EFFECT OF SUPPLEMENTING SLOW RELEASE NITROGEN PRODUCT ON THE LACTATION PERFORMANCE OF DAIRY COWS

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CERTIFICATE

This is to certify that the thesis entitled ***"EFFECT OF SUPPLEMENTING SLOW RELEASE NITROGEN PRODUCT ON THE LACTATION PERFORMANCE OF DAIRY COWS"*** submitted by **Ms. VEENA N., I.D. No. MVHK 1405** in partial fulfillment of the requirements for the award of **MASTER OF VETERINARY SCIENCE** in **ANIMAL NUTRITION** of the Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar, is a record of bonafide research work carried out by her during the period of her study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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Affectionately Dedicated to

My Parents

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LIST OF ABBREVIATIONS

ADF	Acid detergent fiber
AOAC	Association of Official Analytical Chemists
ARC	Agricultural Research Council
BSP	Buffer soluble protein
BW	Body weight
CFM	Compounded feed mixture
CLR	Corrected lactometer reading
CP	Crude protein
DMI	Dry matter intake
DM	Dry matter
EE	Ether extract
FCM	Fat corrected milk
FMS	Finger millet straw
ME	Metabolisable energy
MJ	Mega joule
NDF	Neutral detergent fiber
NE	Net energy
NPN	Non Protein Nitrogen
NRC	National Research Council
OM	Organic matter
RDP	Rumen degradable protein
SBM	Soybean meal
SNF	Solids not fat
SRNP	Slow release nitrogen product
SRU	Slow release urea
TA	Total ash
TDN	Total digestible nutrients
TS	Total solids
UDP	Undegraded dietary protein

Introduction

I. INTRODUCTION

India ranks first in milk production in the world consecutively for the fifth year, with annual production of 166 million metric tons in 2015, contributing nearly 16 per cent of the global milk pool (Anon., 2015). However, the national average of milk yield (kg per cow per day) in India is 2.59 in indigenous and 6.23 in crossbred cows, due to low genetic potential as well as poor nutrition status of the animals.

Energy and protein are the major nutrients that are to be balanced in ruminant diet for optimum production. Many cows are not capable of consuming enough low quality forage to satisfy their maintenance requirement for crude protein (CP). Therefore, it is important to implement a protein supplementation strategy for cows, particularly for additional requirement of gestation, lactation and growth.

Protein supplements are the higher cost ingredients in the ruminant diet and therefore, an economical and judicious way of using protein resources in the ruminant diet become vital. A portion of protein in feeds for ruminants may be provided in the form of simple nitrogen compounds (Non protein Nitrogen, NPN), as rumen microorganisms have ability to utilize ammonia with ATP to form amino acids and synthesize protein. The Microbial protein produced in the rumen would meet 75-95% of the protein requirement of ruminants (Van Soest, 1982). The essential amino acid pattern of microbial protein is of better quality than most dietary ingredients commonly fed to ruminants (Broderick, 1994; Schwab, 1996). Hence, this strategy of replacement of conventional protein sources with NPN sources help to reduce the feed cost without interfering negatively in production.

Among different NPN sources, urea is most commonly used because of its lower cost and higher protein equivalence. In the rumen, urea is rapidly hydrolyzed to ammonia by microbial urease at much faster rate than the ability of the rumen microbes to utilize it. Therefore, ammonia concentration in rumen is liable to rise considerably which may lead to the nitrogen loss and possible 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 and in turn improve microbial efficiency (Newbald and Rust, 1992; Henning *et al.*, 1993).

Several compounds, commonly referred to as slow release nitrogen products (SRNP) have been developed in the last few years, aiming to sustain the rate of release of nitrogen in the rumen and increase the efficiency of nitrogen utilization. These include compounds such as biuret (Waite and Wilson, 1968), urea-corn-carboxy-resin (Huston *et al.*, 1974), starea (Bartley and Deyoe, 1975), urea-formaldehyde (Prokop and Klopfenstein, 1977), uromol (Malik *et al.*, 1978), urea-linseedoil talc (Forero *et al.*, 1980), lactosylurea (Forman *et al.*, 1982), ureapolyvinylalcohol (Sommer *et al.*, 1985), urea-lignocellulose complex (Chahil *et al.*, 1986), Uromalt (Virk *et al.*, 1989), isobutyraldehyde monourea (Mathison *et al.*, 1994) and urea bound to calcium chloride (Huntington *et al.*, 2006). More recently, polymer coated urea (Edward *et al.*, 2009) and urea-calcium sulphate (Cherdthong *et al.*, 2010) products have been developed and demonstrated to provide beneficial effects in ruminal fermentation. Galo *et al.* (2003) observed that polymer coated urea was more slowly hydrolyzed to ammonia than uncoated urea. Golombeski *et al.* (2006) reported that the addition of slow release urea (SRU) released N slowly in the rumen, maintained slow-release properties for long-term feeding regimes and provided equal performance to urea supplements without the potential hazards of toxicity associated with urea. Several positive responses such as low rumen ammonia peak level, increased rumen pH, increased acetate production and decreased butyrate production have been demonstrated due to feeding of improved slow release urea products (Highstreet *et al.*, 2010). However, these beneficial effects of ruminal fermentation have not reflected in the performance of lactating dairy cows (Owens and Zinn, 1988).

Solubility of dietary N has been considered as a factor influencing protein degradation in the rumen. The soluble nitrogen forms an immediate source of nitrogen to the microbes. Natural proteins such as groundnut meal, soybean meal and cottonseed meal have different solubilities thus, varying rates of hydrolysis in the rumen (Krishnamoorthy *et al.*, 1982). The soluble nitrogen content of dietary protein can greatly influence the efficiency of N utilization in the rumen (Krishnamoorthy and Chandrapal Singh, 1985). The optimum level of soluble N stipulated in ruminant feedstuffs have been reported to vary from 25 to 40 per cent (Davis, 1978 and Sahlu *et al.*, 1984). Therefore, it is important to ensure that optimum level of soluble N be provided in the diet.

Urea is readily soluble compound and rapidly hydrolyzed by the microbes. The soluble nitrogen content in urea is 100 per cent. Inclusion of urea at 2 per cent level (in compounded feed mixture) in the diet of cows would normally provide about 25 to 30 per cent of soluble nitrogen (of total nitrogen in diet). In most studies incorporating SRNP to replace urea (on weight basis), it was assumed that all the nitrogen present in the SRNP as 100 per cent soluble. Since, the SRNPs are conjugated nitrogen compounds, the soluble nitrogen content may vary widely (For example, the soluble N content of polymer coated urea was 52 per cent). Therefore, to assume all SRNPs as containing 100 per cent soluble nitrogen and as a replacement to urea may lead to deficiency of soluble nitrogen in the diets. An equivocal response in the performance of dairy cows fed different SRNP may be due to SRNPs differing in their soluble N content and also the dietary proteins used, differing in N solubility.

Experiments conducted on evaluation of SRNP in the diet have assumed the soluble N content to be 100 per cent and replaced with urea on isonitrogenous basis. Characterization of N fraction in different SRNP compounds, especially the soluble N content has not been considered. No literature was available on the evaluation of SRNPs, replacing urea on isosoluble nitrogen basis in the diet of dairy cows. Therefore, this investigation has been taken up to evaluate the performance of dairy cows fed SRNP compound containing 52 per cent soluble nitrogen, when replaced with urea on isosoluble N basis. The objective of this experiment was

To study the effect of feeding slow release nitrogen product on lactation performance of dairy cows.

Review of Literature

II. REVIEW OF LITERATURE

2.1. Scope of Slow Release Nitrogen Product:

The most commonly used source of NPN for ruminants is feed grade urea, because of its lower cost and higher protein equivalence, containing about 42% nitrogen. Nevertheless, the nitrogen loss due to rapid hydrolysis of urea in rumen and the possible toxicity are the constraints due to feeding of urea (Lapierre and Lobley, 2001).

Bloomfield *et al.* (1960) indicated that urea hydrolysis occurred four times faster than uptake of the liberated ammonia and thereby resulted in an eventual loss of available nitrogen for microbial protein synthesis. Rapid release of ammonia is one of the major problems for efficient utilization of urea.

Edward *et al.* (2009) reported that the dietary urea is rapidly hydrolyzed upon entry into the rumen, results in a rapid peak in rumen ammonia concentrations within the first hour after consumption. Much of the excess ammonia is absorbed to the animal's bloodstream, through ruminal epithelium and then, is converted back to urea in the liver and excreted. The lost ammonia is not utilized for protein synthesis, which results in a less efficient utilization of available nitrogen. Ruminal carbohydrate degradation and subsequent microbial growth is a much slower process. A synchrony of these processes would improve the efficiency of NPN incorporation into microbial protein and thereby improve the overall efficiency of N use.

Soto *et al.* (2014) showed that the N retention in the rumen is mainly mediated by the rate of degradation of N compounds, carbohydrates and by the energy available for the process of protein synthesis. They observed that, in high-grain diets (ratio of starch *vs*. acid detergent fibre greater than 5.5 to 1) urea can be supplemented at 50% higher than recommended with positive effects on growth performance or in dietary energy utilization because of the possible synchrony of ruminal degradation rates between urea and starch.

Hence, there is scope for SRNP which aims to slow down the rate of release of nitrogen without limiting the extent of urea degradation in the rumen in order to reach a better synchrony with the carbohydrate fermentation and improve microbial efficiency.

2.2. Development of slow release nitrogen products

Dietary urea has been used for decades as a cheaper source of N for ruminant feeding. Economics is primarily responsible for the increased use of urea and other NPN products. Urea contains 42 per cent nitrogen with a protein equivalence of 262.5 per cent.

A potential way to minimize excess ammonia accumulating in rumen and reaching the liver is to increase microbial utilization of ammonia by modulating its appearance in the rumen. To achieve this goal, some researchers have used microbial urease inhibitors, with mixed results (Whitelaw *et al*., 1991 and Ludden *et al*., 2000). An alternate approach was to develop slow-release urea (SRU) compounds such as biuret (Waite and Wilson 1968 and Loest *et al*., 2001), urea formaldehyde (Prokop and Klopfenstein, 1977), urea phosphate, or urea bound to substrates like calcium chloride (Oltjen *et al*., 1968 and Huntington *et al*., 2006), Starea (Bartley and Deyoe, 1975), urea-corn-carboxy-resin (Huston *et al*., 1974), Uromol (Malik *et al*., 1978), urea coated with linseed oil and talc (Forero *et al.*, 1980), lactosylurea (Forman *et al.*, 1982), urea-polyvinyl-alcohol (Sommer *et al.*, 1985), urealignocellulose complex (Chahil *et al.*, 1986 and Caneque *et al.*, 1998), Uromalt (Virk *et al.*, 1989), and isobutyraldehyde monourea (Mathison *et al.*, 1994), and polymer coated urea (Edward *et al.*, 2009).

Although these methods may be useful in avoiding ammonia toxicity, they rarely improve utilization of dietary nitrogen or improve animal performance compared with standard feed sources (Owens and Zinn, 1988). More recently, slow-release properties have been achieved by using coatings based on oil (Garrett *et al.*, 2005) or polymers (Tedeschi *et al.*, 2002 and Galo *et al.*, 2003) 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 (Males *et al.*, 1979).

Oltjen *et al.* (1969) reported that biuret was better utilized than urea when steers were fed a high roughage diet twice daily. Biuret is a nitrogenous compound that is formed during the manufacturing process of urea. The N content of biuret is 40.77. Scientists have given considerable attention to biuret as a NPN source for ruminants because the slow enzymatic hydrolysis of biuret in the rumen retards ammonia production.

