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Mamata Joysowal
National Dairy Research Institute, Karnal, Haryana, India

AK Tyagi
National Dairy Research Institute, Karnal, Haryana, India

Nitin Tyagi
National Dairy Research Institute, Karnal, Haryana, India

Sachin Kumar
National Dairy Research Institute, Karnal, Haryana, India

Anchal Keshri
National Dairy Research Institute, Karnal, Haryana, India

Digvijay Singh
National Dairy Research Institute, Karnal, Haryana, India

Correspondence
Mamata Joysowal
National Dairy Research Institute, Karnal, Haryana, India

Use of slow release ammonia products in ruminant diet: A review

Mamata Joysowal, AK Tyagi, Nitin Tyagi, Sachin Kumar, Anchal Keshri and Digvijay Singh

Abstract
Ruminant have an unique physiological ability to utilize Nonprotein nitrogen substance in diet. Dietary protein is required to provide amino acid and nitrogen sources for microbial protein synthesis and body requirement. During sacristy period and to reduce the cost of diet the use of NPN substances (urea & their products) is helpful for dairy farmers. The use of urea in the ruminant diet is most accepted because of its low cost compared with other NPN source and availability; mostly protein feeds such as soybean meal are highly rumen degradable. There are many factors which need to be understood before approaching to utilize NPN substance in animal feeding. Addition of urea in diets is limited due to its rapid hydrolysis to ammonia-nitrogen in the rumen by urease enzyme resulting in rapid accumulation and escape of ammonia- nitrogen from the rumen. Slow rumen released nitrogen compound primary stem because of its potentiality for slow ammonia release just after post feeding thereby decreasing peak ammonia concentrations in the rumen that lead to its inefficient utilization by ruminal microorganisms and increased absorption from the rumen, which would also reduce the metabolic cost and ammonia poisoning. This review describes the utilization of slow release urea for a dairy animal in favor of ruminal fermentation and lactation performance.

Keywords: Urea, slow release urea, rumen fermentation, lactation performance

1. Introduction
The quality and cost are the two most important aspects for deciding feeds and fodder to be used in dairy animal feeding. For successful dairy production it is most important to take care about his feeding practice and management. Timely shortage and continues shrinkage in pasture land grassing system near to abolish and animals are raired on intensive fed lost condition. Feeding a high producing animal or providing quality feed according to the local availability and cost effectiveness is going to be difficult. Farmers have advised to adopt advanced feeding strategies to get profit in dairy business and within cost effective expenditure. Animal diet should have to be enough nutrients to support requirements during maintenance, reproduction and lactation. For the purpose a balanced diet with definite ratio of green fodder and concentrates feed are used. Concentrate feeds are used as rich source nutrient like energy, protein, minerals and vitamins. For protein source oil seed cakes like Soybean meal (SBM) has long been used as a prominent source of crude protein for ruminants. However, with its increasing price, the use results in ultimately higher cost of production. Therefore, the use of urea as a protein (NPN source) replacement is attractive in ruminant diets because of its low cost compared with other protein feeds such as SBM with high rumen degradability [44, 46]. The NPN compounds are rapidly degraded in the rumen and ammonia is produced. In the formulation of diets for ruminants, it is important to optimize the balance between the energy and protein contents of the feed, so that balanced rumen fermentation occurs and maximum voluntary intake and feed utilization can achieve. Though pasture grasses contain about 20-30% of their total nitrogen as NPN which includes amino acids, nitrate, nucleic acids and amines. Urea is the common NPN added to poor quality forage. It is relatively cheap and its use can improve the utilization rate of carbohydrates and the feed conversion rate. Urea is a small organic compound that is very rich in N (44.96% N) that is used to supply degradable intake protein (DIP) to ruminants. In ruminants, digestion of the feedstuffs by rumen fermentation contributes to meet the major requirement of energy and protein.

