Comparison between conventional urea and slow-release urea on concentration of ammonia in the rumen: A meta-analysis

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Abstract. Urea is a source of Non-Protein Nitrogen (NPN). The utilization of urea in the ration is useful for increasing digestibility, dry matter intake, and increasing protein content. This study aims to compare the utilization of conventional urea and Slow Release Urea (SRU) to reduce ammonia concentration by in vivo study using meta-analysis. A total of 13 studies were obtained that consisted of 41 data points. The parameters in this study include pH, Dry Matter Intake (DMI), Volatile Fatty Acid (VFA), ammonia concentration, and nitrogen intake. The database compiled was statistically analyzed using a mixed model method. Different studies were considered as random effects, and the level of urea was treated as fixed effects. The model statistics used were the p-values and the Akaike information criterion. The significance of an effect was stated when its p-value was <0.05. The results revealed that level SRU and conventional urea had a significant linear effect on ammonia concentration, DMI, VFA, pH and nitrogen intake. However, the effect of giving SRU was better than conventional urea. It can be concluded that SRU can control ammonia concentration, DMI, VFA, pH and nitrogen intake better than urea.

1. Introduction

Urea is one of the commonly used sources of NPN (Non-protein Nitrogen). Urea is intended as a substitute for protein sources, especially in ruminants receiving basal feed with relatively lower nutritional quality. Urea supplementation in ruminants has several benefits: increasing the efficiency of microbial protein synthesis and N production by rumen microbes [1] because urea contains 46.7% nitrogen supply, it improves the efficiency of microbial protein synthesis [2] causing a synchronization between the ammonia source and the availability of VFA energy in the rumen. However, excessive use of conventional urea on ruminants has a negative impact. Excessive use of urea can cause poisoning of livestock [3]. It can happen because urea is rapidly released (easily degraded) in the rumen, triggering an uncontrolled spike in ammonia levels in the blood.

The disadvantage of using conventional urea is that it is quickly degraded in the rumen to ammonia, especially in the first hour after administration [4]. Therefore, treatment is needed to make urea less prone to degradation in the rumen.

Slow-Release Urea (SRU) is one of the commonly used methods to inhibit the rate of ammonia degradation. The synchronization stage between ammonia levels and VFA energy sources is achieved, resulting in more optimal microbes in the rumen in microbial protein synthesis. A meta-analysis study has been conducted previously to evaluate SRU administration effect on beef cattle and dairy cattle [5]. However, research on the comparison between conventional urea and SRU on the performance of
ruminants has not been carried out. As a result, using a mixed model methodology, this study evaluates the effects of administering conventional urea and SRU by combining data from many various publications.

2. Materials and methods

2.1. Research design
This research was conducted by searching for papers and literature data related to the use of conventional urea and Slow Release Urea (SRU) in vivo in ruminants. The literature obtained comes from Scopus, Science Direct, and Google Scholar in 1975-2021. The keywords used in the literature search were "Slow Release urea" and "rumen." Based on these keywords, 72 papers were found, then further selection was carried out by sorting out research conducted on large ruminants and in vivo studies. Based on the selection results, there were 13 relevant studies used in this study [6–18]. A statistical summary of the database is presented in Table 1 and Table 2. The parameters observed in this study include volatile Fatty Acid (VFA), pH, ammonia, Dry matter Intake (DMI), Nitrogen Intake (NI), and Blood Urea Nitrogen (BUN). All major ruminant categories were included in the database, including steers and heifers.

Table 1. Statistical summary of the database regarding the effects of conventional urea on concentration of ammonia in the rumen.

| Parameter | Unit     | n  | Mean  | SD    | Minimum | Maximum |
|-----------|----------|----|-------|-------|---------|---------|
| VFA       | mmol/l   | 11 | 92.25 | 20.76 | 54.50   | 115.30  |
| pH        |          | 10 | 6.55  | 0.44  | 5.77    | 7.00    |
| NH₃       | mg/l     | 17 | 136.43| 78.79 | 34.20   | 253.80  |
| DMI       | kg/day   | 16 | 10.58 | 7.64  | 2.54    | 28.42   |
| NI        | g/day    | 11 | 147.65| 47.73 | 87.70   | 239.00  |

Table 2. Statistical summary of the database regarding the effects of slow release urea on concentration of ammonia in the rumen.

