Session 3 Utilizing the resources of the subtropics and tropics

The effect of temperature on the ammoniation of wheat straw by urea

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The aqueous ammoniation of wheat straw by urea, as affected by temperature and moisture level, was studied in a 4 × 2 × 6 factorial experiment. Treatments included temperatures of 4, 14, 24 and 35°C, moisture levels of 250 and 375 g/kg wheat straw, and treatment periods of 0, 1, 2, 4, 6 and 8 weeks.

Temperature and moisture levels significantly ($P \leq 0,01$) accelerated ammoniation, as reflected by increased *in vitro* OMD and total % N. Significant ($P \leq 0,01$) temperature × treatment period and moisture level × treatment period interactions, indicated that lower temperatures and moisture levels can partly be compensated for by a longer treatment period. Slow ammonia release at 4°C caused inefficient ammoniation at both moisture levels. Ammoniation became increasingly effective at higher moisture levels and higher temperatures, resulting in a significant ($P \leq 0,01$) interaction between temperature and moisture level.

Die invloed van temperatuur en vogpeil op die ammoniakbehandeling van koringstrooi deur 'n ureumoplossing is in 'n 4 × 2 × 6 faktoriaaleksperiment ondersoek. Behandelings het temperature van 4, 14, 24 en 35°C, vogpeile van 250 en 375 g/kg koringstrooi, en behandelingstye van 0, 1, 2, 4, 6 en 8 weke ingesluit.

Temperatuur en vogpeil het ammoniakbehandeling — soos weerspieël in die *in vitro* OM verteerbaarheid en die totale % N van die monsters — hoogsbetekenisvol ($P \leq 0,01$) versnel. Hoogsbetekenisvolle interaksies tussen temperatuur en behandelingstyd en vogpeil en behandelingstyd dui aan dat die stadiger reaksie by laer temperature en vogpeile gedeeltelik oorkom kan word deur 'n langer behandelingstyd. By 4°C was die behandeling relatief ondoeltreffend omdat daar onvoldoende hoeveelhede ammoniak uit ureum vrygestel is. By hoër temperature was die behandeling egter deurgaans meer doeltreffend by die hoër vogpeil, wat 'n hoogsbetekenisvolle ($P \leq 0,01$) interaksie tussen temperatuur en vogpeil tot gevolg gehad het.

Keywords: Ammoniation, urea, wheat straw, temperature, moisture level, treatment period, *in vitro* digestibility, nitrogen content

Chemical treatment of low-quality roughages as a method of upgrading crop residues is frequently investigated. Previous work at this institute (Kritzinger & Franck, 1981) and elsewhere (Hadjipanayiotou, 1982; Jayasuriya & Perera, 1982) identified aqueous ammoniation by urea as a promising technique. Despite being relatively safe, uncomplicated and inexpensive compared to other chemical treatments, this technique requires a long treatment-period. Thus the possibility of accelerating treatment by means of increased temperature has been investigated.

Materials and Methods

The investigation included temperature treatments of 4, 14, 24 and 35°C, at moisture levels of 250 and 375 g/kg wheat straw. Urea was added at 75 g/kg throughout. Treated straw was sealed in 96 airtight plastic bottles of 1000 ml for periods of 0, 1, 2, 4, 6 and 8 weeks. Samples were dried at 59°C in a fan-oven and subsequently analysed according to the *in vitro* technique (Engels & Van der Merwe, 1967) for organic matter digestibility (OMD). Total nitrogen content (%N) of the samples was determined by the Kjeldhal method. Standard statistical procedures for the analysis of a 4 × 2 × 6 factorial experiment with two replications were followed.

