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Effect of Dietary Protein Sources on Lamb's Performance: A Review

Review Article

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ABSTRACT

Protein and energy are the two major components of feed that influence performance of the growing and fattening lambs. Provision of the quality of protein in the lamb's diet does not only improve the animal performance but also ensures profitable animal production. Different vegetable protein sources are used to formulate the rations for growing and fattening lambs. These protein sources differ in amino acid profiles which results in varied responses of the animals. Protein source with a higher by-pass value have been reported to have more intense effects on N-balance, growth and muscle mass accretion than those which are lower in by-pass protein. Inclusion of protein sources with amino acid profiles matching closely to the amino acid needs of the growing lambs results in better growth performance and nitrogen utilization by the animal. Glucogenic amino acids present in some protein sources also improve the energy status of the animal by increasing gluconeogenesis. Presence of anti-nutritional factors may limit the inclusion of protein sources in the diet. Higher fiber contents like in sunflower meal adversely affect the animal performance by decreasing intake and digestibility. Canola meal has higher S contents that are available to the microbes at ruminal level to produce S containing amino acids. Furthermore, ruminal degradability of protein that is synchronized with carbohydrate digestion also results in better feed utilization and animal performance. So, a good protein source, regardless of its escape protein value, should have better amino acid and micronutrient profiles with safe levels of anti-nutritional factors.

KEY WORDS growth, lambs, protein source.

INTRODUCTION

Performance of ruminants is influenced by the proportion of nutrients in their daily feed intake. Protein and energy are the main determinants in the ruminant feed that can alter the animal's performance. However, in developing countries ruminants are mainly fed on crop residues generally receiving only 62% of their crude protein (CP) requirements (Sarwar *et al.* 2002). Feeding ruminants according to their CP needs not only ensures sufficient protein availability to grazing animals but also reduces the hazards associated with excess and deficiency of this nutrient.

Protein sources differ in their chemistry as far as amino acid profile and availability of CP in rumen and post ruminal level (Gleghorn *et al.* 2004; Bateman *et al.* 2005). Protein is an expensive but essential nutrient for animal growth (Dabiri and Thonney, 2004). Different protein sources have varying effect on ruminant's performance and their serum biochemistry (Jørgensen *et al.* 1984). This varied response in performance may be due to changes in rumen ecology and their different amino acid profiles (Hall and Huntington, 2008) that result in altered nutrient metabolism. Different protein sources in lamb diets like canola meal (CM), cotton seed meal (CSM), corn gluten meal

(CGM) and sunflower meal (SFM) provide the condensed nutrients that may be efficiently utilized at ruminal level (Solomon *et al.* 2008). Quality protein with high escape values and efficient amino acid profiles in diets may result in better growth of lambs. Canola meal has a better amino acid profile with high lysine contents which makes it valuable to attain better growth rates in ruminants (Agbossamey, 1995) and higher sulphur contents that helps the microbes to synthesize essential sulphur containing amino acids and vitamins (Seoane *et al.* 1993). Cotton seed meal contains gossypol but its higher tolerance by ruminants allows its use for feeding (Gamboa *et al.* 2001). It also has a good amino acid profile (Anderson and Warnick, 1966) but with low apparent digestibility (Janssen *et al.* 1979). Corn gluten meal is a valuable source of methionine that complements other protein sources. Sunflower meal is extensively used in animal feeds (Villamide and San Juan, 1998) and contains 1.14% lysine and 0.68% methionine but higher fiber contents. It has low market price that helps in formulating the low cost balanced diets for growing ruminants (Erickson *et al.* 1980; Yagoub and Talha, 2009).

The nutrient profile of these meals in balanced diets with energy sources helps in synthesizing microbial protein which ultimately improves the digestibility of nutrients resulting in increased muscle mass accretion in growing ruminants (NRC, 1985). So the supply of these nutrients should be ensured to maximize the growth rate in young ruminants (Arthington and Kalmbacher, 2003). Microbial protein alone can't satisfy the higher demands for protein in growing ruminants (Chalupa, 1975) and this deficit may be alleviated by the inclusion of a good quality protein source that may resist ruminal degradation (Stern *et al.* 1983).