Huston *et al.* (1974) developed a slow release urea pelleted product using a mixture of urea, corn starch and carboxy resin. *In vitro* experiments were carried out to determine the effects of level of resin and starch on the release rate of urea from the pellets. As the resin content of the pellet increased, the rate of urea release decreased. The preparation that contained the highest content of resin had the slowest release rate, although it was not greatly different from that of the preparation containing only one per cent resin.

Ørskov *et al.* (1974) developed a method of including urea in whole grains; impregnation is another way in which better utilization of urea can be achieved. It is a process that causes whole cereal grains to absorb urea. A 50 per cent solution of urea was sprayed onto the whole grain while it was being mixed in a vertical feed mixer to give a two per cent inclusion of urea. No crystals of urea reformed and the urea appeared to be completely absorbed into the grains.

Bartley and Deyoe (1975) developed starea to improve the utilization of urea N by ruminants. Starea is produced by mixing finely ground grains (corn, barley, wheat, sorghum, etc.) or other economic starch sources with a NPN source such as urea. Starea makes energy available to the rumen microorganisms at a rate similar to that at which urea releases ammonia so the microorganisms are simultaneously provided with the main components for microbial protein synthesis.

Fishwick (1978) prepared a product by coating prilled urea with sulfur and wax and studied the N utilization by ruminants. Two sulfur coated urea products were used. The first product contained 324 g of N per kg and was coated with 277 g of sulfur per kg. The second product contained 342 g N per Kg and was coated with 236 g of sulfur per kg. Both products were coated with 20 g of wax per kg.

Males *et al.* (1979) studied a liquid molasses slow release product. Results showed that the slow release urea molasses did reduce rumen ammonia levels over that of urea plus molasses. Nitrogen digestibility was lower for the slow release urea product indicating that the urea was bound too tight; therefore, not all the urea was released in the rumen.

Owens *et al.* (1980) reported on a slow release urea compound using tung oil. Prilled feed grade urea was mixed in a portable cement mixer with 5 per cent talc. An oil mixture of 10 per cent linseed oil and tung oil, 0.5 per cent manganese octanoate and 0.5 per cent cobalt octanocate was slowly dipped onto the prilled urea and talc as the mixer rotated. Heated air was blown constantly into the mixture while oil was being added to facilitate drying. Coated prills contained 38 per cent N and had a mean diameter of 3 mm.

Galo *et al.* (2003) prepared a product, Optigen 1200 (CPG Nutrients, Syracuse, NY) which is a polymer-coated, controlled-release urea product (PCU) and reported to possess a reduced rate of ammonia release to rumen microbes than feed grade urea.

Cherdthong *et al.* (2010) reported in an in vitro experiment that the, feeding urea calcium sulphate mixtures reduced ruminal NH_3 concentrations and increased cellulolytic bacterial population, when compared with urea. Slow urea release properties have been achieved by binding urea to substrates such as calcium chloride (Huntington *et. al.*, 2006 and Golombeski *et al.*, 2006).

Optigen® II (Alltech Inc.) is a blended, controlled release urea source. Urea is coated in a polyester polyurethane coating which allows the diffusion of the urea through micro-pores that slow down the rate of nitrogen release in the rumen (ICF Consulting, 2004). The value of a slow release urea product lies in its nitrogen density (Harrison and Karnezos, 2005; Tikofsky and Harrison, 2007). Optigen® II is an N dense product (41.41 g N/100g) and contains an energy value in the form of lipids (12.12 g/100g). The space created with a high nitrogen dense diet in the rumen may be used to counteract or improve other nutritional shortcomings especially during stress conditions when feed intake will be reduced. Tikofsky and Harrison, (2007) concluded that Optigen® II (nitrogen dense and slow release NPN source) improved the efficiency of microbial protein synthesis. Alves *et al.* (2014) showed that the replacement of conventional urea with slow release urea (Optigen II) in the diet does not affect the nitrogen balance, nor microbial synthesis and efficiency but observed increased concentrations of urea-N in plasma.

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

Van Horn and Mudd (1971) showed no differences in milk yields, milk fat content or feed intakes in cows fed dry or liquid supplements containing urea, minerals and molasses.

Shiehzadeh and Harbers (1974) reported that, utilization of urea in high roughage rations improved when urea is properly extruded with starch over that of prilled urea. Results showed that cows receiving either soybean meal or starea as the protein supplement in their grain ration consumed more grain and produced more milk than those receiving urea.

Tedeschi *et al.* (2002) fed a polymer-coated slow urea (Optigen 1200) and found an improvement in feed efficiency. The experimental cows fed slow release urea consumed less DM without any change in daily milk yield. He also reported the beneficial effect of Optigen 1200 on the fat yield of milk.

Galo *et al.* (2003) 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. Fat content of the milk approximated 3.7 per cent across diets and is an indicator of good rumen fermentation and fiber digestion.

Golombeski *et al.* (2006) compared two diets containing nitrogen sources either as slow urea diet or no 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 *et al.* (2008) 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 *et al.* (2010) 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 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) tested a product Nitroshure, a slowly rumen released encapsulated urea, which is 0.9 unit urea and 0.1 unit fat according to the manufacturer. Feeding a slowly 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 *et al.* (2010) compared effects of polyurethane coated urea with feed grade urea and isolated soy protein diet and found no effect of dietary treatment on milk fat, lactose content, milk yield and energy-corrected milk yield. With respect to the content of milk protein, significant difference among the dietary treatments was detected ($P<0.04$). Cows consuming polymer coated urea and soybean meal diets had similar milk protein concentration, both being greater than those fed the feed grade urea diet. Milk protein percentage and yield were higher for cows receiving the polymer coated urea diet than the feed grade urea diet but were similar to the SBM diet.

Souza *et al.* (2010) examined the effects of coated urea on production and composition of milk in dairy cows, using a diet with 11.4% soybean and another with 0.4% coated urea + 9.0% soybean meal, and detected no differences in daily production of milk but observed a reduction of the percentage of fat and total solids in the milk when protected urea was utilized.

Santos *et al.* (2011) observed reduced daily dry matter intake in 0.8kg *(P* = 0.04) on feeding of NPN, without affecting milk production and reported improvement feed efficiency without affecting nitrogen balance, when SBM was partially replaced with encapsulated urea or urea, both plus citrus pulp.

Madhura *et al.* (2014) reported that calcium chelated urea liquid supplement could replace 1.5 per cent of urea in the diet of lactating dairy cows and concluded that Slow Release Nitrogen Product (SRNP) provided comparable performance to urea supplements without the potential hazard associated with urea.

Nadeem *et al.* (2014) observed that the use of Optigen in buffalo feed, improved the milk production significantly without affecting milk composition but noticed greater yield of microbial nitrogen in urea fed buffaloes than Optigen fed buffaloes and buffaloes fed with diet without urea (control).

Abreu *et al.* (2014) observed no influence of the levels of slow-release urea on milk yield and on milk components in an average yielding cows. The authors have suggested that urea (fast or slow release) can replace soybean meal, without affecting the productive performance of crossbred dairy cows.

Goncalves *et al.* (2014) evaluated production and composition of milk when soybean meal was partially (at 2.1% dry matter of the diet) replaced by conventional urea and coated urea for dairy cows and reported that these sources of urea can be supplied without production impairment for dairy cows.

Calomeni *et al.* (2015) compared effect of feeding diet with polymer-coated slow-release urea and feed-grade urea with diet without urea and reported decrease in milk yield as well as milk protein yield on feeding of urea, regardless of source. The decrease in milk yield was explained by lower volatile fatty acid production, mainly due to decreased propionate production, which is the main gluconeogenic precursor in ruminants. The decrease in milk protein yield was attributed to insufficient amounts of metabolizable protein reaching the duodenum when urea replaced true protein when cows were fed urea. The insufficient metabolizable protein indicates that urea utilization, regardless of source, would decrease ruminal flow of non-ammonia nitrogen, essential amino acids, and total amino acids, resulting in lower microbial protein synthesis.

Santiago *et al.* (2015) completely substituted soybean meal, source of true protein, with slow-release urea (Optigen®II) source of non-protein nitrogen and concluded that, complete substitution in the diets for dairy cows of medium milk yield potential can be practiced with no deleterious effects on dry matter intake and digestibility, milk yield, or milk composition.

2.4 Effect of SRNP on feed intake and digestibility

Digestion balances and feed intake have been a common means of diet evaluation, to the extent that digestibility values are now as much attributes of a feed or diet as compositional values are (Van Soest, 1994).

Karr *et al.* (1963) conducted a series of metabolism experiments, a feeding experiment and a fermentation study to compare urea and biuret as nitrogen sources in a basal ensiled diet. Addition of biuret to the basal mixture significantly increased nitrogen retention by 1.25 gm in two of the three experiments, while the addition of urea consistently lowers nitrogen retention. There were no differences (both tended to be higher) in DM digestibility co-efficient when either urea or biuret was added to the basal.

Oltjen *et al.* (1968) conducted an experiment using eight 214 kg Angus steers fed a standard diet containing 85 per cent timothy hay supplemented with soybean meal for 21 days. The steers were then changed either to the urea or biuret diet in a single feeding. The NPN sources contributed about 50 per cent of the total nitrogen to each diet and the steers were fed these diets at the rate of 2 per cent of the body weight of each steer. The apparent digestibility of DM and acid detergent fibre were not influenced by NPN source.

Stiles *et al.* (1970) studied the effects of Starea on ammonia toxicity in cattle. Starea was compared with grain that had been cracked, finely ground and pelleted or expanded. All diets contained 57 per cent urea. Two sets of rumen fistulated twins were used. The diet containing Starea was the only diet that was readily consumed. Palatability problems were encountered with other three diets.

Thompson *et al.* (1972) conducted an experiment to compare the urea, starea, urea with sulphur and starea with sulphur supplemented finishing rations. With starea supplementation feed conversion was intermediate and palatability of rations containing starea was apparently improved compared to urea rations since steers fed starea adjusted to full feed earlier and consumed slightly more feed throughout the feeding trials and they reported that replacing urea with a slow-release urea source had not affected DMI as stated in past experiments.

Orskov *et al.* (1974) developed a method of including urea in whole grains and a metabolism trial was conducted to determine the effect of impregnation of whole barley with urea on the voluntary Intake of growing lambs. Treatment 1 was barley alone; treatment 2 was barley with 2 per cent absorbed urea and treatment 3 was barley with 2 per cent urea crystals adhered to the surface of the grain with the aid of 0.25 per cent liquid molasses. The effect of feeding whole barley with urea absorbed into it resulted in an increased voluntary intake of lambs over feeding whole barley with 2 per cent urea crystals.

Shiehzadeh and Harbers (1974) reported that utilization of urea in high roughage rations improved when urea is properly extruded with starch over that of prill urea. Starea was found to be utilized equally as well as soybean meal in lactating dairy cows. Results showed that cows receiving either soybean meal or starea as protein supplement in their grain ration consumed more grain and produced more milk than those receiving urea. Grain intakes were lower for the urea supplemented group in all three periods.

Sheihzadeh and Harbers (1974) designed experiments to compare several extruded starch-urea products with soybean meal and urea in high-roughage lamb rations with 25 crossbred lambs and found an increased feed efficiency with extruded starch-urea products. Slightly more feed was consumed by lambs fed extruded supplements than urea, indicating some improvement in palatability.

Summers and Sherrod (1974) conducted two stage *in vitro* experiments on samples of corn and sorghum grains. Four treatments were used: T1 (control corn + 1.3 per cent added urea), T2 (dry urea (1.3 per cent) impregnated corn), T3 (control sorghum

+ 1.25 per cent added urea) and T4 (dry urea (1.25 per cent) impregnated sorghum). In vitro dry matter disappearance for both T2 and T4 were greater than the control grains. The results indicate an increase in IVDMD when corn and sorghum grains are impregnated with urea over adding free urea. An increase in IVDMD could be the result of slower ammonia release in the rumen from the impregnated grains.