2. Metabolism of NPN compounds

The key to nitrogen metabolism in the ruminant is the ability of the microbial population to utilize ammonia in the presence of adequate energy to synthesize the amino acids for their growth. About 20% of absorbed microbial nitrogen is in the form of nucleic acids and the efficiency of their utilization is poor. Almost 80% of the rumen bacterial species, especially cellulolytic, can utilize ammonia as the sole source of nitrogen for growth while 26% require it absolutely and 55% could use either ammonia or amino acids. Protozoa cannot use ammonia but derive their nitrogen needs by consuming bacteria and particulate matter.

The ingested true protein may be degraded by microorganisms to the extent of 60% and the remaining 40% escapes ruminal degradation. However, the rate of proteolysis is closely related to the solubility of the protein in the rumen fluid. The ingesta moving into the abomasums and small intestine thus contains feed protein which has not been degraded as well as bacterial and protozoal bodies. In the small intestine, enzymatic hydrolysis produces amino acids from the chime plus the endogenous secretions. These are in turn absorbed via the portal circulation in a similar way as it occurs in nonruminants. The caecum and large intestine receive the undigested protein from the small intestine plus urea from the blood. This urea supports an active microbial fermentation. The faeces contain the indigestible feed nitrogen, microbial nitrogen and metabolic nitrogen.

Through, movement of ammonia and urea is unique to the system. In the rumen when ammonia is produced in excess of the ability of the microbes to use it, which can be absorbed into the portal circulation, transported to the liver and converted to urea. The urea can then be either excreted by the kidneys into the urine or recycled into the rumen by way of the saliva or through blood. On the other hand on low protein diets, the kidney reabsorbs a greater quantity of urea and thus is recycled into the rumen to provide added nitrogen for microbial fermentation. While ammonia is toxic in excess, it can be used as a source of N for the synthesis of dispensable amino acids.

Using of urea as a protein equivalent of 281%, incorporation of one unit of urea in a diet can replace five units of soybean meal. The amount of NPN that can be used in the diet is limited because of the rapid hydrolysis of NPN sources to ammonia in the rumen. This rapid breakdown to ammonia can occur at a much faster rate than the uptake of ammonia by the microbes in the rumen (Satter and Roffler, 1975) [1] leading to accumulation of ammonia and toxicity. Since the microbial growth is dependent on energy availability, it is important that the rate of ammonia production in the rumen be sustained and coordinated with the rate of carbohydrate digestion (Newbald and Rust, 1992; Henning *et al*., 1993).