Nutrient intake

Dry matter intake (DMI) may be affected by the dietary protein source as they affect the ability of the rumen to hold ruminal contents (Bandyk *et al.* 2001). Higher intakes were observed in Dorper lambs fed maize stovers as basal diet supplemented with maize meal and CSM (Chakeredza, 2003). Whereas, wether lambs fed wheat forage as a control diet supplemented with CSM, CGM and blood meal (BM) had no effect on forage intake but it resulted in increased digestible DMI (Phillips *et al.* 1995). Ponnampalam *et al.* (2005) observed that DMI was the highest in lambs fed fish meal (FM), moderate fed soybean meal (SBM) and CM and was the lowest in lambs fed basal feed (lucern and oat hay with a ratio of 20:80), respectively. Higher intakes were observed in crossbred wether lambs fed diets supplemented with SFM than those fed rape seed meal (RSM) (Coombe, 1985). Protein intake was higher in finishing lambs fed diets containing varying protein sources than those fed a basal diet having protein in excess of NRC (1985) recommendations for fattening lambs. Khalid *et al.* (2011) also reported significantly higher dry matter (DM), CP, neutral detergent fiber (NDF) and acid detergent fiber (ADF) intakes for growing Kajli male lambs fed diets containing CM as compared to the lambs fed CSM, FSM or CGM based diets. Total DMI was higher in lambs fed a CM diet because of its rapid ingestion and reduced rumen filling effects (Plaisance *et al.* 1997). Another reason for increased DMI might be because of enhanced microbial bio-mass resulting in higher digestion rate and more post-ruminal flow of amino acids (Weisbjerg *et al.* 1992). However, Suliman and Babiker (2007) observed no difference in feed intake ranging from 1.11 to 1.18 kg/d in fattening lambs fed different protein sources like ground nut cake, sesame cake, cotton seed cake and sunflower seed cake. Irshaid *et al.* (2003) also recorded slightly higher daily feed intake in *Awassi* lambs fed SFM (1.94 kg) compared to those fed SBM (1.88 kg) but overall difference was non-significant. Kandylis *et al.* (1999) found no difference in feed intake by growing lambs fed CSM substituted for SFM at 0, 10 and 100% of supplemental protein. Contrary to this, Walz *et al.* (1998) noticed an increased DMI in Suffolk lambs fed FM diets when compared to those fed SBM diets. Krysl *et al.* (1987) reported that the intake of prairie hay was increased from 23.7 to 28.3 g/kg BW, when supplemented with CSM. However, CSM supplementation did not influence ruminal and caecal fermentation and its higher intake may be attributed to a positive relationship between DM and CP intake (Negesse *et al.* 2001). Rule *et al.* (1994) observed non-significant differences in DMI when CM and SBM diets were fed to steers. Erasmus and Botha (1994) reported that DMI was not affected by supplementation of diets with BM, CGM, BM plus CGM and SFM when added as protein source. Ward *et al.* (2008) reported unchanged DMI by Barki lambs fed diets containing SBM, CSM and CSM supplemented with ferrous sulphate although slightly lower DMI was observed in lambs fed SBM diets. Whereas, Yagoub and Talha (2009) found significant effect on feed intake by lambs fed diets in which groundnut meal was replaced with decorticated SFM. Similarly, Karsli *et al.* (2006) reported slightly higher DMI in sheep raised on hazelnut meal diets compared with those fed SBM diet. Wiese *et al.* (2003) noticed improved DMI in lambs fed CM diets compared with lupin and urea diets (1660, 1570 and 1380 g/d, respectively). They further stated that higher DMI in lambs fed CM diet might be attributed to better availability of nutrients in diverse forms and their readily digestion by rumen microbes than those fed lupin and urea diets. Baile and Forbes (1974) also reported higher DMI due to better digestibility. Another plausible explanation for higher DMI in lambs fed CM diet might be the less gut fill effect on reticulo-rumen (Plaisance *et al.* 1997).