Cass *et al.* (1994) conducted a metabolism experiment with 12 wethers to determine the nutritional value of two urea calcium compounds. The compounds were composed of 23-0-0-7 and 10-0-0-11 N, P, K and Ca, respectively. These two compounds were compared to feed grade urea and cotton seed meal for DM intake, over all diet digestibilities of DM and crude protein, nitrogen and calcium utilization. Digestibilities of DM and crude protein were similar across all the treatments though the feed intake and nitrogen intake were lower for 10-0-0-11 treatment compared to urea, 23-0-0-7, and the cotton seed meal treatments. By this it was concluded that compounds that contain a mixture of urea and calcium could be well utilized in ruminant diets as an NPN source.

Cass *et al.* (1995) conducted a feedlot experiment with growing and finishing crossbred steers to determine the effects of a slow ammonia release combined urea calcium compound compared to isonitrogenous diets containing feed grade urea or cottonseed meal. Both tended to improve feed efficiency, however, the extent of improvement was greater for feed efficiency when combined urea calcium compound was supplemented. Energetic efficiency was also improved with combined urea calcium diet.

Duff *et al.* (2000) evaluated the effect of a slow-release urea product (Ruma Pro) on performance of animals. Treatments used in the study included a standard finishing diet with slow-release urea (Ruma Pro) replacing a combination of natural protein and urea in standard diet. For the overall feeding period, daily DMI tended to be less by Ruma Pro fed cattle vs. control cattle and also gain: feed was improved for steers fed Ruma Pro vs. Control.

Tedeschi *et al.* (2002) noted an improvement in feed conversion when Optigen 1200 was substituted for urea at levels normally found in feedlot diets. This improvement would be expected because cows consumed less DM and there was no drop in daily milk yield for cows fed slow urea. Replacement of soybean meal with slow urea (Optigen 1200) significantly improved feed efficiency.

Galo *et al.* (2003) formulated diets by including coated urea in the total mixed ration. The three diets TI (CP18 without coated urea) and T2 (CP18 with coated urea) were formulated to be isonitrogenous, and T3 (CP16 with coated urea) was formulated to contain more forage (55 per cent vs 50 per cent) and have less nitrogen to test for efficiency of N utilization. Total tract apparent DM and CP digestibilities were higher for T2 when compared to T1. Apparent ADF digestibility was lower for both T2 and T3. Total DMI and apparent digestibilities for other feed components (organic matter, NDF, starch, sugar, and NSC) did not differ across diets.

Golombeski *et al.* (2006) in an experiment with 12 lactating Brown Swiss cows averaging 117 DIM (SD = 46) were fed diets with either no slow urea or with slow urea as a nitrogen source, which partially replaced soybean meal. Feeding slow urea decreased the dry matter intake and increased feed efficiency compared with cows fed no slow urea diet.

Edward *et al.* (2009) stated that although apparent total tract digestibilities of DM, OM, NDF and ADF were not affected, the treatment with slow release urea increased fecal N excretion and reduced apparent total tract N digestibility. Intake of DM, OM, NDF, and ADF did not differ among treatments and there were no detrimental effects on DM and fiber digestibility associated with feeding a slow release urea.

Cherdthong *et al.* (2010) compared four diets T1 = urea (control); T2 = soybean meal; T3 = urea $CaCl_2$ mixture; T4 = urea $CaSO_4$ mixture using ruminally fistulated animals. Rice straw, concentrate, total DM intake were not influenced by feeding the different N sources, except NDF digestibility was highest with urea $CaSO_4$ mixture supplementation, intermediate with soy protein and urea $CaCl_2$ mixture and lowest with control ($P \leq 0.05$). Nevertheless, apparent digestibility's of DM, OM, CP and ADF were not affected by the urea calcium treatments.

Highstreet *et al.* (2010) conducted an experiment with an objective to determine if use of a slowly rumen released urea could increase productive performance. Total mixed rations formulated to supply 5 per cent of ration CP from urea or encapsulated urea. Nitroshure, a slowly rumen released encapsulated urea, which is 0.9 unit urea and 0.1 unit fat according to the manufacturer. Fecal digestibility of CP and neutral detergent fiber were unaffected by the treatment with nitroshure.

Rodriguez *et al.* (2010) conducted an experiment with 20 animals randomly assigned to the following treatments: 1) Control (standard diet with soybean meal as protein source; 2) a slow-release coated urea product (Optigen 1200). The DM, CP, NDF, ADF, ash and NEg were similar for experimental diets. The coated urea diet had a higher protein fraction than control and DMI was also unaffected by the treatment, as compared to the control diet.

Xin *et al.* (2010) in their experiment to compare the polymer coated urea and feed grade urea diets and found similar digestibilities of DM, OM, NDF, ADF and CP. DMI of cows fed the polymer coated urea diet was approximately 12.8 per cent greater ($p<0.02$) than that of the feed grade urea diet, and was similar to that of the soy protein diet.

Ribeiroa *et al.* (2011) designed an experiment with four ruminally cannulated beef steers to compare ruminal infusion effects of different sources of non protein nitrogen (NPN) on intake, digestibility, ruminal DM and NDF degradability, ruminal pH and ammonia nitrogen of beef cattle and observes that SRU had a more adequate concentration of N during the fermentation of low quality hay and also had a proper pH for rumen activity.

Umashankar B. C. (2011) reported that there was no significant difference in dry matter intake, digestibility of nutrients and the nitrogen balance when calves were fed with 1.5 per cent SRNP (Calcium chelated urea). Supplementation of SRNP did not influence utilization of nutrients, in this study .

Santos *et al.* (2011) reported the use of slow-release urea in diets for high-yielding cows fed corn silage as the main roughage and noticed decrease in intake and explained that it could be because of the possible existence of a systemic mechanism that was suggested by Wilson *et al.*, (1975), who observed that the intra ruminal infusion of urea was as depressant to intake as the incorporation of urea to the diet.

Silveira *et al.* (2012) used slow release urea for dairy cows, and reported no significant difference for the dry matter intake. The results from this study showed that the partial substitution of soybean meal by Optigen ® II does not affect the production.

Serrano *et al.* (2013) reported the use of slow release urea in diet for steers Nelore improved ruminal apparent digestibility of the fiber without affecting microbial protein synthesis and ruminal kinetics. Digestibility was high with high levels of fiber sources associated with slow - release urea, and So concluded that slow release NPN have greater effect on diets with higher proportion of fiber sources

Soto *et al.* (2014) conducted an experiment to examine the combination of Optigen and Urea in a finishing diet of steers containing different starch: acid detergent fibre ratios (S:F) on the characteristics of digestive function. They also reported positive effects on the microbial nitrogen flow and digestible energy of the diet, when there was a certain proportion (4.5) of starch: ADF in the diet. Either a higher or lower S:F ratio than 4.5 failed to offer advantages over any of the parameters evaluated.

Colomeni *et al.* (2015) showed that feeding of polymer-coated slow-release urea sources lack advantages over feed-grade urea. Also noted an increase in total tract digestibility of CP in cows fed diets containing urea although no differences occurred for nutrient intake, which was related to the level of dietary rumen digestible protein. When urea sources were added to the diet, true protein (soybean meal) is replaced with a NPN 100% soluble in the rumen (NRC, 2001), thereby generating an increase in CP digestibility, with a decrease in excretion of nitrogen in the faeces. However, despite higher digestibility of CP, feeding urea provided a lower efficiency of nitrogen utilization.

Gardinal *et al.* (2016) conducted an experiment with objective of evaluating the effects of polymer coated slow-release urea (SRU) in high-forage diets of beef steers on nutrient intake and digestibility, ruminal fermentation, microbial protein synthesis, and energy balance and concluded that he partial replacement of soybean meal by 1% slow-release urea in a diet with 75% forage does not improve ruminal fermentation and microbial protein synthesis, and shows similar results as feeding feed grade urea to beef steers

2.5 Safety of slow release nitrogen product over urea feeding

Meiske *et al.* (1955) compared urea and biuret and stated that biuret does not seem to be toxic to the animal even when large amounts are given as a drench as compared to urea in the same level of feeding.

Bartley and Deyoe (1975) reported that a number of animals fed high urea diets developed toxic symptoms but that the cattle fed starea were spared from the same as a result of the reduction in solubility of NPN in that form.

Stiles *et al*. (1970) studied the effects of Starea on ammonia toxicity in cattle. Starea was compared with grain that had been cracked, finely ground and pelleted or expanded. All diets contained 57 per cent urea. Two sets of rumen fistulated twins were used. The diet containing starea was the only diet that was readily consumed. Palatability problems were encountered with the other three diets. The rumen ammonia concentration of the starea-fed animals was lower than the controls. Ammonia toxicity did not occur in animals fed starea. Animals fed the three control diets did show symptoms of ammonia toxicity.

Ward and cullison (1970) fed prilled urea and ethyl cellulose-coated urea to ewes in a toxicity study and observed coated urea to be non-toxic when fed at the same level as a toxic amount of uncoated urea.

Owens *et al*. (1980) prepared a slow release urea compound using tung oil. SRU and urea supplements were fed to five fasted steers. Amounts of urea of each form consumed were equal. Toxicity of slow release urea was tested by feeding steers a ration supplemented with 10 per cent prilled urea or slow release urea equal to 10 per cent prilled urea. Muscle tremors were observed in steers fed prilled urea 35 min after feeding. Ruminal ammonia concentrations at evacuation exceeded 120 mg per dl. Steers fed slow release urea exhibited no abnormalities, and rumen ammonia concentrations never exceeded 35 mg per dl. Extrapolated from observed ammonia concentrations, an intake of 900 g urea in the slow release form would be required for toxicity.

Edward *et al.* (2009) conducted an experiment to evaluate the effects of slow release urea versus feed-grade urea on ruminal metabolite characteristics, daily gain and

DMI in steers. Slow release urea can be utilized as an 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.

Mentz *et al.* (2015) studied the effects of replacing rapid-release nitrogen (N) from urea with a graded level of slow-release N (Optigen® II) source on intake, digestibility, rumen fermentation and microbial protein synthesis, when sheep were fed a poor-quality roughage diet. And reported that rumen NH3-N concentration of the 100% Optigen® II treatment was significantly lower than the 100% urea treatment at two and four hours after infusion thus helps in reduction in potential hazards such as ammonia toxicity, which are associated with the use of urea.

Literature reviewed in this chapter has revealed that numerous products of slow release nitrogen / urea have been developed considering the safety of using non protein nitrogen compounds.in the dairy cattle diets. Many studies have been conducted to utilize these in the diet of ruminants to improve rumen fermentation, efficiency of nitrogen utilization, digestibility of nutrients and lactation performance. However, not much success has been achieved in terms of improved lactation performance by using slow nitrogen release products. Further studies are required to elucidate the lack of response in lactation performance by dairy cows after the feeding these slow release nitrogen product.

