PRODUCTIVE PARAMETERS AFFECTED BY PROTEIN FRACTIONS IN RUMINANTS

Mahr-un-Nisa, A. Javaid, M. Sarwar, S.A. Bhatti and M.S. Amjad
Institute of Animal Nutrition and Feed Technology, University of Agriculture, Faisalabad

Protein is an important nutrient which provides amino acids to ruminants to satisfy their maintenance and production demand. Degradability of dietary protein affects the rumen fermentation which leads to influence the efficiency of absorbed nutrients and availability of amounts and proportions of amino acids to ruminants. The dry matter intake (DMI) is increased with increase in ruminally undegradable protein (RUP) in the diet. However, DMI is also increased with increase in ruminally degradable protein (RDP) in diets which are deficient in RDP. The increase in DMI with increase in RDP is due to the increased ruminal NH_3-N concentration because insufficient ruminal NH_3-N depress microbial function and thereby limits intake. Ruminal pH is reduced with supplementation of RDP and this reduction in pH is due to higher bacterial activity, fermentation and volatile fatty acid production. Higher dietary RDP results in increased microbial count in ruminants. The increased microbial count with increasing dietary RDP level is attributed to increased concentrations of ruminal NH_3-N, amino acids, peptides, or branched chain volatile fatty acids required for microbial growth. Dry matter (DM) digestibility is increased with increasing the level of dietary RDP. Increased DM digestibility with increasing level of RDP is attributed to increased ruminal NH_3-N concentration resulting increased ruminal microbial activity. Milk yield and fat correct milk is increased with increasing the level of RUP in the diet of ruminants. The increase in milk yield in lactating ruminants with increasing the dietary level of RUP is due to an increase in DMI as well as the increased supply of metabolizable protein. Ration containing improper proportion of RDP and RUP not only impedes the productive potential of the animal but also aggravates some metabolic changes which ultimately give birth to decreased DMI, lowered digestibility and poor energy utilization by the animal.
Keywords: Ruminant, production, protein

INTRODUCTION

Protein being an important nutrient is necessary for vital body functions. In ruminant protein may be provided through diet, nitrogen (N) recycling and endogenous secretions. Dietary protein is generally divided into RDP and RUP fractions. Ruminally degradable protein provides the mixture of peptides, amino acids and ammonia for the synthesis of microbial protein. The microbial protein consists of 75% amino acids (Tamminga, 2006) and generally supplies 70 to 80% of the required amino acids to ruminants (Chumpawadee *et al.*, 2006). It is important for dairy animals because of its high quality protein with relatively constant amino acids content similar to that of milk protein (Maiga, 1996).

Although there is significant contribution of microbial protein to supply amino acids to the host animal but may not meet the needs of high producing dairy animals particularly in early lactation and growing animals during early growth. Ruminally undegradable protein is the second most important source of amino acids to satisfy the high demand of early lactating and fast growing animals. The RUP supplementation results in increased feed intake resulting increased supply of total nutrients as well as additional amino acids for productive and reproductive purpose in ruminants.

Ruminally degradable protein causes excessive NH_3 production in ruminants when fed in excess. Excessive NH_3 absorbed from the rumen causes loss of substantial proportion of dietary protein. This causes poor microbial protein synthesis and low availability of amino acids for tissue metabolism (Bach *et al.*, 2005). Ammonia in excess of the amount required by ruminal microorganisms absorbs and increases the formation of urea in the liver, which ultimately increases the urinary N excretion with a loss of energy (Bach *et al.*, 2005; Dhali *et al.*, 2006). Imbalance ratio of RDP to RUP can compromise the microbial protein production, ruminal digestion and protein availability to ruminants if RDP is deficient to meet the needs of ruminal microbes (Santos *et al.*, 1998; Reynal and Broderick, 2005). Diet containing improper proportion of RDP and RUP causes some metabolic changes leading to decrease DMI, lowered digestibility and poor energy utilization resulting decreased ruminant productivity (NRC, 2001). This review will focus on the effect of different proportions of RDP and RUP on DMI, ruminal characteristics, digestibility, growth, and milk yield in ruminants.