Dry matter intake is influenced by the ingredient composition of feed (Carneiro *et al*. 2006). Walz *et al*. (1998) reported increased DMI by lambs fed FM diet supplemented with sodium bentonite compared with SBM protein. Thonney and Hogue (1986) also reported lower DMI/per unit gain in steers fed FM diet than those fed CSM diet. Hango *et al*. (2007) also found significant difference in average daily DMI (630 g/goat/d) between the controlled and concentrate supplemented groups. In conclusion, different sources of protein have variable effect on DMI and this depends largely upon composition of the basal diet.

Nutrient digestibility

Different protein sources have varying effects on nutrient digestibility in animals. Khan *et al*. (1997) reported significant effects of CM, CSM and SBM on DM, CP and fiber digestibility in growing Afghani lambs. However, in other study (Paterson *et al*. 1983), different protein sources had no effect on NDF digestibility. Sunflower meal contains more NDF, which would contribute to lower digestibility (Staples *et al*. 1983). Likewise, decreased DM and OM digestibility were noted in sheep when fed cotton seed cake, which might be the result of gossypol contents (Abou-Donia, 1989) that caused depression in nutrient digestibility due to its adverse effect on the digestive enzymes (Chase *et al*. 1994). Milis *et al*. (2005) reported that SBM or CGM had no effect on nutrient digestibility. Irshaid *et al*. (2003) has also reported no effect of SFM or SBM on digestibility of DM, OM, CP, crude fiber (CF), NDF or ADF in Awassi lambs. Phillips and Rao (2001) observed no difference in DM digestibility in lambs fed diets containing pigeon pea, CSM or alfalfa as protein sources. Although lambs fed pigeon pea showed a lower protein digestibility (65.7%) compared to those fed alfalfa diet (72.7%). The CP intakes were 869, 894, 812 and 944 g/d by lambs fed diets containing SBM, heated SBM, menhaden FM and combination of protein supplements, respectively. Bacterial CP flow remained unchanged in cows fed diets supplemented with CGM and extruded soybeans at 2.7% of body weight (Santos-Silva *et al*. 2003; Stern *et al*. 1983). Bowman and Paterson (1988) reported similar digestibility in lambs fed corn plus urea, corn plus SBM or 50% dry, wet or ensiled corn gluten feed in high concentrate diets. Khan *et al*. (1997) also observed no difference in DM and CP digestibility in Afghani lambs fed diets containing SBM and CM, however, differed significantly when fed CSM as the major protein source. Apparent digestion of OM in the reticulo-rumen was lower in steers fed diets supplemented with heated SBM, menhaden FM and combination of protein supplement (Keery *et al*. 1993).

Ward *et al*. (2008) reported that un-decorticated CSM supplemented with ferrous sulphate significantly improved the nutrient digestibility in growing Barki male lambs compared to those lambs fed un-decorticated CSM or SBM without the addition of ferrous sulphate. Hussein and Jordan (1991) reported 78, 52 and 57% degradability of CP from SBM, FM and corn, respectively. Protein efficiency ratios were unaffected across all the diets.