Table 2.1. Effect of supplementing different slow release nitrogen products on the lactation performance of dairy cows reported in literature

Reference	SRNP used	Effect		
		Milk yield	Fat	Protein
Van Horn and Mudd, (1971)	Urea- mieral-molasses liquid supplement	±	±	±
Shiehzadeh and Harbers, (1974)	Starea	+	±	±
Tedeschi *et al.*, (2002)	Polymer coated urea	±	+	±
Galo *et al.*, (2003)	Polymer coated urea	±	±	±
Golombeski *et al.*, (2006)	Calcium chloride-bound Urea	±	±	±
Santos *et al.*, (2008)	Polymer coated urea	±	±	±
Inostroza *et al.*, (2010)	Polymer coated urea	+	±	±
Highstreet *et al.*, (2010)	0.1 % fat encapsulated urea	±	+	+
Xin *et al.*, (2010)	Polymer coated urea	±	±	+
Souza *et al.*, (2010)	Coated urea	±	_	±
Cherdthong *et al.*, (2010)	Urea – $CaSO_4$ mixture	+	±	±
Santos *et al.*, (2011)	Encapsulated urea	±	±	±
Madhura *et al.*, (2014)	Calcium chelated urea	±	±	±
Abreu *et al.*, (2014)	Slow release urea	±	±	±
Goncalves *et al.*, (2014)	Coated urea	±	±	±
Calomeni *et al.*,(2015)	Polymer coated urea	_	±	_
Santiago *et al.*, (2015)	Polymer coated urea	±	±	±

± : No change + : Increase _ : Decrease

Materials and Methods

III. MATERIALS AND METHODS

The experiment was carried out to study the effect of feeding slow release nitrogen product on the lactation performance of dairy cows at the Department of Animal Nutrition, Veterinary College, Bengaluru. The lactation trial was conducted at the dairy farm, Department of Instructional Livestock Farming Complex, Veterinary College, KVAFSU, Bengaluru.

3.1. Lactation trial

3.1.1 Animals and experimental design

Eight crossbred cows in mid late lactation stages were used in a Youden latin square design. The first two blocks were 3x3 latin square, whereas the third block was incomplete latin square with two cows. The blocks were made based on milk production and number of days in lactation. Cows within each block were assigned to one of the three dietary treatments. The particulars of cows used in experiment and the experimental design are presented in Table 3.1 and Fig. 3.1, respectively.

3.1.2 Housing and procurement of feed ingredients

The cows were housed in individual stalls in an open protected animal shed in a single row and were provided with similar management practices. Quantities of finger millet straw and concentrate ingredients sufficient for the entire duration of the study were procured in a single batch and stored. The corn silage was used from three silo pits containing the silage prepared from the same forage.

3.1.3 Dietary treatment

The diet of the experimental cows was made from corn (*Zea mays*) silage and finger millet (*Eleucine coracana*) straw as roughage and a compounded feed mixture (CFM) containing known ME and crude protein (CP) content. The ingredient composition (per cent) of CFM is presented in Table 3.2. The energy (ME, MJ/Kg), CP (per cent) and the UDP (per cent of CP) content of the silage, straw and CFM were analyzed before commencement of the feeding trial and the actual values were used for computing the diets.

The individual cows in the experiment were allocated to one of the three dietary treatments. The treatments were designated as T_1, T2 and T3 and contained urea or SRNP as following treatments:

1. Treatment - 1 (T1): Corn silage, Finger millet straw and Compounded feed mixture containing 2 per cent urea. This group served as control.
2. Treatment – 2 (T2): Corn silage, Finger millet straw and Compounded feed mixture containing 2 per cent SRNP (Urea replaced *per se* with SRNP on isonitrogen basis)
3. Treatment – 3 (T3): Corn silage, Finger millet straw and Compounded feed mixture containing 4 per cent SRNP (Urea replaced with SRNP on isosoluble nitrogen basis).

The SRNP used in the study was a polymer coated urea compound (Optigen-II, a commercial product of M/s. Alltech Biotechnology Private Limited, Bangalore, India) containing 42 per cent total N with 52.1 per cent soluble N. The total N content was analysed by using macro kjeldahl method (AOAC 1995). The buffer soluble nitrogen

(nitrogen soluble in borate phosphate buffer at 7.8 pH) content of SRNP was determined by the method described by Krishnamoorthy *et al.* (1982).

Diets for the experimental cows were formulated individually to meet the energy and protein requirement as per ARC (1984). Cows were fed with the required amount of energy in the diet to maintain body weight and milk production. Animals were fed daily with fixed quantities of corn silage (20 kg) and finger millet straw (1 kg) separately. The allowance of CFM for individual cows was varied to supply the required ME. The total protein in the diet supplied adequate amounts of rumen degraded protein (RDP) and undegraded dietary protein (UDP) as per the stipulations of ARC (1984). The daily allowance of finger millet straw was offered at 08:00 hours and corn silage in portions at 10:00, 14:30 and 18:00 hours of the day. The CFM was fed in two equal parts at 05:00 and 13:30 hours. The ort of corn silage was weighed on the next day at 06:30 hours. The cows were provided with sufficient drinking water throughout the day.

3.1.4 Duration of trial

The total duration of the trial was twelve weeks, comprising three periods of four weeks each with an adjustment period of three weeks and observation period of one week, during which time milk yield, milk composition (total solids, ash, fat, protein, lactose and solids not fat (SNF)), feed intake, body weight changes and body condition scores were recorded.

3.1.5 Parameters studied

3.1.5.1 Dry matter intake

Daily intake of corn silage, finger millet straw and CFM were recorded. Samples of corn silage, finger millet straw and CFM offered were collected and analyzed once in a week for the estimation of DM. Dry matter was estimated by drying samples at 105°C to constant weight. Dry matter intake was calculated by deducting the left over from the mean daily offered quantities of corn silage, finger millet straw and CFM.

3.1.5.2 Body weight

The cows were weighed in the beginning and at the end of each period (on the same days and same time), after milking and before having access to feed and water. The body weights were recorded using a platform weighing scale (Avery India Ltd).

3.1.5.3 Body condition scores

The cows were scored for the body condition in the beginning and at the end of each period. The scoring was done on five point scale according to NRC (2001).

3.1.5.3 Milk yield and milk composition

The cows were milked using milking machine twice daily at 05:00 and 13:30 hours. The daily milk yields were recorded in kg using a digital weighing scale (Fontec India Ltd.). Four per cent fat corrected milk (FCM) yield was calculated using the equation of NRC (2001) [4 per cent fat corrected milk (FCM) = (0.4 x kg of milk) + (15 x kg of fat)]. Three milk samples were collected (Saturday, Monday and Wednesday) during the fourth week of each period and analyzed for the milk constituents. Pooled samples of milk obtained from mixing of morning and evening samples in proportion to the corresponding yield were used for analysis. Milk samples were analyzed for total solids (TS), total ash, milk fat (electronic milk tester) and milk protein according to AOAC (1995). The solids not fat (SNF) was calculated as the difference between TS (per cent) and fat (per cent) content in milk and expressed as per cent. The lactose content of milk was calculated by difference [total solids - (protein + ash + fat)]. Density of milk was recorded as lactometer reading, after applying factors for variations in temperature and expressed as corrected lactometer reading (CLR).

3.2 Digestion trial

Digestion trials were completed using all animals, during the last week of the each period of the lactation trial. Digestion trial was conducted by indicator method using ADF ash as an internal marker in a "grab collection" method as described in Singh *et al.* (1994).

3.2.1 Sampling of feeds and residue

Representative samples of the feed offered and residues left were collected daily during the collection period for analyses of DM and nutrients.

3.2.2 Faecal collection

Five grab samples of faeces were collected from each cow in three days period by rectal sampling in a design that equally represents the 78 hours collection period as well as 24 hours of the day (1030 hours on day 1st, 0545 hours on day 2nd, 0100 and 2015 hours on day 3rd and 1525 hours on day 4th). Four hundred grams of the faecal sample collected each time was composited and frozen (-20 ^{o}C) until analyses. Composited samples of faeces were thawed to room temperature, mixed thoroughly and dried at 55 ^{o}C for analyses.

3.2.3 Analytical methods

Concentrate mixtures, corn silage, finger millet straw orts and dried faecal samples were ground through 1 mm sieve using Foss mill and stored in air tight polyethylene containers until analyzed. The DM, OM and N contents were determined using AOAC (1995) procedures. The NDF, ADF and ADF ash were estimated as described by Van Soest *et al.* (1991).

3.2.4 Calculation of digestibility of nutrients

The digestibility of DM, OM, N, NDF and ADF was calculated by using the following equations.

$$\text{Digestibility of DM (\%)} = 100 - 100 \times \frac{\text{[per cent indicator in DM of feed]}}{\text{[per cent indicator in DM of faeces]}}$$

$$\text{Digestibility of nutrients (\%)} = 100 - 100 \times \frac{\text{[per cent indicator in feed} \times \text{per cent nutrient in faeces]}}{\text{[per cent indicator in faeces} \times \text{per cent nutrient in feed]}}$$

3.3 Chemical analysis

3.3.1 Analytical procedures

The DM content of feed samples and ort was analyzed by drying the samples to a constant weight in a forced hot air oven at 105°C (98 to 100^{o}C for milk samples). The ash content in the samples was estimated as residue obtained after incineration of samples at 600°C for 3 hours. Crude protein (N X 6.25) was analyzed using Gerhardt digestion and distillation unit that agrees with macro Kjeldahl standards (AOAC, 1995). The ether extract (EE) content in the feed samples was analyzed after extraction with petroleum ether using the procedure of AOAC (1995). The neutral detergent fiber (NDF) and acid detergent fiber (ADF) was determined according to the methods described by Van Soest *et al.* (1991). The fat content of milk was analysed using electronic milk tester.

3.4 Statistical analysis

Data on DMI, milk yield (total and 4 per cent FCM), milk composition (fat, SNF, protein and lactose) body condition score and BW gain were analyzed by ANOVA using Graph pad Prism software (Version 5.00). Individual difference among treatment means were determined by Bonferroni 't' test, when treatment effect was significant and results interpreted accordingly.

Table 3.1. Particulars of cows used in the experiment

Cow Number	Body Weight (kg)	Milk Yield (kg)	Days in Lactation
P30	394	14.8	257
P21	420	13.3	51
P37	418	14.4	45
P1	470	10.7	290
P2	548	9.60	235
P19	465	13.1	305
P24	500	8.2	550
P28	460	8.10	538
AVERAGE	**459**	**11.5**	

Table 3.2 Ingredient composition (per cent) of compounded feed mixture.

Ingredient	Parts		
	T1	**T2**	**T3**
Corn	50	50	50
Wheat bran	45	45	43
Urea	2	-	-
SRNP	-	2	4
Salt	1	1	1
Mineral Mixture	2	2	2
TOTAL	**100**	**100**	**100**

T1 = 2 per cent Urea diet; T2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

Fig. 3.1. Experimental design

	Animal No.	P1	P2	P3
Block 1	30	T1	T2	T3
	21	T2	T3	T1
	37	T3	T1	T2
Block 2	1	T1	T3	T2
	2	T3	T2	T1
	19	T2	T1	T3
Block 3	24	T2	T1	T3
	28	T1	T3	T2
		-	-	-

Blocks – 1, 2 and 3; Each block is a 3x3 Latin square (Block-3 is incomplete Latin square)

P1, P2 and P3 are periods; T1 = 2 per cent Urea diet; T2 = Urea replaced by 2 per cent SRNP on isonitrogen basis; T3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

Results

IV. RESULTS

4.1 Chemical composition of diets

The chemical composition, energy value and protein fractions of composite samples of finger millet (*Eleucine coracana)* straw, corn (*Zea mays*) silage and compounded feed mixture fed to experimental animals during feeding trial are presented in Table 4.1 and Table 4.2. Corn silage contained 92.3 per cent OM, 5.2 per cent CP and 1.41 per cent EE. The NDF, ADF and ADF ash contents (per cent) were 66.6, 42.7 and 4.42 per cent, respectively. The energy content was 7.1 MJ/kg DM. As a per cent of DM, finger millet straw contained 94.3 OM, 3.75 CP, 0.73 EE, 5.74 TA, 39.7 ADF, 69.41 NDF and 1.7 ADF ash. The ME content was 5.98 MJ/kg DM. The compounded feed mixture contained (per cent on DM basis) 96.3, 15.6, 1.88, 3.69, 31.6, 5.31, 0.03 per cent of OM, CP, EE, TA, NDF, ADF, ADF ash respectively. The ME content was 10.5 MJ/kg DM.