Results and Discussion

In vitro organic matter digestibility

Temperature, moisture level and treatment period, significantly ($P \leq 0,01$) affected OMD (Table 1), temperature × moisture level, temperature × treatment period and moisture level × treatment period interactions were also significant ($P \leq 0,01$). Treatment for one and two weeks at 35°C resulted in comparable OMD-values of approximately 45 and 52% obtained after eight weeks at 24°C for the moisture levels of 250 and 375 g/kg respectively. At 4°C reaction was slow, resulting in almost no improvement of OMD. The results are generally in agreement with those obtained on anhydrous ammoniation, published by Waagepetersen & Vestergaard Thomsen, (1977) and Sundstøl, Coxworth & Mowat (1978). Sundstøl *et al.* (1978), however, reported an improvement in OMD at low temperatures as well. The different findings may be due to addition of ammonia as such in an anhydrous

Table 1 The effect of temperature and moisture level on the % OMD of wheat straw ammoniated by urea, determined *in vitro*

Temperature	Moisture level	Treatment period (weeks)*			
°C	g/kg straw	1	2	4	8
4	250	35,9	37,7	40,1	40,1
	375	38,1	38,2	40,6	41,3
14	250	38,4	38,1	37,2	38,8
	375	38,6	43,0	44,1	43,5
24	250	40,2	38,3	41,0	45,2
	375	46,7	47,7	47,8	52,0
35	250	42,7	45,5	44,6	44,9
	375	53,1	54,3	51,3	51,5

SE mean for the analysis — 0,147

* The mean OMD-value (±SD) for the treatment period of 0 weeks was 37,4 ± 1,6 (n = 16). The values for 6 weeks of treatment were intermediate between 4 and 8 weeks, and have therefore been omitted.

treatment, while the urea treatment is dependent on the enzymatic release of ammonia from urea. The interaction between temperature and treatment period, indicating that lower temperatures can partly be compensated for by a longer treatment, also agrees with results obtained by Sundstøl, *et al.*, (1978) and Waagepetersen & Vestergaard Thomsen, (1977).

Treatment was faster and more effective at the higher moisture level, in agreement with results published by Kritzinger & Franck, (1981). The interaction between moisture level and treatment period indicates that the slow reaction at low moisture-levels can partly be overcome by a long treatment period. At 4°C no differences in OMD between moisture levels were observed, most likely due to the slow enzymatic release of ammonia. At higher temperatures ammoniation became increasingly more effective at the higher moisture level, resulting in the observed interaction between temperature and moisture level.

Total N-content

Temperature, moisture level and treatment period significantly ($P \leq 0,01$) affected % N (Table 2). All interactions were statistically significant ($P \leq 0,01$). Almost no urea seemed to be converted to ammonia at 4°C, in agreement with observations previously mentioned. The higher temperatures and moisture levels resulted in accelerated ammonia release, causing temperature × treatment period and moisture level × treatment period interactions. At 4°C nitrogen-loss tended to be less at the higher moisture level compared to the lower moisture level. At higher temperatures more urea was converted to ammonia at the higher moisture levels throughout, causing a temperature × moisture level interaction. At 35°C, however, nitrogen loss was much less compared to lower temperatures. Furthermore % N tended to increase at the higher temperatures and moisture levels after a treatment period of four weeks. These observations resulted in an interaction between temperature, moisture level and treatment period.

Table 2 The effect of temperature and moisture level on the % N in wheat straw ammoniated by urea

Temperature	Moisture level	Treatment period (weeks)*			
°C	g/kg straw	1	2	4	8
4	250	3,63	3,54	3,63	3,40
	375	3,77	3,73	3,71	3,59
14	250	3,71	3,78	3,41	3,15
	375	3,62	3,46	2,74	2,19
24	250	3,44	3,23	3,24	3,18
	375	2,39	1,56	1,75	2,14
35	250	3,55	3,53	3,54	3,56
	375	2,91	2,64	3,21	3,37

SE mean for the analysis — 0,0074

* The mean % N (±SD) for the treatment period of 0 weeks was 3,81 ± 0,08 (n = 16). The values for 6 weeks of treatment were intermediate between 4 and 8 weeks, and have therefore been omitted.

Conclusions

From the *in vitro* results it is clear that aqueous ammoniation by urea can be accelerated at higher temperatures and moisture levels. Significant temperature × treatment period and moisture level × treatment interactions indicate that the slower reaction at lower temperature levels can partly be compensated for by a longer treatment.

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