Karsli *et al*. (2006) reported no difference in the NDF and ADF digestibilities due to changing protein source. Merchen *et al*. (1987) also found higher DM and OM digestibility and lower N digestibility in lambs fed urea, SBM and CGM as protein supplements in corn silage diet. Similarly, Swanson *et al*. (2000) observed better digestibility of DM, OM and CP with protein supplementation in sheep fed grass hay: straw mixture. Jaster *et al*. (1984) reported that DM digestibility was higher (76.6%) in heifers fed wet corn gluten feed compared with alfalfa haylage (60.67%). In the same study, the digestibility of CP, NDF and ADF was increased in wet corn gluten feed compared with other feeds. Bernard *et al*. (1991) also reported higher apparent DM digestibility when wet or dry corn gluten feed was fed. However, Drackley *et al*. (1985) reported decreased fiber digestion in steers fed diets containing sunflower seeds whereas, Nelson and Watkins (1967) found non-significant differences in DM (55.5 versus 55.6), protein (39.1 and 40.5) and fiber (54.1 and 54.3) digestibility in lambs offered diets containing CSM given after every 6 days as compared to daily supplementation. Similar results were obtained by Zinn (1993). Leupp *et al*. (2006) reported higher apparent CP digestibility in steers given feed supplemented with CM compared to the control. Whereas, Richardson *et al*. (1981) substituted CSM with SFM in a growing finishing feedlot diet at levels of 0, 5.5, 11 and 22% and found no difference in digestibility which indicated that solvent processed CSM was similar to solvent extracted SFM when fed on an equal CP and fiber basis.

Blood metabolites

Blood urea nitrogen (BUN) is a measure to assess protein status of the animal. Blood urea nitrogen and protein intake should have a positive relationship indicating that BUN could be an indicator of protein intake (Preston *et al*. 1965; Rusche *et al*. 1993). Higher BUN in lambs fed concentrate diets might be the result of incapacity of ruminal microflora to detain maximum ammonia (Butler, 1998). Ponnampalam *et al*. (2005) reported non-significant difference in plasma urea and glucose in crossbred lambs at d 1 of the trial due to CM, SBM and FM supplemented to control diet (lucerne hay: oat hay; 30:70). However, sampling at d 30 and 53 revealed a significant increase in plasma glucose and urea N concentration except for a decrease in urea N concentration in basal treatment. Lupin supplementation as a protein source on a weekly basis increased levels of urea in plasma whereas variations were found in blood glucose levels (Master *et al.* 2002). Plasma glucose and urea N were unaffected in lambs fed concentrate diets (Carro *et al.* 2006) Increase in glucose concentration may be due to more by-pass protein and increased availability of glucogenic amino acids for glucose synthesis (Sano *et al.* 2007). In contrast, Rusche *et al.* (1993) observed that feeding CP source with high escape protein decreased plasma glucose and urea N concentration. Whereas, supplementation of lucerne chaff with CSM resulted in an increase in glucose and urea concentration in lambs indicating better energy and protein status (Sainz *et al.* 1994). Paterson *et al.* (1983) observed lower BUN in lambs offered escape protein supplements compared with SBM supplement (11.07 versus 16.44 mg/100 mL). However, Davies *et al.* (2007) noticed no difference in plasma glucose, urea N and plasma minerals in response to various protein sources.

In conclusion, feeding protein with high rumen un-degradable value resulted in increased concentration of blood glucose due to more glucogenic amino acids available for gluconeogenesis.

Nitrogen balance

Nitrogen intake and faecal and urinary N are determinants of nitrogen balance (N-balance), whereas N intake depends upon DM and CP intake. Feeding high CP diets may also result in greater faecal and urinary N excretion (Fahmy *et al.* 1992; Phillips and Rao, 2001). Increased urinary N may be the result of increased post-ruminal amino acids absorption that is surplus to the tissue needs or ruminal or post-ruminal absorption of ammonia (Williams, 1991).

