans by young calves was improved by roasting but not by microwave cooking for 2 min. Glimy *et al*. (1967) also reported that decreasing protein solubilities from 72 to 35 % by dry heat, which increased protein utilization by lambs. During winter, calves fed with high (49%) percentage of the dietary CP as RUP had similar BW gain and efficiency of feed usage as did calves fed with a moderate percentage (39 %), but during summer, calves fed with the high percentage of RUP had greater BW gain and efficiency than did calves fed moderate percentage of RUP (Bunting *et al*. 1996). Evidence exists that increased RUP percentage might increase the productivity of heat-stressed lactating cows (Taylor *et al*. 1991) and growing calves (White *et al*. 1992). Cows fed heated soybeans consumed more metabolizable energy than raw soybean (61.6 vs 60.4 Mcal/d) (Ruegseggev *et al*. 1985). Heat-treated rapeseed expeller proved to be a more effective protein supplement than solvent-extracted soyabean meal for cows offered grass silage based diets (Shingfieldt *et al*. 2003). Abdelgadir *et al*. (1996) reported that performance of calves fed soybeans roasted at 146°C plus raw corn was superior to that of calves fed soybean meal plus raw corn, but was similar to the performance of calves fed soybean meal plus roasted corn.

Aapparent N digestibility, N absorption and retention were similar ($P > 0.05$) for lambs fed non-roasted as well as roasted at 102, 128, 144 and 159°C SBM (Plegge *et al*. 1982). Roasting SBM at 185°C depressed ($P < 0.05$) apparent N digestibility and absorption, but did not affect ($P > 0.05$) N retention. Reddy and Morril (1993) reported that performance of calves fed soybeans processed at 146°C was superior to that of calves fed soybeans processed at 132 or 163°C. Rumen undegradable intake protein, determined by a protease method, increased with increasing roasting temperature, but unavailable protein as calculated from ADIN was higher for soybeans roasted at 165°C. Abdelgadir *et al*. (1984) reported that soybeans processed at 171°C resulted in calf performance that was similar to that of calves fed soybeans processed at 138°C or 191°C.

Demjanec *et al*. (1995) reported that SI digestibilities were moderately increased by heating SBM to 150 min, then declined dramatically when SBM was heated for 180 and 210 min. Maximum quantities of total and individual AA absorbed from the SI were observed when wethers were fed SBM roasted at 165°C for 150 min. Heat treatment of soybeans had little effect on ADIN content, except for soybeans heated at 160°C for 90 and 120 min (Faldet *et al*. 1992). Thus, the effect of heat treatment is a function of both temperature and time of heat exposure.

Groundnut cake (GNC): Miller (1972) found that HCHO treatment of GNC did not affect digestibility of lambs. However, N flow to abomasum was increased as was faecal N excretion. Approximately, 70 % of extra N reaching abomasum was absorbed. Ray *et al*. (1975) reported that there was no difference in control and experimental groups as far as the growth rate and digestibilities of CP and DM were concerned, when crossbred calves were given FT treated GNC as a protein supplement along with prime jowar. However, N retention was significantly higher in treatment group. An increase in DMI with HCHO treated (0.7 g/100 g CP) GNC compared to untreated GNC fed to buffalo calves (Prasad and Mudgal1979). But, the increase in body weight gain and N retention was non-significant in FT group, perhaps due to the lower level of HCHO used for the treatment. Singh *et al*. (1980) reported that CP digestibility decreased significantly and DMI increased when HCHO treated GNC was fed to lambs. The wool yield and quality showed no significant effect of HCHO treatment.

Walli *et al*. (1980) suggested 1.2 g HCHO/100 g CP as the optimum level to protect GNC protein from ruminal degradation. Gupta and Gupta (1984) reported increase in DMI/100 kg BW from 2.11 to 2.32 and live weight gain from 617.18 to 709.79 g/d in group given GNC treated with HCHO @ 1 % of CP, but both DMI and live weight gain decreased when the cake was treated with HCHO @ 2 % of CP. Kumar *et al*. (1988) and Kumar and Walli 1994a reported higher growth rate and feed conversion efficiency in crossbred heifers when fed HCHO treated (% of CP) GNC based concentrate along untreated wheat straw. N retention of heifer fed on treated GNC was higher than that of heifers fed on untreated GNC (Ramachandra and Sampath 1995). However, treatment had no effect on DM, OM or CP digestibility. Increased average daily weight gain and increased utilization of N in crossbred calves fed HCHO treated GNC compared to untreated GNC (Shinde *et al*. (1995).

Malik *et al*. (1981) studied the effect of HCHO at different levels (1 and 2% of CP) on growth rate and N balance in buffalo calves and obtained significant increase in growth rate and nitrogen balance with HCHO treatment at the level of 1 % of CP. Walli *et al*. (1984) observed significantly higher growth rate in buffalo calves fed GNC treated with HCHO @ 1.2 g/100 g CP than the control group. Srivastava and Hosmani (1989) reported increase in body weight of buffalo calves when fed treated GNC over control group. However, DM and CP digestibility and DM intake was nonsignificant due to feeding HCHO treated cake. Significant increase in growth rate in kids fed HCHO treated GNC with no significant difference in digestibility of nutrients (Sengar and Mudgal 1982). A significant increase in growth rate and feed conversion efficiency of crossbred kids fed HCHO treated GNC (Gupta and Walli 1987). However, when 50 % of the treated cake N was replaced by urea, the growth rate was reduced significantly. Feeding of FT treated (1% of CP) GNC resulted in significant increase in the growth rate of goat kids compared to untreated cake (Pratihar and Walli 1995).