4.2 Feeding trial

4.2.1 Dry matter intake

The mean DMI (kg/day) of corn silage, finger millet straw and compounded feed mixture and the total DMI for the treatment groups T1, T2 and T3 are presented in Table 4.3. The mean total DMI (kg per day), DMI as per cent body weight and the DMI (g per day) per kg metabolic body weight of individual cows in different treatment groups are presented in Appendix I, II and III, respectively. The total DMI (kg per day) for treatment diets T1 T2 and T3 were 12.35, 12.40 and 12.32, respectively. As a proportion of the body weight, these amounts to 2.68, 2.68 and 2.66, respectively. The DMI (g/day) per kg metabolic body weight for treatments T1, T2 and T3 were 124.3, 124.2 and 123.6, respectively. There was no significant difference in DMI (as kg per day or per cent body weight or per kg metabolic body weight) among the treatment groups.

4.2.2 Intake of NDF, ADF, Energy and protein

The overall mean NDF and ADF intake for the three treatment groups are presented in Table 4.3. The NDF and ADF intakes (kg/d) during the experimental period are presented in Appendix IV and VI, respectively. The NDF and ADF intakes as per cent of body weight of individual animals are presented in Appendix V and VII, respectively. The average daily NDF intake as per cent of body weight was 1.32, 1.32 and 1.30 kg for groups T1, T2 and T3, respectively whereas, ADF intake as a per cent of body weight was 1.02, 1.02 and 1.01 for groups T1, T2 and T3, respectively. The NDF and ADF intake (kg per day or per cent of body weight) were not significantly different among the treatment groups.

The mean energy and protein intake for the three treatment groups are presented in Table 4.7. The intake of energy (ME, MJ per day) was 107.8, 108.1 and 107.7 for groups T1, T2 and T3, respectively and that of protein (CP, g per day) was 1315, 1317 and 1554 for groups T1, T2 and T3, respectively. The intake of energy was similar among all three treatment groups. The intake of CP and RDP was significantly ($P \leq 0.05$) higher in T3 than T1 and T2 groups, whereas the intake of total soluble protein was significantly higher in T1 and T3 compared to T2 group ($P \leq 0.05$).

4.2.3 Milk yield

The mean daily milk yield and the 4 per cent FCM yield (kg) of the three groups are presented in Table 4.4. The daily milk yield (kg) and 4 per cent FCM yield (kg) of individual cow in three groups during last week of each period of the study are presented in appendix IX and X, respectively. The FCM yield (kg) was 10.96, 10.67 and 10.45, respectively for treatment groups T1, T2 and T3. Milk yield (kg) was 11.37, 11.11 and 10.89, respectively for treatment groups T1, T2 and T3. There was no significant difference observed in the yield of whole milk or FCM among the treatment groups.

4.2.4 Milk composition

4.2.4.1 Total solids

The average total solids content (per cent) and yield (kg/day) for all three groups are presented in the Table 4.4. The milk total solids content (per cent) for individual animal in three treatments T1, T2 and T3 are presented in Appendix XII. The mean total solids (per cent) and yield (kg/day) for the treatments T1, T2 and T3 were 13.41, 1.53; 13.34, 1.48; and 13.34, 1.45, respectively. There was no significant difference in the total solids (per cent or yield) among the treatment groups.

4.2.4.2 Milk fat

The average milk fat content (per cent) and yield (kg/day) for all three groups are presented in Table 4.4. The milk fat content (per cent) of the animals for the treatment groups T1 (urea), T2 (2% SRNP) and T3 (4% SRNP) are presented in Appendix XIII. The average fat content (per cent) and yield (kg/day) for treatments T1, T2 and T3 were

3.89, 0.44; 3.88, 0.43 and 3.88, 0.42, respectively. There was no significant difference in fat per cent or yield of fat among the treatment groups.

4.2.4.3 Solids not fat (SNF)

The average SNF content and yield of three treatment groups are presented in Table 4.4. The SNF content in the milk of individual animal in treatment groups T1, T2 and T3 are presented in Appendix XIV. The mean SNF content (per cent) and yield (kg/day) for the three treatments T1, T2 and T3 were 9.52, 1.08; 9.46, 1.05 and 9.47, 1.03, respectively. There was no significant difference in both SNF content and yield among three treatment groups.

4.2.4.4 Milk protein

The mean protein content and yield of protein of all three groups are presented in Table 4.4. The protein content in the milk of individual animal in treatment groups T1, T2 and T3 are presented in Appendix XV. The mean protein content (per cent) and yield (kg/day) for the treatments T1, T2 and T3 were 3.32, 0.38; 3.12, 0.35 and 3.16, 0.34, respectively. The protein content (per cent) or protein yield were not different among three treatment groups.

4.2.4.5 Milk ash

The average ash content and yield in all treatment groups are presented in Table 4.4. The mean values of ash content (per cent) in milk of individual animal in treatments T1, T2 and T3 are presented in Appendix XVI. The average ash content (per cent) and yield (kg/day) of ash for the three treatment groups T1, T2 and T3 were 0.72, 0.08; 0.70, 0.07 and 0.74, 0.08, respectively. The differences in the ash content or ash yield among three treatments were statistically non-significant.

4.2.4.6 Milk lactose

The average lactose content (per cent) and yield (kg/day) for each treatment is presented in Table 4.4. The milk lactose content of cows in treatment groups T1, T2 and T3 are presented in Appendix XVII. The average lactose content for treatment diets T1, T2 and T3 were 5.48, 5.64 and 5.57 per cent, respectively. Similarly the average lactose yield for treatments T1, T2 and T3 was 0.62, 0.63 and 0.61 kg per day, respectively. The differences in the lactose content or lactose yield among three treatments was statistically non-significant.

4.2.4.7 Corrected lactometer reading (CLR)

The CLR of cows milk in treatment groups T1, T2 and T3 are presented in Appendix XI. The average CLR of milk for treatment diets T1, T2 and T3 was 29.29, 29.25 and 29.24, respectively. The differences in the CLR of milk among different treatments were statistically non-significant.

4.2.5 Body weight

The mean body weight change for the three groups during three periods of the study is presented in Table 4.5. The body weight (kg) of cows in different treatment groups during the experimental period are presented in Appendix VIII. The body weight gains (g per day) were 238, 214 and 196 for treatment groups T1, T2 and T3, respectively. The body weight gain of animals among the three treatment groups was not significantly different.

4.2.6 Body condition score

The mean change in body condition scores in treatments T1, T2 and T3 are presented in Table 4.5. The body condition scoring was done on a 1-5 point scale as described by NRC (2001). The mean gain in condition score was calculated as a difference in the body condition score at the beginning and at the end of each period, over four weeks of different periods of the experiment. The difference in body condition score among the three treatments was not statistically significant.

4.2.7 Apparent digestibility of the nutrients

The intake (kg per day) and apparent digestibility of nutrients (per cent) of experimental cows during digestion trial period are presented in Table 4.6. The apparent digestibility (per cent) of the nutrients viz. DM, OM, CP, NDF and ADF of the three experimental diets T1, T2 and T3 were 54.03, 58.84 and 51.85; 65.88, 69.22 and 64.03; 62.87, 64.68 and 64.33; 64.80, 65.87 and 56.66 and 49.89, 55.57 and 48.35 respectively. The intake of digestible organic matter of the diets T1, T2 and T3 were 7.70, 8.08 and 7.49 kg per day, respectively. There was no significant difference in the digestibility of nutrients among the treatment groups.

Table 4.1. Chemical composition[1] (per cent DM) of compounded feed mixture, corn silage and finger millet straw

Parameter	Compounded feed mixture	Corn Silage	Finger millet straw
Dry matter	91.9	29.4	93.3
Organic matter	96.3	92.3	94.3
Crude protein	15.6	5.20	3.75
Ether extract	1.88	1.41	0.73
Total ash	3.69	7.72	5.74
Neutral detergent fiber	31.6	66.6	69.4
Acid detergent fiber	5.31	42.7	39.7
Acid detergent lignin	1.65	4.19	5.21
Acid detergent ash	0.03	4.42	1.70

[1] Mean of two replicates. Variations in duplicate measurements were within ± 3% of the mean

Table 4.2. Composition[1] of energy and protein in feed ingredients[2]

Parameter	Compounded feed mixture	Corn silage	Finger millet straw
ME[3], MJ/kg	10.5	7.00	5.98
Crude protein, %	15.6	5.21	3.75
Rumen degraded protein[4] (as % of total CP)	67.1	71.1	61.5
Undegraded dietary protein[5] (as % of total CP)	32.9	28.9	38.5
Total soluble protein[6], g/d (as % of total CP)	34.8	41.3	31.4

[1]On dry matter basis

[2]Mean of two replicates. Variations in duplicate measurements were within ± 3% of the mean

[3] Determined by RIVGPT (Menke *et al.,* 1979)

[4]Estimated according to Krishnamoorthy *et al.,* 1983

[5]100-RDP % (per cent of CP)

[6]Estimated according to Krishnamoorthy *et al.*, 1982

Table 4.3. Daily mean intake of DM, NDF and ADF in experimental cows

Parameter	T1	T2	T3	SEM
Dry Matter Intake				
CFM (kg/day)	6.28	6.28	6.30	1.13
Corn silage (kg/day)	5.14	5.19	5.09	1.05
Finger millet straw (kg/day)	0.93	0.93	0.93	0.0
Total DMI (kg/day)	12.35	12.40	12.32	0.38
% of body weight	2.68	2.68	2.66	0.28
g per kg BW0.75	124.3	124.2	123.6	10.08
NDF intake (kg/day)	6.10	6.13	6.07	0.17
% of body weight	1.32	1.32	1.31	0.14
ADF intake (kg/day)	4.74	4.76	4.73	0.13
% of body weight	1.02	1.02	1.02	0.10

T1 = 2 per cent Urea diet; T2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

SEM: Standard error of means

Table 4.4. Yield and composition of milk in experimental cows

Parameter	T1	T2	T3	SEM
Milk yield, kg/day	11.37	11.11	10.89	5.12
*4% FCM yield, kg/day	10.96	10.67	10.45	3.60
Milk composition				
Total solids, %	13.41	13.34	13.34	2.34
Yield, kg/day	1.53	1.48	1.45	1.25
Solids not fat, %	9.52	9.46	9.47	1.44
Yield, kg/day	1.08	1.05	1.03	0.88
Fat, %	3.89	3.88	3.88	1.12
Yield, kg/day	0.44	0.43	0.42	0.38
Protein, %	3.32	3.12	3.16	0.93
Yield, kg/day	0.38	0.35	0.34	0.31
Lactose, %	5.48	5.64	5.57	0.98
Yield, kg/day	0.62	0.63	0.61	0.52
Ash, %	0.72	0.70	0.74	0.09
Yield, kg/day	0.08	0.07	0.08	0.07
Corrected lactometer reading	29.29	29.25	29.24	2.62

T1 = 2 per cent Urea diet; T2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

SEM: Standard error of means

*4 per cent FCM = (0.4× kg of milk) + (15× kg of fat)

Table 4.5. Average body weight gain (g/day) and body condition score of experimental cows during lactation trial

Parameter	T1	T2	T3	SEM
Body weight				
gain, g/day	238	214	196	46.39
Body Condition Score				
Initial	2.62	2.97	3.03	
Final	3.11	3.38	3.34	
Difference	0.49	0.41	0.31	

T1 = 2 per cent Urea diet; T2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

SEM: Standard error of means

Table 4.6. **Intake (kg per day) and apparent digestibility of nutrients (per cent) during digestion trial period in experimental cows**