A positive N-balance ranging between 4.1-6.4 g/h/d was recorded in lambs fed diets supplemented with protein source. Lambs fed SBM and CSM (supplemented with ferrous sulphate) diets retained the higher N compared to those lambs fed CSM (un-supplemented with ferrous sulphate) based diet (Ward *et al.* 2008). Low N-retention by lambs fed CSM could be the result of poor digestibility of N or due to the poor usage of absorbed N (Woods *et al.* 1962). Phillips and Rao (2001) observed significant difference in N intake in lambs fed diets containing pigeon pea, CSM or alfalfa as the protein source. Replacing the alfalfa pellets or CSM with pigeon pea increased the amount of faecal N (6.66 versus 4.7 g/d), but didn't increase the amount of urinary N. Utilization of protein sources after absorption was not different. There were no differences among diets containing three protein sources, but, the lambs retained a smaller proportion of the N when fed diets containing pigeon pea and other protein sources. Matras *et al.* (1991) reported that grain source didn't influence N-retention, however, urea supplemented diets resulted in lower N-balance in lambs. Karsli *et al.* (2006) reported that sheep fed either SBM or hazelnut meal diet had similar amounts of CP flowing to the lower digestive tract. However, the proportion of total CP flow from un-degraded N was lower in sheep fed hazelnut meal than those fed SBM diet. Faecal, urinary and total N excretion were unaffected by protein source (Knowlton *et al.* 2001). Contrary to this, Murphy *et al.* (1994) observed that N-balance and digestion improved with increasing protein concentrate in the diet of growing lambs. Swanson *et al.* (2000) pointed out that supplementation of grass hay: straw mixture with protein resulted in an increased N intake, urinary N, N digestion, apparent N absorption and N-retention in sheep. However, Merchen *et al.* (1987) fed corn based diets supplemented with urea, SBM and CGM as protein source in lamb diet and found that protein source had no effect on N-retention indicating that supplementing diets with un-degradable protein had no added advantage. The N-retention or balance may be related to normal CP synthesis (Fahmy *et al.* 1992). Using high RUP sources to meet the N needs could reduce more than 15% N excretion (Tomilnson *et al.* 1996) when compared with CP standards of national research council (NRC, 1985). Nitrogen balance was higher for ruminally un-degradable (RUP) protein supplements (+5.7 g N versus +1.7 g N day^{-1}) than for un-supplemented lambs (Bailey and Sims, 1998). Increased N-retention was observed in lambs fed diets supplemented with CSM as protein source (Caton *et al.* 1988).

Protein supplements tended to increase N-retention (g/d) in lambs (Phillips *et al.* 1995). Irshaid *et al.* (2003) formulated diets for fattening *Awassi* lambs containing SFM, SBM and replacing SBM with SFM at 50 and 100% level reported no difference in N-balance. Similarly, Milis *et al.* (2005) reported that protein source (SBM or CGM) did not affect N-balance of diets suggesting that an increase in RUP didn't negatively affect digestibility or nutritive value. Whereas, nitrogen balance in lambs for protein supplements containing SFM and RSM (mean 2.68 g/d) was higher than those fed the urea (-3.70 g/d) diet (Coombe, 1985). Firkins *et al.* (1984) observed higher amount of N reaching the lower digestive tract for wet distillers grains and dried distillers grains (64.1 and 74.7 g/d) compared with wet and dry corn gluten feed (41.3 and 32.7 g/d). However, Knowlton *et al.* (2001) reported no difference in faecal, urinary and total N excretion in cows fed diets supplemented with SBM or a blend of SBM and BM as protein source to meet the 16.2% CP requirements. Tanksley *et al.* (1981) reported higher digestibility of N and essential amino acids at small intestine and over the total digestive tract with glandless CSM and SBM compared with direct solvent and screw pressed CSM. Danke *et al.* (1966) observed that heating of CSM for 30-45 minutes increased N-retention from 25-32.5%, but additional heating for 45, 60 or 75 minutes had no effect on

N-retention, suggesting that CSM should be autoclaved for 45 minutes for maximum N-retention. In contrast, Woods *et al.* (1962) reported CSM as an inferior protein supplement for growing lambs compared with sesame or SBM which may be due to the high crude fiber as compared to the sesame or SBM. Significantly increased N intake and balance in *Kajli* growing lambs fed CM based diets as compared to those fed CSM, CGM or SFM diet has also been reported by Khalid *et al.* (2011). Briggs and Heller (1942) reported higher average N-retention in fattening lambs fed diets containing high CSM compared with low CSM (73.3 versus 38.8%) diets. Nelson and Watkins (1967) found that N-retention by lambs was significantly higher (15.5% versus 9.5%) when CSM was fed daily compared with every 6 days supplementation. In conclusion, organic N sources with high RUP are more efficient in improving the N-balance when compared to lower RUP or inorganic N sources.