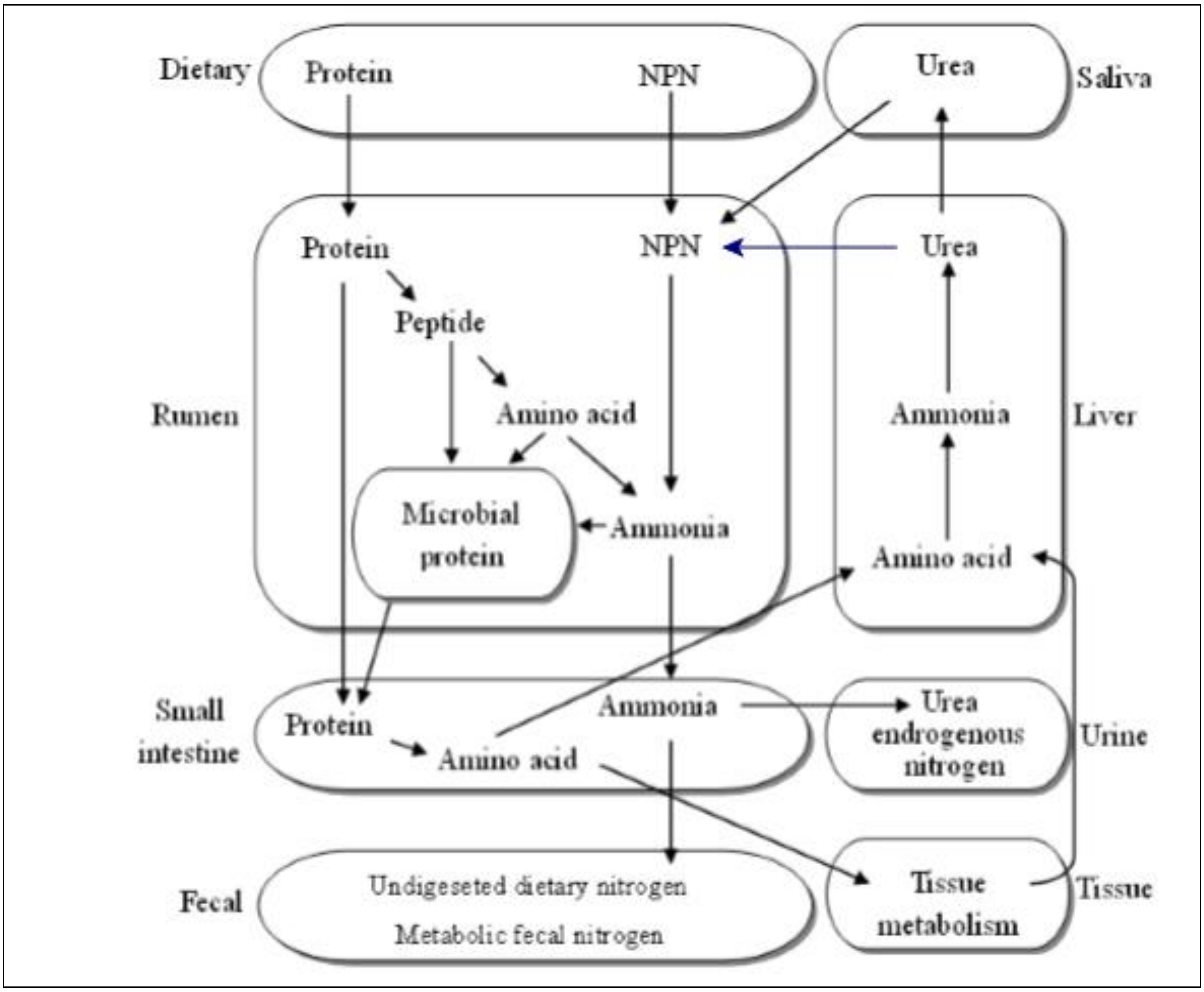

Fig 1: A model of the metabolism of nitrogen in the rumen (Leng and Nolan, 1984) [23].

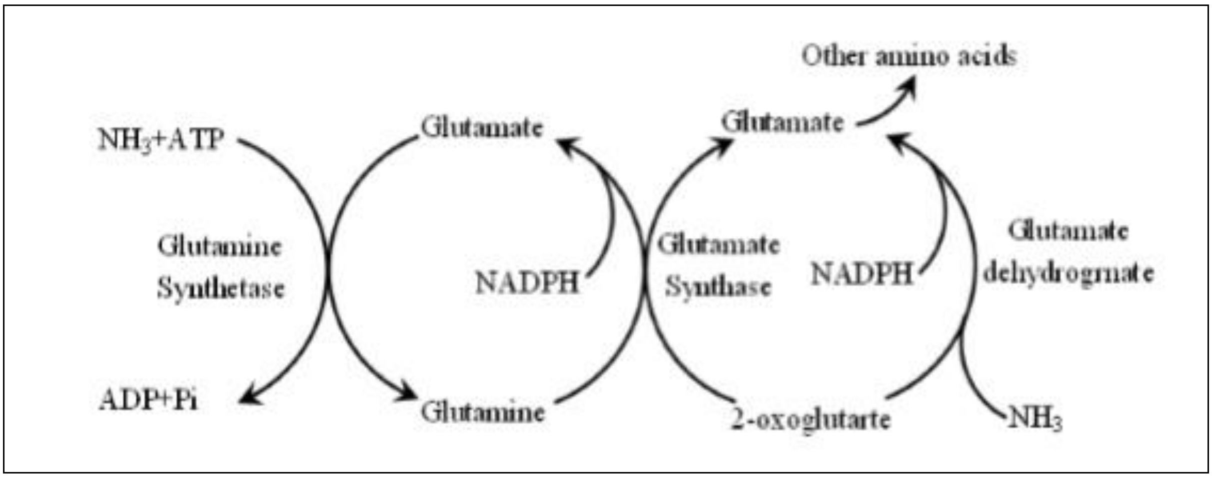

Fig 2: Two-step process by which ammonia is assimilated by bacteria [23]