Dry matter intake

Increase in dietary RUP results in increased DMI in cows and buffaloes (Westwood *et al.*, 2000; Chaturvedi and Walli, 2001; Kumar *et al.*, 2005; Javaid *et al.*, 2007b). Similarly, Kridli *et al.* (2001) and Haddad *et al.* (2005) reported increased DMI in sheep. Another study on early lactating dairy goats fed three levels of RUP also reported increased DMI with increasing RUP during 1st month postpartum, whereas, it remained unaltered during 2 to 4 month postpartum (Lee *et al.*, 2001).

Paengkoum *et al.* (2004) reported linear increase in DMI (729, 791, 818 and 829 g/d) with increasing level of RUP (0, 2, 4 and 6 % of crude protein; CP) in goats. Increase in DMI with increasing RUP at the expense of RDP might be attributed to low level of ruminal NH_3-N and BUN concentrations due to decreased protein degradation.

Dry matter intake reduces when cows feed high RUP contents of animal sources (Henson *et al.*, 1997). The decrease in DMI is be because of unpalatable RUP sources. Moreover, decreased DMI with animal protein sources may be due to low level of ruminal NH_3-N which reduces ruminal microbial proliferation, fermentation and digestibility thus reduces nutrient intake (Faverdin, 1999).

Dry matter intake increases with increasing RDP contents when dietary RDP is inadequate to fulfill the requirement of ruminal microbes (Kalscheur *et al.*, 2006). Erdman and Vandersall (1983) reported increased DMI with increased RDP in the diet of early lactating cows. Similarly, in lambs the DMI was increased with supplementation of RDP (Kozloski *et al.*, 2007). The provision of adequate amount of RDP ensures optimum microbial activity and proliferation which increases dry matter (DM) digestibility and its intake. The increased DMI observed with high RDP diets may be due to the increased ruminal NH_3-N concentration associated with these diets. Insufficient ruminal NH_3-N may depress microbial function (growth, fiber digestion) and thereby limits intake. However, when ruminal NH_3-N is adequate, the DMI did not differ with additional RDP provision (Sannes *et al.*, 2002).

Ruminal characteristics

Ruminal NH_3-N

Ruminal NH_3-N concentration in dairy animals is one of the important determinants of DM intake and its digestibility (Poos *et al.*, 1979). Increase in dietary RDP level gives rise to increased the ruminal NH_3-N concentration (Kung *et al.*, 1983; Stokes *et al.*, 1991; Fu *et al.*, 2001; Lee *et al.*, 2001; Baumann *et al.*, 2004; Javaid *et al.*, 2007) and ultimately increases fermentation of diet (Davidson *et al.*, 2003). Gressley and Armentano (2007) reported low NH_3-N in Holstein cows fed low RDP compared with those fed adequate RDP. The requirement for NH_3-N in ruminants is directly related to substrate availability, fermentation rate, microbial mass and yield (Hespell and Bryant, 1979; Russell *et al.*, 1983). Fiber-degrading bacteria use NH_3 as an N source and the minimum of NH_3-N concentration in rumen fluid required for microbial growth and activity depends on carbohydrate availability (Erdman *et al.*, 1986).

Erdman *et al.* (1986) infused increasing level of urea into the rumen of cows fed diet containing 7.4 % CP to study the effect of ruminal NH_3-N concentration on *in situ* DM digestibility of different feed stuffs. Maximum digestibility was recorded at 25, 17 and 4.5 mg/dL ruminal NH_3-N concentration for ground corn with solvent soybean meal, cotton seed meal with corn gluten meal and alfalfa hay, respectively. The ruminal NH_3-N concentration required for optimum digestion and microbial yield increases with increasing fermentation of diet. Balcells *et al.* (1993) studied the effects of urea supplementation of alkali treated barley straw and found that a minimum ruminal NH_3-N concentration of 5mg/dL was necessary to avoid reduction in intake and fermentation rate of alkali-treated barley straw. However, maximum microbial protein flow from the rumen required ammonia concentration of 11 mg/dL (Balcells *et al.*, 1993).