Parameter	T1	T2	T3	SEM
Dry matter				
Intake	12.37	12.36	12.38	0.41
Digestibility	54.03	58.84	51.85	13.82
Organic matter				
Intake	11.69	11.68	11.7	0.39
Digestibility	65.88	69.22	64.03	10.34
Crude protein				
Intake	1.31	1.31	1.64	5.88
Digestibility	62.87	64.68	64.33	12.33
Neutral detergent fibre				
Intake	6.07	6.06	6.07	0.14
Digestibility	64.80	65.87	56.66	12.68
Acid detergent fibre				
Intake	4.72	4.72	4.73	0.20
Digestibility	49.89	55.57	48.35	11.43
DOMI[1]	7.70	8.08	7.49	0.17

T1 = 2 per cent Urea diet; T2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

SEM: Standard error of means

[1]DOMI = Digestible organic matter intake

Table 4.7. Daily intake of energy and protein by cows in different experimental groups

Parameter	T-1	T-2	T-3	SEM
ME, MJ/d	107.8 (112)	108.1 (110)	107.7 (109)	2.11
Crude protein,Total g/d	1315^{a}	1317^{a}	1554^{b}	24.6
Rumen degraded protein, g/d	941^{a} (874)	942^{a} (858)	1149^{b} (856)	19.3
Undegraded dietary protein, g/d	374 (73)	375 (66)	405 (61)	6.92
Total soluble protein, g/d	592^{b} (394)	433^{a} (395)	582^{b} (466)*	7.13

T1 = 2 per cent Urea diet; T2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

SEM: Standard error of means

Values in parenthesis are stipulated intake values of ARC (1984)

*Stipulated intake (for soluble protein) based on 30 per cent of total protein intake

Mean values in the same row bearing different superscripts differ ($P \leq 0.05$)

Discussion

V. DISCUSSION

The present study was conducted to determine the effect of a slow release nitrogen product (SRNP) on the lactation performance of dairy cows. The experiment comprised of a feeding trial with three treatment groups receiving T1, T2 and T3 diets containing 2 % urea, 2% SRNP and 4% SRNP, respectively. The influence of replacing urea by SRNP at two levels, on the basis of isonitrogen content (T2) or isosoluble nitrogen content (T3) on the lactation performance, feed intake and digestibility of nutrients was investigated.

5.1 Chemical composition of diets.

The diet fed to experimental cows consisted of corn silage, finger millet straw as roughage source and a CFM. The diets were formulated to meet the requirement of energy for maintenance and milk production. Although the quantities of roughages and CFM varied, the ratio of roughage to concentrate in the diet of cows of three treatment groups was similar (49.1:50.9, 49.4: 50.6 and 48.9: 51.1 for T1, T2 and T3 groups, respectively). Cows in all the treatments were provided with fixed quantity of roughage (1 kg finger millet straw and 20 kg corn silage), while the amount of CFM varied and fed in calculated quantities, to provide the required energy. The NDF and ADF contents in all the treatment diets were sufficient to meet the recommended level as per ARC (1984) standards. The experimental diets provided adequate energy, as the calculated quantities of CFM offered to individual cows was based on maintenance and milk production to meet the ME as stipulated by ARC (1984). The CP content of the complete diet was 13.04, 13.17 and 16.44 per cent for T1, T2 and T3, respectively. The RDP content (as per cent CP) of the experimental diets was about 65 per cent. The quantities of CP and RDP supplied in the diets were sufficient to meet the requirements as specified by the ARC (1984) (Table 4.7). The amounts of UDP supplied was about 300 g in excess of the requirement (Table 4.7). The diet of T1 and T2 contained similar protein content as the amount of urea in T2 diet was replaced by SRNP on isonitrogenous basis, whereas, diet T3 contained higher percentage of protein due to 2 per cent higher supplementation of the SRNP in the CFM. The buffer soluble protein (BSP) content was 39.4, 32.3 and 41.1 per cent, respectively for diets T1, T2 and T3 (Table 4.7). Lower BSP content in T2 was expected due to the lower soluble nitrogen content in the SRNP used in the experiment, however, supplementation of 2 per cent higher level of SRNP in T3 diet resulted in similar BSP content in diets T1 and T3. The nutritional characteristics of all the experimental diets were similar with regard to all nutrients except BSP (and total CP). Therefore, any difference in the lactation performance could only be attributed to the effect of BSP content of the diets.

5.2 Dry matter intake

The DMI (kg/day) was 12.35, 12.40 and 12.32, respectively for groups T1, T2 and T3 (Table 4.3). The DMI (total, as per cent body weight and per kg metabolic body weight) for all three diets was similar. While some of the previous studies reported no effect of supplementation of SRNP on DMI, (Tedeschi *et al.*, 2002; Galo *et al.*, 2003; Edward *et al.*, 2009; Silveira *et al.,* 2012), and few others reported increased DMI with the substitution of urea by SRNP in the diet (Owens *et al.*, 1980; Xin *et al.*, 2010). Xin *et al.* (2010) stated that, the DMI of cows fed the polymer coated urea diet was approximately 12.8 per cent greater ($P<0.02$) than that of the feed grade urea diet whereas, others (Van Horn *et al.,* 1971 and Santos *et al*., 2011) reported decreased intake of DM with inclusion of slow release urea in high yielding cows. The results of the present study corroborated with the recent findings of Madhura *et al*. (2014), who observed no difference in the roughage or total DMI of cows fed a SRNP supplement, replaced to urea (1.5 per cent) in dairy cows fed straw based diets.

5.3 NDF and ADF intake

There were no significant differences in both NDF and ADF intake (total and as per cent body weight) among three treatment groups (Table 4.3). The NDF percentages in the complete diet were 49.1, 49.2 and 49.0, respectively for T1, T2 and T3 groups. Similarly, the ADF percentages in the total diet were 38.2, 38.2 and 38.2 for T1, T2 and T3, respectively. In order to maintain normal fat percentage; the ARC (1984) stipulates that, the diet of dairy cattle yielding 15 kg of milk per day should contain a minimum of 28 per cent NDF and 21 per cent ADF. Since, the average daily milk yield of the experimental cows was 11.1 kg, the intake of NDF or ADF of all the treatment groups in this study was quite adequate and at the recommended levels of ARC (1984). These results were similar to the findings of Edward *et al.* (2009), Xin *et al.* (2010) and Madhura *et al.* (2014), who also observed similar intake between urea and SRNP supplemented diets.

5.4 Energy intake

The respective energy intake for animals in each treatment group was estimated using values of energy in finger millet straw, corn silage and CFM (Table 4.2). The energy requirements were calculated and provided in the diets to meet the maintenance requirement and milk production (4 per cent FCM yield). The intake of energy in the groups T1, T2 and T3 was about 2 to 4 MJ of ME lower than the stipulation of ARC (1984) (Table 4.7), which could be due to difference in the values obtained in analytical procedures. Nevertheless, the energy intake was adequate, as reflected by the increase in body weight and the body condition score of cows in all the three treatment groups.

5.5 Protein intake

The CP intake was higher in all the treatment groups compared to specifications of the ARC (1984) (Table 4.7). Since, protein content of the T3 diet was 3.4 per cent higher than T1 or T2 group, the intake of protein in T3 was 237 g higher than the other two groups of cows ($P \leq 0.05$). Since the diets were formulated to meet the RDP and the soluble protein requirement of the cows, the higher UDP content of the feed ingredients obviously resulted in higher protein intake by the cows.

The RDP intake of cows in all the experimental groups were adequate as stipulated by the ARC (1984). While the intake of RDP was marginally higher (about 70 to 80 g) in T1 and T2 groups, the intake was 293 grams higher in T3 group. In view of the fact that the optimum requirement of RDP is vital for meeting the requirement of microbes, the RDP intake of cows in all the treatment groups was assured and provided in excess of the requirement. The intake of UDP was similar in all the three group of animals. The intake of UDP far exceeded the requirement, providing 300 to 350 g in excess of the recommendation (ARC, 1984). The ARC (1984) stipulates that, in low producing animals (up to 25 kg milk per day) RDP would meet the protein requirement through the microbial protein synthesised in the rumen and therefore, the UDP requirement is minimal (60-70 g per day) (Table 4.7). However, in a practical diet formulation, it is not possible to provide less than 250 g UDP and consequently, the higher UDP amounts provided by all the three diets in the experiment.

The buffer soluble protein content (per cent of CP) in diets T1, T2 and T3 was 39.4, 32.3 and 41.1, respectively. Buffer soluble protein is the rapidly degraded fraction of the RDP and serve as an immediate source of nitrogen for microbes (Van Soest, 1994). The optimum level of soluble nitrogen in the diet of lactating dairy cows is reported to be in the range of 25 to 40 % of total protein (Majdoub *et al.* 1978; Sahlu *et al.*, 1984; Krishnamoorthy and Chandrapal Singh, 1985). Deficiency of soluble nitrogen in the diet lead to decreased efficiency of nitrogen utilisation and decreased milk yield (Davis, 1978; Majdoub *et al.*, 1978). Urea is a source of soluble N (100 per cent soluble nitrogen) and is rapidly degraded in the rumen. In most situations, the solubility of N in SRNPs is assumed to be the same as urea, but solubility can vary widely depending on the polymerisation of N in SRNP. The N content of SRNP used in this study is 42 per cent and the soluble N content (determined by Krishnamoorthy *et al.*, 1982) was 51.1 per cent. In diet T2, the urea (2 per cent in diet T1) is replaced by SRNP on isonitrogenous basis (2 per cent) and therefore it can be expected that the soluble nitrogen content of the diet T2 to be lower than T1. In Diet T3, the urea is replaced by SRNP on isosoluble nitrogen basis (4 per cent) and hence, the solubility expected to be similar to diet T1. The estimated soluble N content of diet T1, T2 and T3 was 39.4, 32.3 and 41.1, respectively. Although, the soluble N content varied among diets, adequate levels of soluble N (more than 30 per cent) were maintained in all the three diets.

5.6 Body weight gain

The body weight changes of experimental animals in T1, T2 and T3 are presented in Table 4.5. There was no significant difference in the body weight changes (238g in T1, 214g in T2 and 196g in T3) among treatment groups indicating that supplementation of SRNP in the diet did not bring any significant difference in weight gain of animals. Oltjen *et al.* (1969), Thompson *et al.* (1972), Tedeschi *et al.* (2002), Galo *et al.*(2003) and Umashankar (2011) also reported that supplementation of SRNP had no effect on the average daily gain in animals. A marginal increase in body weight gain in all the groups indicated that the cows were on positive energy and nitrogen balance.

5.7 Body condition scores

The body condition score is an indication of energy state of the body, to reflect the plane of nutrition of the animal, and is usually correlated with body weight of the animals. In the present study, the change in the body condition score for the animals in the treatment groups T1, T2 and T3 were 0.49, 0.41 and 0.31, respectively, with no significant difference in body condition score among treatment groups. The increased body condition score indicated that the cows were on positive energy balance.

5.8 Milk yield

The mean FCM yield of treatment groups T1, T2 and T3 were 10.96, 10.67 and 10.45 kg per day, respectively (Table 4.4). There was no difference in FCM yield among T1, T2 and T3. Galo *et al.* (2003), Golombeski *et al.* (2006), Xin *et al.* (2010) and Santiago *et al.* (2015) reported that feeding lactating dairy cows with a diet including slow release urea had no effect on milk production. However, there have also been reports of trends for increased milk yield when slow release urea product or coated urea replaced urea in the diets of dairy cattle diets (Garg *et al*., 2007; Inostroza *et al*., 2010; Cherdthong *et al*., 2010) where as Calomeni *et al.* (2015) reported decreased milk yield on feeding of polymer coated urea.