Growth performance

The supply of dietary protein is vital for growth in lambs. Reduced CP intake may affect the growth performance (NRC, 1985) and the provision of nutrient dense diets may be a better strategy to attain maximum growth rate (Arthington and Kalmbacher, 2003). Increased post-ruminal flow of glucogenic amino acids (Erasmus *et al.* 1992) and lipogenic moieties (Bruno *et al.* 2009) results in improved muscle mass accretion (McClure *et al.* 1994). Urbaniak (1995) observed higher weight gain in Merino rams fed diet supplemented with FM (197 g/d) followed by those fed BM, SBM and casein supplemented diets (181 g, 175 g and 114 g/d, respectively). Differences in gain might be due to extent of rumen degradation of various protein sources which in turn, leads to different amino acids supply (Urbaniak, 1995). Supplementation of CM and FM to grass silage diets improved the average daily gain by 60.2% and 49.7% in lambs, respectively than lambs fed control diets (Plaisance *et al.* 1997). Increased weight gain was also reported in lambs fed CSM and CGM diets but the relative effect of CSM was almost double than that of maize meal (Chakeredza, 2003) which might be due to the extent of degradation of proteins in the rumen that provided essential amino acid supplies at gut level.

Ponnampalam *et al.* (2005) observed significant increase in live weight gain of cross bred lambs consuming forage based diets supplemented with CM and SBM as protein source. Similarly, Braman *et al.* (1973) reported that the steers fed SBM supplements had greater rates of gain and better efficiency of feed utilization as compared to steers fed diets supplemented with urea. Abdullah and Awawdeh (2004) reported that lambs fed un-treated protein sources showed better daily weight gain compared to those fed formaldehyde treated diets. Nsahlai *et al.* (2002) reported that lambs fed FM based diets gained more weight than those fed SFM diets. Walz *et al.* (1998) also observed increased weight gain in Suffolk lambs fed FM diets compared to SBM diets. Hussein and Jordan (1991) reviewed FM as a protein source in ruminant diet and reported that weight gain and feed efficiency was improved when FM was added in medium or poor quality silages in comparison with high quality silages. Contrary to this, Mandell *et al.* (1997) observed no difference in weight gain in beef cattle fed FM as protein source. Titi (2003) found higher weight gain for kids fed SFM with enzyme; however no difference was noticed on SBM and SFM supplemented diets. Weight gain during the three trials was 221.7, 155.8 and 141.6 g, respectively. This study indicated that SFM can successfully replace SBM as protein source in fattening diets. Khan *et al.* (1997) reported higher weight gain (244 and 233 g/d, respectively) in lambs fed SBM and CM diets compared to 213 g/d in lambs fed CSM diet suggesting that CM and SBM are better protein sources for growing lambs than CSM. Canola meal is relatively rich in vitamins and minerals and is high in sulphur containing amino acids (methionine and cystine) that may have resulted in better growth performance in lambs (Khan *et al.* 1997). Replacement of SBM with FM as protein source had no effect on weight gain in growing lambs (Dabiri and Thonney, 2004). Yagoub and Talha (2009) concluded that the replacement of groundnut meal with decorticated SFM at 0%, 50% and 100% didn't influence the final body weight and daily weight gain in Sudanese desert lambs. Kandylis *et al.* (1999) also reported no difference in weight gain by lambs in a feedlot study when compared CSM with SFM indicating that lambs utilized CSM as effectively as SFM when fed on an equal CP and crude fiber basis. Other researchers (Santos-Silva *et al.