| Parameter | Unit     | n  | Mean  | SD    | Minimum | Maximum |
|-----------|----------|----|-------|-------|---------|---------|
| VFA       | mmol/l   | 15 | 97.63 | 20.71 | 55.70   | 119.20  |
| pH        |          | 14 | 6.42  | 0.39  | 5.75    | 6.95    |
| NH₃       | mg/l     | 20 | 126.55| 54.20 | 40.20   | 210.30  |
| DMI       | kg/day   | 21 | 10.51 | 6.84  | 2.87    | 28.72   |
| NI        | g/day    | 14 | 156.06| 45.98 | 92.50   | 245.00  |

2.2. Data analysis
The statistical analysis methodology used in this study used a mixed model [19,20]. In this study, study differences were considered a random effect, while the level of addition of conventional urea and SRU was treated as a fixed effect. Initially, the quadratic mixed-model method was applied to see the effect of conventional urea and SRU on the experimental parameters. When the quadratic mixed model is not significant (P<0.05), then the linear mixed model is used.

3. Results and discussion

3.1. Ammonia concentration
The study results showed that the administration of conventional urea and SRU affected (P<0.01) the concentration of rumen ammonia (Table 3 and Table 4). Giving conventional urea has an impact on the occurrence of spikes in ammonia levels. It is different from the administration of SRU, which has a much lower ammonia concentration. It happens because in SRU supplementation, urea is protected by active substance. It can be protected by rumen microbes, especially one hour after feeding. This study
is in line with the results of research [6] which showed that administration of Optigen brand SRU to dairy cows resulted in a lower rumen ammonia concentration of 46.62 mg/l compared to conventional urea supplementation of 52.38 mg/l.

Table 3. Effects of conventional urea on concentration of ammonia in the rumen

| Response parameter | Unit     | n   | Intercept | SE Intercept | Slope | SE Slope | P-Value | RMSE |
|--------------------|----------|-----|-----------|--------------|-------|----------|---------|------|
| VFA                | mmol/l   | 11  | 89.22     | 8.75         | 4.04  | 3.23     | <0.01   | 4.05 |
| pH                 |          | 10  | 6.5       | 0.19         | 0.04  | 0.04     | 0.02    | 0.07 |
| NH₃                | mg/l     | 17  | 110.13    | 27.22        | 14.67 | 5.96     | <0.01   | 23.64|
| DMI                | kg/day   | 16  | 9.38      | 2.47         | 0.2   | 0.31     | <0.01   | 0.3  |
| NI                 | g/day    | 11  | 158.69    | 20.62        | -6.68 | 4.98     | <0.01   | 7.67 |

Table 4. Effects of slow release urea on concentration of ammonia in the rumen

| Response parameter | Unit     | n   | Intercept | SE Intercept | Slope | SE Slope | P-Value | RMSE |
|--------------------|----------|-----|-----------|--------------|-------|----------|---------|------|
| VFA                | mmol/l   | 11  | 92.54     | 8.54         | 1.86  | 1.66     | <0.01   | 2.09 |
| pH                 |          | 10  | 6.46      | 0.18         | 0.006 | 0.02     | <0.01   | 0.06 |
| NH₃                | mg/l     | 17  | 104.76    | 18.77        | 5.18  | 2.76     | <0.01   | 23.48|
| DMI                | kg/day   | 16  | 9.21      | 2.61         | 0.28  | 0.31     | <0.01   | 0.37 |
| NI                 | g/day    | 11  | 165.61    | 24.51        | -4.38 | 4.49     | <0.01   | 11.16|

The disadvantage of conventional urea is rapid release. It is quickly degraded in the rumen to form ammonia, especially in the first hour after consumption [4]. Urea was able to increase the ammonia concentration 58% more than SRU [21]. It shows that SRU can inhibit ammonia release and effectively reduces the concentration of rumen ammonia when replacing conventional urea.

The results of a previous study Edwards et al. [21] on steers by comparing using SRU and feed grade urea on ruminal metabolite characteristics, DMI, and gain showed compared to feed grade urea, SRU was able to reduce ammonia concentrations and tended to increase the activity of urease enzyme. SRU can reduce the rate of release of ammonia from the rumen without affecting other metabolic activities. After SRU was given for 35 days, the results showed no activity from rumen microbes that adapted to SRU products. It shows that SRU will maintain its ability to slow down the ammonia degradation process in the rumen. This study shows that SRU can optimally utilize N supplementation to modulate ammonia production in the rumen and can be used to replace feed-grade urea with lower risk. SRU can be hydrolyzed more slowly to ammonia than conventional urea and potentially more efficiently by rumen microbes with the consequent reduction of ammonia concentration [22]. However, these results are different from other studies [7]. In this study, feed-grade urea and SRU had no different ammonia concentrations (P > 0.05). It could be due to the low availability of energy in the rumen. Energy can be a limiting factor in the growth of rumen microorganisms for animals fed urea-containing feed.