Ruminal pH

Ruminal pH reflects the rumen fermentation. Increased fermented organic matter gives rise to decreased ruminal pH. Increasing RDP contents in the diet of ruminants causes deceased ruminal pH (Koster *et al.*, 1996; Javaid *et al.*, 2007a). A study conducted on lambs reveals that supplementation of RDP resulted in reduced ruminal pH and this decline in pH values was probably due to higher bacterial activity, fermentation and volatile fatty acid production (Kozloski *et al.*, 2007). Baumann *et al.* (2004) reported depressed ruminal pH with addition of RDP to corn base diets in steers. However, ruminal pH remained unaltered when cannulated crossbred steers were fed increasing level of RDP (3.4, 6.2, 8.8 and 11.6 % of DM). Lee *et al.* (2001) investigated the effect of varying RDP level on ruminal pH in goats and reported slight decrease in ruminal pH with increasing the level of RDP, however, the decline was nonsignificant. Likewise, Kung *et al.* (1983) reported that ruminal pH was not changed by changing the dietary RDP level in lactating cows. Stokes *et al.* (1991) also examined the effect of varying RDP level on rumen pH in lactating cows. They reported 6.6, 6.3 and 5.9 rumen pH when RDP level was increased from 49.9, 64.4 to 73.3 % of CP, respectively. The decline in ruminal pH with increasing RDP level reflected increased ruminal fermentation.

Microbial count and growth

Higher dietary RDP results in increased microbial count in ruminants (Stokes *et al.,* 1991; Fu *et al.* 2001; Javaid *et al.*, 2007). Stokes *et al.* (1991) reported higher microbial protein production when Holstein cows fed diets containing 11.8 or 13.7 % RDP than those fed 9 % RDP. They further explained that higher microbial protein synthesis in cows fed high RDP was due to high concentration of ruminal NH_3-N. Similarly, bacterial N production increased linearly with increasing dietary RDP level in crossbred steers (Fu *et al.*, 2001). The increase in microbial production with increasing dietary RDP is due to higher concentration of ruminal NH_3-N, amino acids and peptides (Pimpa *et al.*, 1996; Javaid *et al.*, 2007).

The increased microbial count with increasing dietary RDP level may be attributed to increased concentrations of ruminal NH_3-N, amino acids, peptides, or branched chain volatile fatty acids (VFA) required for microbial growth (Bryant and Robinson, 1962). Decreased microbial count with reduced ruminal NH_3-N concentration has been reported by other workers (Maeng and Baldwin, 1976; Argyle and Baldwin, 1989).

Dhiman and Satter (1997) reported that 9.3 % RDP of DM supplied enough N precursors to support maximum microbial growth in cow. Similarly, 9.6 % RDP of DM is considered sufficient to meet the N needs of microbial protein synthesis in the rumen (NRC, 1989). Thus, provision of adequate dietary RDP is essential to maximize microbial protein synthesis in the rumen before the supplementation of RUP. Satter and Slyter (1974) reported that microbial protein production increased with increasing NH_3-N concentration and then leveled off when ruminal NH_3-N reached 5 mg/dL of ruminal fluid, whereas, Wanapat and Pimpa (1999) reported that ruminal NH_3-N concentration higher than 13.6 mg/dL in swamp buffaloes were considered optimum for DMI, microbial protein synthesis and digestibility. However, in dairy cow for optimum rumen fermentation and microbial yield, the ruminal NH_3-N should be between 10-25 mg/dL (Leng, 1990; Orskov, 1992).

Nutrient digestibility

Availability of dietary RDP is of vital significance as far as ruminal microbial activity and nutrient degradation is concerned. Providing RDP less than rumen microbial requirement adversely affects the ruminal fermentation by decreasing the microbial proliferation which not only reduces the VFAs production but also decreases nutrient digestibility.