5.9 Milk composition

5.9.1 Milk fat

The mean fat content (per cent) for the treatment groups T1, T2 and T3 was 3.89, 3.88 and 3.88. The fat yield (kg/day) was 0.44, 0.43 and 0.42, respectively (Table 4.4). There was no difference in fat content among treatment groups. Similarly there were no differences in the fat yield among T1, T2 and T3 groups. Golombeski *et al.* (2006), Inostroza *et al*. (2010) and Madhura *et al.* (2014) found no significant difference in the yield of fat between urea fed group and SRNP fed groups. In contrast Tedeschi *et al.* (2002) reported that Optigen (a slow release urea product) had a beneficial effect on the milk fat yield of lactating cattle. Depending on the particular feed regimen, the milk fat yield varied form a small increase to as high as 14%, based on the milk fat content. Highstreet *et al.* (2010) stated that feeding a slowly rumen released urea increased milk fat in early lactation in high producing dairy cows.

5.9.2 Solids not fat

In the present study, the SNF content (per cent) and yield (kg per day) of treatment groups T1, T2 and T3 were 9.52; 1.08, 9.46; 1.05 and 9.47; 0.1.03, respectively (Table 4.4). The SNF content and yield for the three groups were not significantly different. Previous reports have also found no significant difference in solids not fat content between the slow release urea and SBM diets (Abreu *et al.*, 2014; Madhura *et al.*, 2014; Santiago *et al.*, 2015).

5.9.3 Milk protein

The mean protein content (per cent) and yield (kg per day) of treatment groups T1, T2 and T3 were 3.32, 0.38; 3.12, 0.35 and 3.16, 0.34, respectively (Table 4.4). The difference in protein content among the treatment groups was not statistically significant. Protein yield was also not statistically significant among T1, T2 and T3. While Galo *et al.* (2003), Golombeski *et al.* (2006) and Inostroza *et al.* (2010) stated that, the dietary treatment with slow release urea had no effect on milk protein percentage, whereas Calomeni *et al.* (2015) noticed decrease in milk protein content in cows fed polymer coated urea compared to non urea fed cows. Xin *et al.* (2010) stated that milk protein percentage and yield were higher for cows receiving the polymer coated urea diet than the feed grade urea diet but were similar to the SBM diet. Tedeschi *et al.* (2002), Highstreet *et al.* (2010) and Goncalves *et al.* (2014) also reported that milk protein percentage was unaffected by treatment with slow release urea.

5.10 Apparent digestibility of nutrients

The apparent digestibility (per cent) of T1, T2 and T3 experimental diets are presented in Table 4.6. There was no significant difference in the apparent digestibility of various nutrients viz. DM, OM, CP, NDF and ADF among the three experimental diets. The digestible organic matter (per cent DOM, comparable to TDN) content of T1, T2 and T3 diets was 62.25, 65.37 and 60.50, respectively. Edward *et al.* (2009) and Xin *et al.* (2010) also reported similar findings with no significant difference in digestibility of DM, OM, CP, NDF or ADF in the diets containing slow release urea product as compared to uncoated urea, while Cherdthong *et al.* (2010) reported higher digestibility of NDF on supplementation of $CaSO_4$ based urea. Findings of the digestion trial in this study indicated that the incorporation of SRNP had no effect on the digestibility of nutrients in the diet.

The overall effect of replacing urea by SRNP, either on milk yield (total or fat corrected milk) or the milk constituents (per cent or yield) in this study indicated that, substitution on isonitrogenous or isosoluble nitrogen basis has no effect on the lactational performance. Ideally, an improved utilisation of nitrogen in the rumen was expected with SRNP supplementation in diets T2 and T3, due to sustained release of nitrogen or due to supply of isosoluble nitrogen with higher level of supplementation in T3 group. Lack of response may be explained partly by the fact that the amount of RDP provided in the diet was adequate and well above the minimum requirement as specified by ARC (1984) (Table 4.7). Balancing the soluble nitrogen in diet T3 with that of diet T1 was not beneficial, probably due to higher concentration of soluble nitrogen with corn silage (41.2), a basal roughage used in the experiment. In a fresh silage, the soluble nitrogen can be expected to be much higher than the estimated value, since the drying of silage during processing of feed for analyses would decrease the solubility (Van Soest, 1982) and therefore, it might be expected that the amount of soluble nitrogen provided in all the three diets exceeded the minimum expected level of 30 per cent (39.4, 32.3 and 41.1 in T1, T2 and T3 diet, respectively). Therefore, it may be concluded that the supplementation of SRNP at higher level has no advantage and it would only be a waste and uneconomical.

Comparing the lactational performance of animals in different experimental groups, it may be inferred that the feeding of urea (T1) as non protein nitrogen supplement is still a best option (not withstanding the fact that the dairy farmers have rejected feeding of urea due to fear of toxicity and the SRNP is therefore an alternative option) especially considering the fact that the SRNPs are at least 20 times more expensive compared to urea on unit N cost basis. Comparing diets T2 and T3, replacing urea by supplementing the SRNP (used in this study, as Optigen II), on isonitrogenous basis would suffice the RDP, including the soluble protein requirement of cows. Therefore, it was concluded that feeding of SRNP has no advantage over urea, however, SRNP can replace urea in diet without affecting the performance of lactating dairy cows. Further, replacing urea with SRNP *per se* (per cent) basis would suffice and a higher level of feeding is unwarranted.

The results of the present study however, should be extrapolated to other feeding management systems with caution. For example, lack of response due to supplemental SRNP in diets T2 or T3, may be due to the corn silage used as a basal diet in this study, which has provided adequate amounts of soluble N as stipulated in the diets. At 13 per cent CP provided in the diets, the RDP and soluble protein would supply as much as more ammonia and amino acids to rumen micro-organisms than they can utilise (Van Soest, 1982). Further, the particular SRNP compound used in the study, with the total N or soluble N content would have met the N requirement of rumen of low milk producing (about 11 kg per day) cows.

Summary

VI. SUMMARY

This study was undertaken to evaluate the effect of feeding slow release nitrogen product (SRNP) on the lactation performance of crossbred dairy cows. This objective was achieved by conducting a lactation trial using crossbred dairy cows fed three treatment diets viz. T1 containing 2.0 per cent urea in the diet, T2, containing SRNP (2.0 per cent), replacing urea on isonitrogen basis and T3 diet, containing SRNP (4.0 per cent), replacing urea on isosoluble nitrogen basis, and comparing the lactational performance (milk yield and milk constituents). The SRNP used in the study was a polymer coated urea compound containing 42 per cent total N with 52.1 per cent soluble N. The lactation trial was followed by a digestion trial conducted by grab sampling method, to estimate the digestibility of nutrients in the diets.

Eight crossbred cows in mid-late lactation were used in a Youden latin square design. The diet of the experimental cows comprised corn (*Zea mays*) silage and finger millet (*Eleucine coracana*) straw as roughage and a compounded feed mixture (CFM) containing known ME and crude protein (CP) content. The individual cows in the experiment were allocated to one of the three dietary treatments. All the experimental cows were fed diets with balanced energy and protein (RDP, UDP) as stipulated by ARC (1984) and offered same management throughout the study.

There was no difference in the feed dry matter intake, milk yield (total or 4 per cent FCM) or milk constituents among the treatment groups. The total milk yield and 4 per cent FCM yield (kg per day) for T1, T2 and T3 groups were 11.37, 10.96; 11.11, 10.67 and 10.89, 10.45, respectively. The SNF (9.52, 9.46 and 9.47 per cent for T1, T2 and T3, respectively), protein (3.32, 3.12 and 3.16 per cent for T1, T2 and T3, respectively), fat (3.89, 3.88 and 3.88 for T1, T2 and T3, respectively), and lactose (5.48, 5.64 and 5.57 per cent for T1, T2 and T3, respectively) in the milk of cows of three experimental groups were not significantly different.

The results of the digestion trial indicated that the digestibility of nutrients were not significantly different among the treatment groups. The percentage digestibility of diets in T1, T2 and T3 groups for DM, OM, CP, NDF and ADF were 54.03, 65.88, 62.87, 64.80 and 49.89; 58.84, 69.22, 64.68, 65.87 and 55.57, and 51.05, 64.03, 64.33, 56.66 and 48.35 respectively. Similar digestibility of nutrients in the diet of three experimental groups indicated that the supplementation of SRNP had no influence on the utilization of nutrients in the lactating dairy cows.

Data on the milk yield and milk composition of the experimental cows suggests that substitution of slow release nitrogen product for urea in the diet on isonitrogenous basis or isosoluble nitrogen basis as having no beneficial effects on the lactation performance of crossbred dairy cows.

Comparing the performance of T1 and T2, it was concluded that feeding of SRNP has no advantage over urea as a non protein nitrogen source. Urea as a non protein nitrogen supplement is still a best option especially considering the fact that the SRNPs are at least 20 times more expensive compared to urea on unit N cost basis. Since the dairy farmers have rejected feeding of urea due to fear of toxicity, SRNP could be therefore an alternative option. In a feeding management system, comprising corn silage, finger millet straw and a compounded feed mixture in the diet of dairy cows, feeding

SRNP to replace urea on isosoluble nitrogen is not advantageous. It was concluded that in the diet of dairy cows, SRNP can replace urea without affecting the performance of lactating dairy cows. Further, feeding of SRNP on weight (per cent) basis would suffice and a higher level of feeding is unwarranted.

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Abstract

VIII. ABSTRACT

A study was undertaken to evaluate the effect of feeding slow release nitrogen product (SRNP) on the lactation performance of crossbred dairy cows. Eight crossbred cows in mid-late lactation were used in a Youden latin square design. Treatment diets were T1 containing 2.0 per cent urea in the concentrate portion of diet, T2, containing SRNP (2.0 per cent), replacing urea on isonitrogen basis and T3 diet, containing SRNP (4.0 per cent), replacing urea on isosoluble nitrogen basis. The SRNP used in the study was a polymer coated urea compound containing 42 per cent total N with 52.1 per cent soluble N. The diet of the experimental cows comprised corn (*Zea mays*) silage and finger millet (*Eleucine coracana*) straw as roughage and a compounded feed mixture. There was no difference in the feed dry matter intake, milk yield (total or 4 per cent FCM) or milk constituents among the treatment groups. The total milk yield and 4 per cent FCM yield (kg per day) for T1, T2 and T3 groups were 11.37, 10.96; 11.11, 10.67 and 10.89, 10.45, respectively. The SNF (9.52, 9.46 and 9.47 per cent for T1, T2 and T3, respectively), protein (3.32, 3.12 and 3.16 per cent for T1, T2 and T3, respectively), fat (3.89, 3.88 and 3.88 for T1, T2 and T3, respectively) and lactose (5.48, 5.64 and 5.57 per cent for T1, T2 and T3, respectively) contents in the milk of cows of three experimental groups were not significantly different. Similar digestibility of nutrients in the diet of three experimental groups indicated that, the supplementation of SRNP had no influence on the utilization of nutrients in the lactating dairy cows. Comparing the lactational performance, feeding of SRNP has no advantage over urea as a non protein nitrogen source. In a feeding management system, comprising corn silage, finger millet straw and a compounded feed mixture in the diet of dairy cows, feeding SRNP to replace urea on isosoluble nitrogen is not advantageous. It was concluded that in the diet of dairy cows, SRNP can replace urea without affecting the performance of lactating dairy cows.