* 2003; Fielding and Kyomo, 1979; Merchen *et al.* 1987) have also reported that the protein source utilised has no effect on the growth performance of animals. Walz *et al.* (1998) reported an increase in weight gain by lambs fed FM diet supplemented with sodium bentonite in replacing SBM as protein source. Similarly, Brandt and Klopfenstein (1986) reported that supplementation of slowly degradable protein to alfalfa and corn cob based diets resulted in higher weight gain in lambs and steers. Similarly, Peter *et al.* (1971) concluded that SBM treated with aldehyde resulted in better gain and better feed utilization compared to lambs receiving the water treated SBM. The probable reason for this could be that treatment of SBM with aldehyde improved the bypass protein value of the SBM which provides essential amino acids at intestinal level, thus improving weight gain of the animals. In conclusion, protein source may have significant impact on weight gain and the effect is more pronounced when protein source is supplemented in poor quality feed. Feed efficiency is the measure of animal product output per unit of feed intake. Better performance may be obtained by improving the feed efficiency (Kabir *et al.* 2004). Improved feed efficiency (32.4%) was observed in lambs fed grass silage based diets supplemented with FM, CM and heat treated CM as protein source compared to those fed control diet (Plaisance *et al.* 1997). The lambs fed SFM diet consumed more feed (7.93 versus 6.49 kg) per kg weight gain compared to lambs fed SBM (Irshaid *et al.* 2003). Waller *et al.* (1980) reported improved weight gain and feed efficiency in lambs fed CM compared to those fed CSM diet. The improvement in weight and efficiency of gain was highest in growing ruminants fed RUP (Chalupa, 1975) because of the increased amino acid supply available to meet the metabolic amino acid requirements for maintenance and growth. Ivan *et al.* (2004) reported that sunflower seed supplementation in high concentrate diets resulted in improved feed conversion ratio (FCR). Khan *et al.* (1997) observed better efficiency of feed utilization in lambs fed iso-nitrogenous and iso-caloric diets containing SBM (8.98) and CM (8.58) compared to those fed CSM (9.79). However, observed that different protein sources (BM, meat and bone meal, dehydrated alfalfa and SBM) had no effect on FCR in steers and lambs. Brand *et al.* (2001) observed 21% lower FCR in finishing South African mutton Merino lambs fed diets containing 0, 6, 12 or 18% full fat canola diets, indicating that inclusion of full fat canola up to 18% had no negative impact on average daily gain or FCR in lambs. Whereas, Khalid *et al.* (2011) reported significantly higher weight gain and better FCR by lambs fed CM based diets as compared to those fed CSM, CGM or SFM based diets. This might be related to better nutrient intake and digestibility and N-balance in lambs fed CM based diets (Khan *et al.* 1997; Atti *et al.* 2004). Furthermore, CM also contain higher sulfur contents that may improve the microbial growth (Sniffen and Robinson, 1987), leading to more digestibility and availability of energy for muscle mass accretion. In the rumen, sulfur is also required for the microbial synthesis of sulfur containing amino acids and vitamins (NRC, 1985) which are generally involved in protein synthesis and thereby resulting in better growth performance by the lambs (Brown and Johnson, 1991). Therefore, beside protein contents, micro-nutrient and amino acid profiles of the protein source can also affect the growth performance of the lambs.