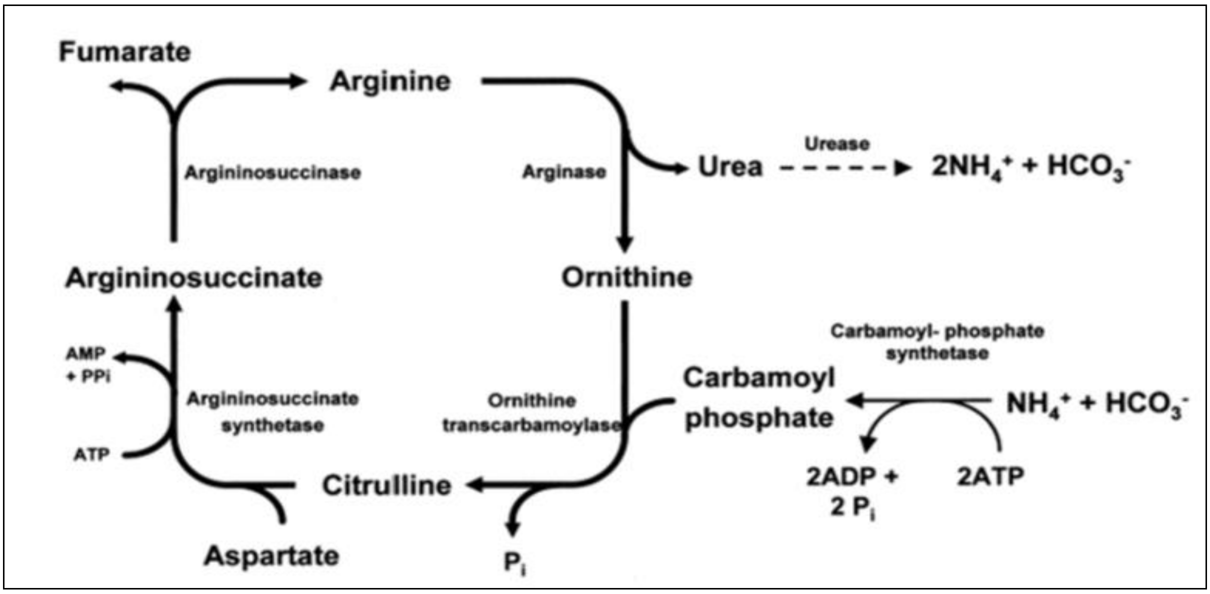

Fig 3: Urea cycle in the liver of ruminants [44]

3. Development of slow release nitrogen products

One kilogram of urea provides 5 to 6 kg of vegetable protein supplementation on nitrogen equivalent basis and 281 per cent crude protein; this compares to 44 per cent for cottonseed meal and 50 per cent for soybean meal. Plasma urea and level of rumen ammonia peak relatively quicker just after feeding in ruminants, within 1–4 hr, and then decline afterwards [18]. However, because repeating hydrolysis of urea into the NH3 in the rumen by microbial enzymes is faster than NH3 utilization by rumen bacteria [20], excessive urea nitrogen in the diet can lead to a waste of nitrogen via urine, and can even cause ammonia poisoning [6].

Discharge of nitrogen in the environment causes environmental pollution leading to economic losses as cost of nitrogen source is more than an energy source. So the potential way of reducing rate of rumen ammonia production and maximize microbial utilization of ammonia is modulating hydrolysis in the rumen. To achieve this goal, some of the researchers have used microbial urease inhibitors [45].