The DM digestibility is increased with increasing the level of dietary RDP in cows (Fu *et al.*, 2001; Griswold *et al.*, 2003; Javaid *et al.*, 2007a). The DM and organic matter digestibilities were higher in lambs supplemented with RDP either from true protein or NPN sources (Kozloski et al., 2007). Gressley and Armentano (2007) reported that organic matter digestibility was high in cows fed high amount of dietary RDP and it reduced with decreasing RDP. Increased DM digestibility with increasing level of RDP is attributed to increased ruminal NH_3-N concentration with increasing ruminal microbial activity (Erdman *et al.*, 1986; Javaid *et al.*, 2007a).

Reduced neutral detergent fiber (NDF) digestibility with increasing dietary level of RDP is reported by many researchers (Wankhede and Kalbande, 2001; Pattanaik *et al.*, 2003; Javaid *et al.*, 2007), however, reduced *in situ* NDF digestibility in cows is reported by Gressley and Armentano (2007). Decreased NDF digestibility with increased RDP level might be attributed to decrease in ruminal pH (Koster *et al.*, 1996; Bodine *et al.*, 2000; Javaid *et al.*, 2007). Bach *et al.* (2005) reported reduction in CP and NDF digestibilities when ruminal pH decreased from 6.3 to 5.9. Decreased ruminal pH reduced the cellulolytic bacterial counts about 50% and NDF digestibility from 35.6 to 29.5 % with this decrease in ruminal pH. It is hypothesized that reduction in cellulolytic bacteria due to low pH may reduce the NDF digestibility. Decreased fiber digestibility with reduced rumen pH has been reported by Mould *et al.* (1983).

Growth and nitrogen balance

The RUP supplements are being used to increase N and amino acid flow to the small intestine, to enhance growth and to reduce urea and ammonia excretion in ruminant animals without compromising productive performance (Spears *et al.,* 1985; White *et al.* 2000). Positive response to the inclusion of RUP supplements is likely to occur in ruminants during compensatory growth or in the physiological stage of maximum growth where protein and essential amino acids requirements are highest (Owens *et al.,* 1993). The N retention was improved in lambs when their diet was supplemented with both RDP and non-forage carbohydrates but most of the additional N was excreted in urine (Kozloski *et al.*, 2007).

Ruminally undegradable protein improves N utilization and growth rates in steers (Spears *et al.*1985). Similarly, in goat, the N retention was increased linearly with increasing dietary RUP contents (Paengkoum *et al.*, 2004). Pattanaik *et al.* (2003) reported higher N retention in calves fed higher RUP contents (51 vs 45 % of CP).

Increase in dietary RDP contents results in increased fecal N excretion (Kalscheur *et al.*, 2006), however, fecal N excretion remained unaltered in cows fed diet containing varying RDP level (Davidson *et al.*, 2003). The N excretion in urine was increased by increasing protein degradability in the diet. Increase in dietary RDP contents results in increased urinary N excretion (Castillo *et al.*, 2001; Davidson *et al.*, 2003; Kalscheur *et al.*, 2006. Rapid degradation of protein causes excessive ruminal NH_3-N concentration. The increased urinary N was due to poor ability of ruminal microbes to capture ruminal NH_3-N concentration with rapid degradation of protein.

Milk yield

Milk yield and fat correct milk (FCM) is increased with increasing the level of RUP in the diet of ruminants (Kalscheur *et al.*, 1999; Mccormick *et al.*, 1999; Westwood *et al.*, 2000; Lee *et al.*, 2001; Kumar *et al.*, 2005). During early lactation microbial protein synthesis is not capable of supplying adequate protein and essential amino acids to meet requirements in lactating ruminants and RUP supplements are more beneficial regarding milk yield where energy and protein are limiting (Kaim *et al.* 1987; Hamilton *et al.*, 1992; NRC, 2001; Gulati *et al.*, 2005).