3.2. Total VFA
The study results showed that the administration of SRU had an impact (P<0.01) on decreasing the total concentration of VFA compared to conventional urea (Table 3 and Table 4). It happened because when SRU was given, the process of releasing ammonia was slower so that the synchronization between ammonia and VFA concentrations in forming microbial protein synthesis became more optimal. The findings of this investigation corroborate previous findings by Munoz et al. [6] showed that administration of SRU at a level of 0.42% in cannulated Holstein steers was proven to reduce the level of rumen degradation and total VFA. Total VFA decreased because there was a synchronization process between the SRU used in the study and the VFA source in the rumen, thus enabling rumen microbes to more optimally utilize ammonia and energy availability to form microbial protein.
In the results of research conducted by Munoz et al. [6], the use of SRU *in vivo* in steers was able to reduce the level of degradation and the molar concentration of total VFA, as well as increase the concentration of ammonia when the treatment was given feed containing urea, SRU, and Urea+SRU+AA. The decrease in ammonia concentration may occur because the use of Urea+SRU+AA causes the synchronization of energy available from the feed with nitrogen sources from Urea+SRU+AA.

### 3.3. Fermentability

The study results showed that conventional urea and SRU affected (P<0.05) on rumen pH (Table 3 and Table 4). In both treatments, SRU had a more negligible effect than the administration of urea. However, the effect of giving urea and SRU was still in the normal pH range. According to Suharti et al. [23], the normal pH range of the rumen is 6-7. Acidity levels that are too high or low will affect rumen microbial activity. According to Arora [24], rumen pH affects the process of rumen ammonia absorbance. The low rumen pH causes the absorbance process to be not optimal. The low pH causes many rumen microbes to die so that the ammonia absorption process does not run optimally.

The outcomes of this investigation corroborate prior studies by Kardava et al. [25] which showed that the administration of urea and urea-impregnated zeolite as slow-release urea in local lambs affected (P<0.05) on the rumen pH value. In this study, the lower rumen pH value occurred because zeolite could bind ammonia through its cation exchange capacity. Accordingly, a higher rumen pH occurred because the urea contained in the ration was a rapid release or easily hydrolyzed to form ammonia and increased rumen pH. Based on this, it may be inferred that the concentration of rumen ammonia is one of the factors that can increase the rumen pH value. According to Mlay et al. [26], the effect of urea on rumen pH can increase pH value due to the alkalinity of urea, or it can decrease rumen pH because of the impact of VFA production and its better fermentability in the rumen.

### 3.4. Dry matter and nitrogen intake

The analysis results showed that conventional urea and SRU affected (P<0.01) dry matter intake (Table 3 and Table 4). However, the effects of urea and SRU are relatively the same. The results of this analysis are in line with the results of research conducted by Riberio et al. [27], which showed that conventional urea and slow-release polymer-coated urea in beef cattle had an (P<0.01) on increasing DM intake. In this study, cattle treated with SRU and U+SRU had a much higher DM intake than other treatments without urea. The increase in DMI may occur because SRU is one of the high N source feeds, allowing SRU to provide adequate N to increase rumen fermentation, which has an impact on increasing DMI from hay (basal feed) compared to other treatments. According to Xin et al. [28], SRU supplementation can improve the intake of DM and other nutrients compared to conventional urea because SRU administration increases the activity of fibrinolytic bacteria resulting from the utilization of N and VFA energy sources by rumen microorganisms. However, giving urea can also have an impact on reducing DMI. According to Wilson et al. [29], the decrease in DMI occurred due to the administration of excessive urea resulting in intermediate metabolites from the high urea catabolism process. This urea administration will impact reducing DMI if given more than 20g/kg dry matter.

The results of the study showed that conventional urea and SRU affected N intake. Giving SRU and urea has an impact on decreasing N intake. These results are in line with the meta-analysis conducted by Salami et al. [5]. The analysis explained that giving SRU to dairy cows' production performance impacted decreasing (P<0.05) DMI and N intake. It happens because conventional urea and SRU are compounds that can be used to source Rumen Digestible Protein (RDP) [30]. However, the use of this urea has limitations. Namely, urea is rapid release or easily hydrolyzed in the rumen to form ammonia, resulting in a lack of synchronization between ammonia and energy sources. The consequence of these conditions is a decrease in protein production by rumen microbes, a decrease in N utilization efficiency (NUE and total N intake), and increased N excretion [31].
4. Conclusions

Administration of conventional urea and SRU affects ammonia concentration, DMI, VFA, pH and nitrogen intake. However, SRU is more able to control the hydrolysis of rumen ammonia than conventional urea.

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