An alternate approach was to develop slow-release urea (SRU) compounds such as biuret [43], urea formaldehyde [33], urea phosphate, or urea bound to substrates like Calcium chloride [29, 21], Starea [1], Urea-corn-carboxy-resin [22], Uromol [26], Urea coated with linseed oil and talc [10], Lactosylurea [11], Urea-polyvinyl-alcohol, Urea lignocellulose complex [3, 2], Uromalt [42] and Isobutyraldehydemonourea [27], Neem coated urea, Sulphur coated urea, Zinc coated urea, Fatty acid coated urea, Herbal coated urea, Mollases coated urea.

Although these methods may be useful in terms of avoiding ammonia toxicity, which also improves urea utilization of dietary nitrogen for improvement of animal performance compared with standard feed sources [30]. More recently, properties of slow-release urea have been achieved by using coatings based on oil [14] or polymers [40, 13] to control the release rate of ammonia from urea. The development of products that slow down the ruminal release of ammonia without limiting the extent of urea degradation in the rumen has been challenging [25]. Galo [13] prepared a product, Optigen 1200 (CPG Nutrients, Syracuse, NY) is a polymer-coated, controlled-release urea product (PCU) that, compared with feed-grade urea, is believed to possess a reduced rate of ammonia release to rumen microbes. Edwards [8] demonstrated Polymer-coated urea (Optigen 1200) to reduce ruminal ammonia concentrations compared with feed grade urea. Cherdthong [4] in an *in vitro* experiment shown, urea calcium sulfate mixtures reduced ruminal NH_3 concentrations, as well as increased the cellulolytic bacterial population when compared with urea. Slow urea release properties have been achieved by binding urea to substrates such as calcium chloride [15].

4. Effect of Slow-release Urea on Rumen Fermentation Parameters

The development of slow-release urea product is very challenging that slow the ruminal release of NH3-N without limiting the extent of urea degradation in the rumen. Owens [31] reported that in comparison to uncoated urea release of ammonia nitrogen slower in case of slow release product causes improvement of diet acceptability and rumen fermentation in ruminants. Another report supported that addition of 10, 20 or 30% CRUS supplementation along with sugar cane tops (*Saccharum offcinarum*), corn stubble (*Zea mays*) and King grass (*Pennisetum purpureum*) (high fiber diets) with controlled- release urea supplement (CRUS) did improve fermentation in sheep in terms of NH3-N and VFA production.

This is the strategies to improve the nutrient utilization of those feeds, which provide supplements to correct the nutrient imbalances for rumen bacteria (Nocek and Russell, 1988) [28].

Leng and Nolan, 1984 [23] found in his study that controlled release urea source could provide continousNH3-N for microbial growth superior the minimum of 15-30 mg NH3-N/100 ml rumen fluid for maximizing microbial growth. In some studies, Xin [44] who evaluated the effects of three different treatment diets with isonitrogenous contents (13.0% CP) were prepared: i) feed grade urea (FGU) diet; ii) polyurethane coated urea (PCU) diet; and iii) isolated soy protein (ISP) diet polyurethane coated urea on ruminal VFA concentration of Holstein dairy cows fed a steam-flaked corn-based diet which showed that there were no significant differences in terms total VFA concentration among the three dietary treatments. Because ruminal VFAs are derived mainly from dietary carbohydrate fermentation [9], the similar total ruminal VFA concentrations reflected no adverse fermentation by addition of feed grade urea or poly urethane coated slow release urea product to the diet. Due to dietary treatment Molar percentages of individual VFAs were significantly altered (p<0.05).Urea-based diets resulted in a higher proportion of acetate and less propionate than the isolated protein based diet, which caused a significantly higher ratio of acetate to propionate (p<0.01).