Increased milk production with increasing dietary RUP was reported by Pailan and Kaur (1996) and Lee *et al.* (2001) in dairy goat. On the other hand, Sahlu *et al.* (1993) did not find any effect of dietary RUP on milk yield in dairy goat. Another study conducted on Awassi ewes by Haddad *et al.* (2005) explained that although the influence of dietary RUP on milk yield was nonsignificant, however, there was a quadratic response in milk yield with increasing RUP contents in the diet. The increase in milk yield in lactating ruminants with increasing the dietary level of RUP is due to an increase in DMI as well as the increased supply of metabolizable protein and amino acids (Westwood *et al.*, 2000; Gulati *et al.*, 2005).

The RUP may increase the milk yield either directly or indirectly (Clark, 1975). The direct role may be through either increased supply of limiting amino acids to mammary glands for protein synthesis or through enhanced gluconeogenesis in liver resulting in increased supply of glucose to mammary glands for lactose synthesis. The indirect role may be mediated through altered hormonal status, specially increased concentration of plasma growth hormone which causes nutrients partitioning in favour of growth and milk production and away from the fat deposition (Sartin *et al.*, 1985).

Milk yield and FCM yield is increased with increasing the dietary level of RDP while keeping the RUP proportion constant in cows (Sklan and Tinsky, 1993; Kalscheur *et al.*, 2006). Increased milk production in response to increasing the dietary RDP is the result of providing additional N for ruminal microbial protein synthesis and greater microbial protein synthesis supports greater milk production. However, milk yield and FCM remained unaltered in cows fed increasing level of RDP as reported by many researchers (Kung *et al.*, 1983; Erdman and Vandersall, 1983; Reynal and Broderick, 2005). Milk yield was similar in cows fed diet containing adequate or 28 % less RDP than requirements (Gressley and Armentano, 2007). The unchanged milk yield in lactating cows fed increasing level of RDP might be attributed to the fact that cows might be having already sufficient RDP to ensure optimum ruminal microbial synthesis and further increase in RDP could not enhance microbial protein and thus milk yield.

Rumen protected vegetable proteins such as heat-treated rapeseed meal or soybean meal produced variable responses in milk yield. The reason for this includes variation in the degree of protein protection and digestibility of the amino acids in the small intestine. This variation demonstrates the need to ensure that RUP supplements should be of consistent quality with respect to rumen protection, bio-availability and digestibility of the essential amino acids in the small intestine. Such characteristics are essential with respect to improving milk yield, protein content and N excretion (Santos *et al.*, 1998). Although responses are variable among the various protein supplements, however, chemically treated soybean meal and fish meal are the most effective in increasing milk yield.

Amino acids balance is more important than total RUP supplementation to get milk response in lactating animals (Noftsger and St-Pierre, 2003). A positive response in milk protein yield is attained if amino acids profile of RUP supplemented to lactating animal is balanced (Wright *et al.*, 1998).

The milk protein contents increase linearly by increasing dietary RUP level (Chaturvedi and Walli, 2001; Lee *et al.*, 2001). It is reported that milk protein content can be controlled by using high RUP diets (Santos *et al.*, 1998) and synthetic amino acids (Bertrand *et al.*, 1998). In contrast, milk protein yield is increased with increasing level of RDP (as % of DM) in lactating cows (Erdman and Vandersall, 1983; Broderick, 2003; Reynal and Broderick, 2005; Kalscheur *et al.*, 2006). Chaturvedi and Walli (2001) reported that percent of milk fat increased linearly when the lactating crossbred cows were fed diet containing increasing amount of RUP (29, 42 and 56 % of CP), on the other hand, Erdman and Vandersall (1983) reported unaltered milk fat percent when early lactating cows were fed diet containing 53 or 73 % RDP of CP. Lactose contents were increased with increasing the level of dietary RUP (Rusche *et al.*, 1993). Taylor *et al.* (1991) observed that cows fed high RUP (45 vs 36 %) produced more milk with high (5.01 vs 4.84 %) lactose contents. Increased supply of amino acids with increasing dietary RUP may enhance the gluconeogenesis in liver resulting in increased supply of glucose to mammary glands for enhanced synthesis of lactose.

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