Carcass characteristics

Different protein sources may affect the carcass characteristics and meat composition. Carcass characteristics include the hot carcass weight (HCW), cold carcass weight, dressing percentage (DP) and bone to meat ratio. Relationship between frame size and growth rate is affected by the energy contents of the finishing diet. It is well documented that the carcass fatness is influenced by energy density of the diet of finishing lamb. Growth of muscle tissues and extent and site of marbling in carcass affects the value and mass of meat (Mahgoub *et al.* 1978). Strategic supplementation may be helpful in achieving better carcass yield in small ruminants (Butterfield *et al.* 1988; Hogg *et al.* 1992). Greater DP might be due to higher slaughter weights (Lupton *et al.* 2007, 2008). Diaz *et al.* (2002) reported more DP for lambs with higher body weights (Lee *et al.* 1990). Protein concentrate supplementation to the diets of goat kids had no influence on their slaughter weight, slaughter and dissection data (Todaro *et al.* 2006). Whereas, carcass weight and DP increased with increasing amount of concentrate feed made up of a mixture of hominy meal 77%, and cotton seed cake 21% having a CP content of 16%. These observations can be related to more carcass fat, because of high energy and CP intake resultantly more muscle mass accretion (Hango *et al.* 2007). Plaisance *et al.* (1997) studied FM, CM, and heat treated CM as a protein supplements to grass silage diets and found no effect on carcass yield of lambs. Higher slaughter weights and carcass weights were observed in lambs fed CSM diet compared with peanut meal (Nagalakshmi *et al.* 2002). Improvement in carcass weight was noted in lambs fed CSM and maize meal as protein supplements compared to those fed unsupplemented diets. Lambs fed groundnut cake produced the heaviest slaughter weight and carcass weights than those fed sesame, cottonseed and sunflower seed cakes. Hot carcass weights were increased in lambs fed FM supplemented diets followed by those fed CM and SBM in crossbred lambs (Ponnampalam *et al.* 2005). However, ground nut cake, sesame cake, cotton seed cake and sunflower seed cake used as protein source in the diets of fattening lambs had no effect on the proportion of muscle, bone, fat and trim tissues (Suliman and Babiker, 2007). The proportion (lean, fat and bone) was not affected by various protein sources in Sarda lambs, except for fat of hind legs (Rizzi *et al.* 2002). Abdullah and Awawdeh (2004) found that protein source had a significant effect on hot and cold carcass weight within lambs fed SBM reporting higher values compared to lambs fed SFM and CSM. Supplementation with RUP had a significant effect on DP, final live weight and hot and cold carcass weight. Wiese *et al.* (2003) observed non-significant differences in carcass weight, DP and meat colour in lambs fed CM based diets compared with lupin and urea diets. Nsahlai *et al.* (2002) observed that lambs fed FM diet deposited more carcass and carcass protein than those fed SFM diet. Ponnampalam and Hosking (1994) also reported that increasing the energy-protein ratio of the lamb diet by supplementation with lupins (1.8 kg/wk) CSM (1.2

kg/wk) or FM (0.75 kg/wk) resulted in significantly higher carcass weight compared with lambs fed basal diet comprising of oaten chaff and 15% lucerne. However, when the comparison was made on empty body weight basis, the lambs offered protein source diets recorded decreased carcass fat, higher water and protein content in comparison with lambs fed the basal diet. In contrast, Baranowski *et al.* (2007) observed similar DP in un-supplemented groups (47.39%) compared with the supplemented lambs (48.22%). In the same study, the share of primal cuts and fat contents confirmed the same slaughter value (47.39%, 42.65%, 1.74% versus 48.22%, 42.36%, 1.95%, respectively) among the un-supplemented and the lambs supplemented with linseed or mineral bioplex. No difference was also observed in weights of legs (2.20 and 2.10 kg respectively) between both the groups. Dressing percentage, carcass muscle fat and bone percentage remained unaffected by concentrate supplementation. Santos-Silva *et al.* (2003) observed that supplementation of grass fed lambs with sunflower seed had non-significant effects on carcass quality.

CONCLUSION

Different vegetable and animal protein sources exert different responses on the growth performance of lambs which might possibly be due to the differences in processing techniques used, presence of anti-nutritional factors, different amino acid profiles and micro-nutrient composition. Furthermore, certain additives may also improve the utilization of protein sources by reducing the effect of intrinsic anti-nutritional factors and by improving the ruminal fermentation.

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