Table 1: Effects of slow-release urea products on rumen fermentation parameters

Source	Type of SRU	Suppl., % diet	Animal	NH3-N, mg%	Total VFA, (mt//L)	VFA %		
						C2	C3	C4
Galina *et al.* (2003) [12].	SRU	0	Beef	6.8	-	78.2	14.4	7.4
	SRU	1.8		123	-	72.2	16.0	11.8
Golombeski *et al.* (2006) [15].	Ruma Pro	0	Cows	54	54.0	62.9	21.2	11.4
	Ruma Pro	0.61		6.0	5	63.2	21.5	11.1
Taylor-Edwards *et al.* (2009) [8].	Urea	1.6	Steers	14.1	99.7	62.7	19.7	14.0
	SRU	1.6		8.9	103.2	63.6	20.3	13.8
Pinos-Rodriguez *et al.*, 2010 [35].	Optigen	0.6	Steers	-	97.6	52.0	34.9	13.0
	OPtigen	1.1		-	94.8	523	35.2	12.5
Xin *et al.* (2010) [44].	Urea	0.6	Cows	2.0	64.08	56.8	33.3	5.3
	Polyurethane coated urea	0.6		1.4	66.08	56.3	34.4	5.3

5. Effect of SRNP on the Yield and Composition of milk

A various research scientist has shown the impact of slow release urea product on milk yield and composition. Tedeschi [40] has conducted an experiment on polymer-coated slow urea (Optigen 1200) and found an improvement in feed efficiency and this would be expected because cows consumed less DM and there was no drop in daily milk yield for cows fed slow release urea. Optigen 1200 also had a beneficial effect on the fat yield of milk and also protein yield of milk. However, the addition of slow-release urea had no overall impact on milk component composition. Galo [13] reported that feeding lactating dairy cows with a diet including 0.77 per cent polymer-coated urea had no impact on milk production. The diets did not affect milk fat percentage or milk true protein percentage. The fat content of the milk approximated 3.7 percent across diets and is an indicator of good rumen fermentation and fiber digestion. Golombeski [15] compared two diets containing nitrogen sources either as slow urea diet or without slow urea diet, which partially replaced soybean meal. Dietary treatment had no effect on energy-corrected milk, milk fat yield, milk protein percentage, or milk urea N. Replacement of soybean meal with slow release urea did not alter true protein percentage or yield demonstrating that slow urea can be an alternative source of N in dairy cow diets without causing inefficient use of N. Santos and Huber (2008) [36] reported that milk yield was unaffected when SBM was partially replaced by Optigen and when uncoated prilled urea plus RUP sources were partially replaced by a polymer coated prilled urea product. Inostroza carried out an experiment to determine the effect of Optigen, as a source of NPN on milk yield, milk composition, and milk component yields. There have been reports of increased milk yield when Optigen partially replaced either uncoated prilled urea [19] or an oilseed meal mixture in dairy cattle diets. Yields of milk fat, milk protein, and milk protein percentage were unaffected by treatment. Highstreet *et al*. (2010) [20] tested a slow rumen released encapsulated urea product (Nitroshure) which is 0.9 unit urea and 0.1 unit fat according to the manufacturer. Feeding a slow rumen released urea increased milk fat, protein and energy output in early lactation high producing dairy cows fed a diet high in soluble N, versus feeding an equivalent amount of urea on an N basis, but that it had little impact in mid-lactation cows. Xin [44] showed that cows consuming polymer-coated urea and diet containing soybean meal had a similar effect on milk protein concentration and the both being higher than the feed grade urea diet. It is also having a greater impact on milk protein percentage and yield so which were higher for cows receiving the polymer coated urea diet than the feed grade urea diet but were similar were found SBM based diet and no effect seen in the dietary treatment of milk fat, lactose content, milk yield and energy-corrected milk yield.

Thompson *et al*. (1972) found a peak rumen NH3-N for Starea rations after 90 min of feeding. Although rumen NH3-N values for Urea and Starea were not significantly different at either 1 or 2 h, the decline in NH3-N from 1 to 2 h was 12.8 mg percent for Urea and 6.4 mg percent for Starea, suggesting slower hydrolysis for Starea than Urea rations. Owens *et al*. (1980) [31] compared a "slow- release" urea supplement with prilled feed grade urea. The data indicated that the ammonia concentration in cattle rumen was 53 mg per dl with prilled urea and 32 mg per dl with the "slow- release" urea. This represented a 40 percent reduction of rumen ammonia. Ammonia concentration at 3 hours of incubation was reduced by 68 percent when a slow release urea product (Optigen 1200) replaced urea as the NPN supplement.