Appendices

APPENDIX-I

Average feed dry matter intake (kg/d) of cows in different treatment groups during the experimental period

Cow no.	T1	T2	T3
P1	12.11	12.39	12.32
P2	12.72	12.78	12.75
P19	12.72	12.78	12.68
P21	12.17	11.73	12.25
P24	11.89	12.29	12.02
P28	12.14	11.88	12.14
P30	12.44	12.63	12.05
P37	13.09	13.12	12.86

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-II

Average feed dry matter intake (per cent of body weight) of cows in different treatment groups during the experimental period

Cow no.	T1	T2	T3
P1	2.576	2.550	2.573
P2	2.247	2.282	2.326
P19	2.717	2.749	2.686
P21	2.899	2.660	2.830
P24	2.378	2.392	2.298
P28	2.561	2.475	2.638
P30	3.035	3.205	2.875
P37	3.037	3.095	3.077

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-III

Average feed dry matter intake (g) (per kg metabolic body weight) of cows in different treatment groups during the experimental period

Cow no.	T1	T2	T3
P1	119.9	119.7	120.4
P2	109.6	111.0	112.5
P19	126.4	127.7	125.2
P21	131.2	121.9	129.1
P24	112.5	113.9	109.9
P28	119.5	115.9	122.2
P30	136.6	142.8	130.1
P37	138.4	140.5	139.1

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-IV

Average NDF intake (kg per day) of cows in different treatment groups during the experimental period

Cow no.	T1	T2	T3
P1	5.899	6.077	5.950
P2	6.156	6.118	6.129
P19	6.143	6.194	6.195
P21	6.036	5.872	6.017
P24	5.868	6.104	5.942
P28	6.026	5.876	5.988
P30	6.150	6.269	5.971
P37	6.490	6.488	6.364

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-V

Average NDF intake (per cent body weight) of cows in different treatment groups during the experimental period

Cow no.	T1	T2	T3
P1	1.255	1.250	1.242
P2	1.088	1.092	1.118
P19	1.313	1.332	1.312
P21	1.437	1.331	1.390
P24	1.174	1.188	1.136
P28	1.271	1.224	1.302
P30	1.500	1.591	1.425
P37	1.506	1.530	1.523

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-VI

Average ADF intake (kg per day) of cows in different treatment groups during the experimental period

Cow no.	T1	T2	T3
P1	4.635	4.757	4.720
P2	4.883	4.903	4.892
P19	4.881	4.911	4.872
P21	4.672	4.493	4.700
P24	4.552	4.722	4.606
P28	4.658	4.549	4.653
P30	4.781	4.860	4.619
P37	4.874	4.886	4.779

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-VII

Average ADF intake (per cent body weight) of cows in different treatment groups during the experimental period

Cow no.	T1	T2	T3
P1	0.9862	0.9787	0.9854
P2	0.8627	0.8755	0.8927
P19	1.0430	1.0561	1.0321
P21	1.1123	1.0189	1.0854
P24	0.9105	0.9187	0.8807
P28	0.9826	0.9478	1.0116
P30	1.1661	1.2335	1.1025
P37	1.1308	1.1525	1.1433

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-VIII

Body weight (kg) of cows in different treatment groups during the experimental period

Cow No.	T1	T2	T3
P1	474	486	479
P2	565	559	554
P19	472	468	476
P21	427	434	431
P24	473	508	511
P28	504	466	469
P30	407	398	410
P37	431	427	423

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-IX

Milk yield (kg) of cows in different treatment groups during the experimental period

Cow No.	T1	T2	T3
P1	11.2	9.9	10.7
	11.6	9.9	10.3
	11.0	10.2	10.5
P2	8.18	9.0	8.8
	8.15	9.0	8.8
	8.34	9.0	8.9
P19	12.7	13.4	11.2
	11.8	12.7	10.9
	12.4	12.9	13.4
P21	14.2	11.0	13.4
	14.4	11.2	13.2
	14.0	11.5	13.4
P24	8.7	8.0	7.4
	8.4	7.7	7.2
	8.3	7.6	7.4
P28	7.8	6.7	7.0
	7.5	6.7	6.7
	7.4	7.0	7.0
P30	13.5	14.8	13.2
	13.2	15.1	12.8
	13.0	14.7	13.3
P37	16.1	16.2	15.7
	15.5	16.3	15.3
	15.6	16.0	15.0

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-X

Four per cent fat corrected milk yield (kg/day) of cows in different treatment groups during the experimental period

Cow no.	T1	T2	T3
P1	11.77	10.55	10.83
	12.21	10.02	10.43
	11.41	10.74	10.67
P2	8.68	9.57	9.407
	8.62	9.45	9.302
	8.74	9.35	9.461
P19	12.93	13.86	11.67
	12.10	13.23	11.34
	12.74	13.42	14.41
P21	13.09	10.42	12.21
	13.23	10.68	11.91
	12.59	11.02	12.13
P24	8.817	8.00	7.911
	8.312	7.884	7.632
	8.524	7.679	7.666
P28	8.654	7.273	7.441
	8.288	7.022	7.082
	8.255	7.546	7.410
P30	12.33	13.82	12.41
	12.15	14.04	11.99
	11.99	13.60	12.38
P37	12.79	12.38	12.14
	12.20	12.36	11.51
	12.56	12.21	11.56

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-XI

Corrected lactometer reading of milk of cows in different treatment groups during the experimental period

Cow No.	T1	T2	T3
P1	29.0	29.0	29.0
	29.7	29.0	29.4
	29.0	29.7	29.0
P2	29.6	28.4	28.0
	28.0	28.6	29.6
	29.7	28.5	29.7
P19	30.9	30.6	31.6
	31.4	31.6	30.6
	31.6	31.4	31.4
P21	29.6	29.6	28.3
	28.5	28.5	28.5
	29.4	29.4	28.3
P24	29.1	28.7	29.1
	30.0	29.8	30.0
	29.5	28.6	29.5
P28	31.1	31.1	31
	30.6	30.6	31.5
	31.2	31.2	30.6
P30	29.2	30.1	30.1
	28.3	28.8	28.8
	28.5	29.7	29.7
P37	27.1	27.1	26.5
	26.5	26.5	26.3
	25.5	25.5	25.3

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-XII

Total solids content (per cent) in milk of cows in different treatment groups during the experimental period

Cow No.	T1	T2	T3
P1	13.32	13.02	13.73
	13.59	13.23	13.53
	13.60	13.86	13.79
P2	13.63	13.63	13.73
	13.88	14.01	13.72
	13.66	13.94	14.14
P19	14.25	14.4	14.94
	15.41	14.43	14.69
	14.57	14.62	14.63
P21	12.22	13.01	11.57
	12.28	12.77	12.36
	12.23	12.61	12.52
P24	13.98	13.2	13.68
	14.08	13.52	13.68
	13.80	13.85	14.49
P28	15.20	15.08	15.54
	15.84	14.82	14.87
	15.46	14.55	14.75
P30	12.64	12.69	12.91
	12.94	12.67	12.8
	12.81	12.69	13.05
P37	10.67	09.96	10.67
	10.74	10.14	10.21
	11.14	13.42	10.26

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-XIII

Fat content (per cent) in milk of cows in different treatment groups during the experimental period

Cow No.	T1	T2	T3
P1	4.34	4.44	4.08
	4.35	4.08	4.08
	4.25	4.35	4.11
P2	4.41	4.42	4.46
	4.38	4.33	4.38
	4.32	4.26	4.42
P19	4.12	4.23	4.28
	4.17	4.28	4.27
	4.18	4.27	4.50
P21	3.48	3.65	3.41
	3.46	3.69	3.35
	3.33	3.72	3.37
P24	4.09	4.00	4.46
	3.93	4.16	4.40
	4.18	4.07	4.24
P28	4.73	4.57	4.42
	4.70	4.32	4.38
	4.77	4.52	4.39
P30	3.42	3.56	3.60
	3.47	3.53	3.58
	3.48	3.50	3.54
P37	2.63	2.43	2.49
	2.58	2.39	2.35
	2.70	2.42	2.47

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX XIV

Solids-not-fat (per cent) in milk of cows in different treatment groups during the experimental period

Cow no.	T1	T2	T3
P1	8.98	8.58	9.65
	9.24	9.15	9.45
	9.35	9.51	9.68
P2	9.22	9.21	9.27
	9.50	9.68	9.34
	9.34	9.68	9.72
P19	10.13	10.17	10.66
	11.24	10.15	10.42
	10.39	10.35	10.13
P21	8.74	9.36	8.16
	8.82	9.08	9.01
	8.90	8.89	9.15
P24	9.89	9.20	9.22
	10.15	9.36	9.28
	9.62	9.78	10.25
P28	10.47	10.51	11.12
	11.14	10.5	10.49
	10.69	10.03	10.36
P30	9.22	9.13	9.31
	9.47	9.14	9.22
	9.33	9.19	9.51
P37	8.04	7.53	8.18
	8.16	7.75	7.86
	8.44	11.0	7.79

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-XV

Protein content (per cent) in milk of cows in different treatment groups during the experimental period

Cow no.	T1	T2	T3
P1	2.98	2.99	3.03
	3.34	2.92	3.06
	3.47	2.92	3.03
P2	3.07	3.23	3.32
	3.13	3.21	2.88
	3.12	3.30	3.32
P19	3.86	2.84	3.92
	3.89	2.83	3.99
	3.78	2.90	3.90
P21	3.42	2.77	2.58
	3.56	2.63	2.62
	3.75	2.60	2.73
P24	3.56	3.74	3.34
	3.42	3.57	3.37
	3.75	3.61	3.29
P28	3.76	4.16	3.95
	4.14	4.35	3.92
	3.81	3.97	3.82
P30	3.15	3.34	2.84
	2.99	3.04	2.96
	3.17	3.00	2.98
P37	2.24	2.34	2.23
	2.14	2.23	2.42
	2.14	2.36	2.28

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-XVI

Ash content (per cent) in milk of cows in different treatment groups during the experimental period

Cow no.	T1	T2	T3
P1	0.743	0.679	0.731
	0.690	0.753	0.709
	0.702	0.762	0.711
P2	0.630	0.644	0.686
	0.725	0.689	0.674
	0.714	0.645	0.681
P19	0.741	0.804	0.791
	0.726	0.703	0.796
	0.715	0.730	0.784
P21	0.667	0.667	0.716
	0.678	0.684	0.640
	0.660	0.698	0.632
P24	0.736	0.698	0.747
	0.692	0.749	0.755
	0.731	0.674	0.725
P28	0.731	0.683	0.748
	0.780	0.506	0.737
	0.760	0.611	0.694
P30	0.670	0.766	0.769
	0.720	0.710	0.790
	0.692	0.718	0.766
P37	0.764	0.680	0.863
	0.759	0.767	0.747
	0.769	0.750	0.760

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis

APPENDIX-XVII

Lactose content (per cent) in milk of cows in different treatment groups during the experimental period

Cow no.	T1	T2	T3
P1	5.257	4.911	5.889
	5.210	5.477	5.681
	5.178	5.828	5.939
P2	5.520	5.336	5.264
	5.645	5.781	5.786
	5.506	5.735	5.719
P19	5.529	6.526	5.949
	6.624	6.617	5.634
	5.895	6.720	5.446
P21	4.653	5.923	4.864
	4.582	5.766	5.750
	4.490	5.592	5.788
P24	5.594	4.762	5.133
	6.038	5.041	5.155
	5.139	5.496	6.235
P28	5.979	5.667	6.422
	6.220	5.644	5.833
	6.120	5.449	5.846
P30	5.400	5.024	5.701
	5.760	5.390	5.470
	5.468	5.472	5.764
P37	5.036	4.510	5.087
	5.261	4.753	4.693
	5.531	7.890	4.750

T-1 = 2 per cent Urea diet; T-2 = Urea replaced by 2 per cent SRNP on isonitrogen basis

T-3 = Urea replaced by 4 per cent SRNP on isosoluble nitrogen basis