Mustard cake (MC): Very few studies have been conducted on formaldehyde treatment of mustard cake in comparison to GNC or SBM. Sharma *et al*. (1972) did not find any significant change in daily liveweight gain or feed conversion efficiency in calves fed rapeseed meal treated with HCHO @ 5.6 g/100 CP. Sharma *et al*. (1974) reported that flow of total N to intestines remains same in cattle when fed rapeseed cake treated with HCHO @ 0.7 g/100 g CP and there was no significant change in growth rate. Lower level of HCHO used in this experiment was perhaps the reason for nonsignificant effect on growth performance.

Tiwari and Yadava (1990) conducted a study to see the effect of HCHO treatment of mustard cake (MC) in buffalo calves. The treatments were control (untreated MC) 100 and 50 % replacement of untreated MC by HCHO treated (@ 1% of CP) MC and 100 and 50 % replacement of MC by HCHO treated (@ 2% of CP) MC. There was no significant difference in DM intake or digestibility of DM and N. However, N balance was significantly higher in treated groups, being highest in the 100 % replacement by 1 % HCHO treated MC. These authors also concluded that HCHO @ 1 g/100 g CP is sufficient for protection of MC.

Tiwari and Yadava (1994) reported that feed conversion efficiency was significantly higher in groups fed ration containing HCHO treated (@ 1% of CP) MC in growing male buffalo calves. Though digestibilities of nutrients were not significantly different, the highest N balance or body weight gain was observed in group in which untreated MC was totally (100%) replaced by treated MC.

Feeding of HCHO treated MC resulted in a significant increase in growth rate of goat kids compared to untreated MC (Pratihar and Walli 1995). There was no significant difference in DM intake or CP digestibility of kids seen by these workers. Chatterjee and Walli (1998) studied the effect of feeding formaldehyde treated mustard cake on growth performance of buffalo calves. These workers found that the digestibility coefficients for DM, OM and total CHO were significantly ($P < 0.05$) higher in treated group than control group. However, no significant difference between the 2 groups was found with respect to the digestibility coefficient of CP, EE and NDF. The nutritive value of the 2 diets in terms of CP (%), DCP (%) and TDN (%) also showed nonsignificant difference between the 2 groups. The total N intake as well as N intake through roughage or concentrate did not show any significant difference between the 2 groups. There was no significant difference between the 2 groups with respect to total N outgo as well as N outgo through faeces or through urine as g/d. However, N balance (g/d) was higher ($P < 0.01$) in treated group than control. The average daily body weight gain (g/d) over the whole periods of 16 wks was 386.0 in untreated group and 600.0 in treated group. The difference in growth rate between 2 groups was highly significant ($P < 0.01$). The group fed HCHO treated MC recorded as 55 % increase in growth rate over the group fed untreated cake. Plasma protein and plasma glucose concentration showed no significant difference between the two groups. However, plasma urea concentration was significantly higher ($P < 0.01$) in untreated group than in the treated group.

Chatterjee and Walli (2003a) reported that the cost of feeding per kg live gain was lower in formaldehyde treated mustard cake group (Rs 21.42) than untreated group (Rs 31.22), which suggested that raising each kg of liveweight was cheaper by Rs.8.90 in the formaldehyde treated mustard cake than in untreated group.

In the literature scanned, we could not come across references where roasted soybean cake was compared with the formaldehyde treated soyabean cake, with respect to protein degradability and growth performance of buffalo calves. Roasted cotton seed feeding improved nutrient digestibility and production performance (Piers *et al*. 1997). Abbelgadir *et al*. (1984) reported that calves consuming the starters containing soyabeans processed at 170°C consumed more feed, gained faster, had lower fecal scores and less mortality. So, roasting certainly has some advantages which may increase animal's appetite, so that total DMI is increased. The roasting of soybean leads to improved digestibility of ruminally undegraded amino acids in roosters (Aldrich *et al*. 1997) and steers (Aldrich *et al*. 1995). Roasting of cottonseed increased the flow of total amino acids to the intestine (Pena *et al*. 1986). Nitrogen digestibilities of the rations were not significantly different. However, nitrogen retention for the roasted soybean ration was higher than that of raw or microwave heated soybean rations (Prasad and Morril 1976).

The comparison between 2 methods of protein protection was reported by Kumar *et al.* (2010) and found that the higher CP digestibility in roasted group could be due to lower protection of proteins by roasting soybean at 160°C for 30 min, compared to the formaldehyde application @ 1.2 g/100 g CP, as reflected by slightly higher ECP degradability for roasted cake than HCHO treated cake (Kumar *et al.* 2011). The excess absorption of N in roasted cake may be due to more ammonia production and its absorption from the rumen, resulting in higher total tract digestibility of CP. However, this needs to be confirmed through further experimentations. A similar trend in feed conversion efficiency of nutrients, DM, CP and TDN in the experiment between the 2 groups fed soybean cake processed/protected by 2 different methods, viz. formaline (chemical) and roasting (physical), only suggested that the 2 methods are equally good for protection of soybean protein from ruminal degradation, reflected by similar growth rate and feed conversion efficiency (Kumar *et al*. 2010).

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