Owens [31] evaluated slow release urea (prilled urea coated with a tung oil-linseed oil talc-catalyst mixture) product for ammonia nitrogen release rate. They reported that ruminal ammonia release was slower for an oil-coated prilled urea product than for uncoated prilled urea, thereby increasing diet acceptability and reducing urea toxicity in steers. The totality of release was evaluated by measuring ruminal ammonia of steers fed prilled urea or slow release urea at 2 h intervals and both produced virtually equal ruminal ammonia concentration. This observation suggests that an equal amount of ammonia nitrogen was eventually released from both SRU and prilled urea. Alternatively, SRU degradation or ammonia absorption and /or utilization may differ. Recently, Galo [13] fed polymer-coated urea to dairy cows and observed coated urea is more slowly hydrolyzed to ammonia than unprotected urea and could potentially be used more efficiently by rumen microorganisms. The report in which urea release from polymer-coated urea was 83 percent as extensive as uncoated urea after 1h incubation with distilled water. Other products, such as a urea-calcium combination had similar effects. Golombeski [15] compared two diets containing nitrogen sources either as slow urea diet or no slow urea diet, which partially replaced soybean meal. Ruminal ammonia N did not differ across diets, suggesting that slow urea (0.61 percent Ruma Pro, XF Enterprises, Hereford, TX), did exhibit slow-release properties as demonstrated by [21]. More recently, Huntington [21] concluded that urea-calcium was effective in mitigating rapid ammonia release in the rumen and subsequent effects on ammonia metabolism. Slow-release urea and other similar products attempt to achieve a slower rate of N release in the rumen and allow time to use N more efficiently while preventing ammonia toxicity. Gonzalez [17] reported lower ruminal and plasma ammonia concentrations for steers fed Optigen than for steers fed uncoated prilled urea; the in situ 20 rate of nitrogen disappearance for Optigen was 0.237 percent per hour. These authors concluded that Optigen is a rumen protected source of NPN with controlled-release characteristics in the rumen, which is in agreement with the report by [38]. Edwards [7] conducted an experiment to evaluate the effects of slow release urea versus feed-grade urea on ruminal metabolite characteristics and concluded that slow release urea reduces the rapidity of ammonia release in the rumen without affecting other ruminal fermentation metabolites. After 35 d of feeding, there was no evidence of microbial adaptation to the slow release urea product, suggesting that the slow release urea will continue to maintain slow release properties for long term feeding regimes. These experiments demonstrate that slow release urea can be utilized as N supplement to modulate the appearance of N in the rumen and can provide equal performance to urea supplements without the potential hazards associated with feed grade urea. Rodriguez [35] conducted an experiment with 20 animals to compare a diet containing slow-release coated urea product (Optigen 1200, Alltech Inc. Nicholasville, KY USA) with a Control diet (standard diet with soybean meal as protein source); The coated urea did not affect ruminal fermentation patterns (i.e, pH and AGV) as compared to the control diet, which agrees with previous studies using the same coated urea product [17, 19]. Ruminal ammonia N was higher ($P<0.05$) with coated urea than the control diet. Cherdthong [4] conducted an experiment with four ruminally fistulated crossbred (Brahman × native) beef cattle steers. *In vitro* incubations of urea, urea $CaCl_2$ mixture and urea $CaSO_4$ mixture showed the slower release rates of urea in both urea $CaCl_2$ mixture and urea $CaSO_4$ mixture versus uncoated Urea and the rumen pH was unaffected by the different nitrogen sources.

Conclusion

Slow release urea product can be a better and safe option as a source of nitrogen in comparison to the urea or other Non-protein nitrogenous compounds. Many slow release ammonia products are still need to go through validation and approval by higher regulatory authorities. After the proper experiment and validation it can be helpful to reduce feed cost and give profit to farmers. Coated urea products are slowly degradable which reduces ruminal ammonia nitrogen concentration without much effect in lactation performance. Based on this review it could be concluded that up to some extend slow urea products can replace costlier protein source and safely introduced in ruminant feed.

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