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Short communication

The effect of calcium hydroxide and urea treatment of barley straw on chemical composition and digestibility in vitro

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Abstract

An experiment was conducted to investigate the effectiveness of calcium hydroxide ($Ca(OH)_2$) and urea treatment of straw. Chopped barley straw was treated with mixtures of $Ca(OH)_2$ (0, 30 and 60 g kg^{-1} straw dry matter, DM) and urea (0, 30 and 60 g kg^{-1} straw DM) dissolved in 0.8 l water kg^{-1} straw DM and 'ensiled' in a polythene bag (1.0 kg per bag) at 15°C or 25°C for 60 days. Control treatment at each temperature involved untreated straw and treatment with 30 or 60 g NaOH kg^{-1} straw DM dissolved in 0.8 l water kg^{-1} straw DM. Ensiled straws were examined for mould, chemically analysed and assessed for organic matter digestibility (OMD) in vitro.

Mould occurred in $Ca(OH)_2$-alone and water-alone ensiled straw, but other ensiled straws were apparently mould free. In the presence of $Ca(OH)_2$ with urea treatment, the nitrogen content of ensiled straw increased more than urea-alone treatment. Analysis of variance of OMD in vitro results showed that $Ca(OH)_2$, urea and temperature interact significantly ($P<0.01$). Interactions were found to be non-significant for other parameters (nitrogen, acid detergent fibre and hemicellulose). However, straw ensiled at 15°C with 30 g urea + 60 g $Ca(OH)_2$ kg^{-1} straw DM, 60 g urea + 60 g $Ca(OH)_2$ kg^{-1} straw DM or 30 g NaOH kg^{-1} straw DM had similar OMD in vitro (67%). Untreated straw OMD was 48.5%. It can be concluded that mixtures of $Ca(OH)_2$ and urea would be the alternative chemicals to NaOH or ammonia for improvement of the nutritive value of straw.

Keywords: Barley; Straw; Calcium hydroxide treatment; Urea treatment

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1. Introduction

The improvements to the nutritive value of cereal straws by NaOH and ammonia treatment have been reviewed (Sundstøl and Owen, 1984). However, both chemicals are costly and dangerous to handle, especially in developing countries. On the other hand, compared with NaOH and ammonia, calcium hydroxide ($Ca(OH)_2$) is cheaper and easy to handle. However, one problem identified by several researchers (Owen et al., 1984) is that $Ca(OH)_2$-treated material becomes mouldy with time. Ammonia-treated straw is generally mould-free because ammonia inhibits mould growth. Treatment of straw with urea or urine which is subsequently hydrolysed to ammonia has been investigated in tropical countries (Haque et al., 1983; Doyle, 1984) and it has been found that urea or urine serves as a good preservative for treatment of straw. The present study was therefore undertaken to investigate the effect of treating barley straw with mixtures of $Ca(OH)_2$ and urea in the 'ensiled' form on chemical composition and digestibility in vitro.

2. Materials and methods

2.1. Treatment procedure

Spring-sown barley (*Hordeum vulgare*) straw was chopped into 5 cm average lengths and 'ensiled' for 60 days after treatment with $Ca(OH)_2$ and urea using 0.8 l water kg^{-1} straw dry matter (DM). A 3×3×2 factorial trial with three replicates was used to investigate three levels (0, 30, 60 g kg^{-1} straw DM) each of $Ca(OH)_2$ and urea and ensiling at 15°C or 25°C. Control treatments at each temperature involved untreated straw (unwetted) and treatment with 30 or 60 g NaOH kg^{-1} straw DM using 0.8 l water kg^{-1} straw DM.

A 1 kg amount of chopped straw was put into a new plastic fertilizer bag (86 cm×55 cm). Appropriate amounts of chemical and 0.8 l cold tap water kg^{-1} straw DM were thoroughly mixed in a plastic bucket. The resultant alkaline solution or suspension was sprayed on to straw inside the bag using a compressed-air, garden hand sprayer and the straw was mixed by hand over a 10 min period, spraying and mixing concurrently. When mixing was completed each bag was compressed with the feet to exclude air, and then securely tied with wire. Seventy-two bags of straw were prepared and stored in controlled-temperature rooms, 36 bags being stored in a room maintained at 25°C whilst the remaining 36 were stored in a room maintained at 15°C for 60 days. After ensiling, replicate mini-silos were opened. On opening the silos, the extent of mould growth was scored by visual scoring on a scale 0 to 2 (Table 1). Subsamples of each silo were used for pH measurement, DM determination and freeze-dried for subsequent chemical analysis and digestibility in vitro.

2.2. Chemical analyses

Ensiled straw was analysed for the following: DM, ash, (Association of Official Analytical Chemists, 1975), total nitrogen (Crooke and Simpson, 1971), calcium (Ministry of Agriculture, Fisheries and Food, 1973), acid detergent fibre (ADF) and neutral detergent fibre (NDF) (Goering and Van Soest, 1970). Hemicellulose was calculated as the difference between NDF and ADF. pH was measured following the method of Jayasuriya (1974). The digestibility in vitro was determined according to the two-stage technique of Tilley and Terry (1963). Data were analysed using the computer program GENSTAT (Lawes Agricultural Trust, 1980).

3. Results and discussion

Mould occurred on the straw of $Ca(OH)_2$-alone and water-alone treatments, while other treatments were apparently mould-free (Table 1). Most moulds are found to grow at a favourable pH ranging from 5.5 to 6.5 (Carpenter, 1972). In the present study mould was found on treated straw at a pH of 6.2–8.2 (Table 1). However, the pH values of the other treatments were between 8.2 and 9.2 and these were apparently mould-free. In fact $Ca(OH)_2$-treated material producing mould has been reported elsewhere (Owen et al., 1984). In the presence of urea, all treated straws were mould-free. Many experiments in Bangladesh (Saadullah et al., 1981) and Sri Lanka (Jayasuriya and Perera, 1982; Jayasuriya and Pearce, 1983) showed that urea served as a good preservative for treatment of rice straw.

Temperature is one of the most important factors influencing the growth of mould (Carpenter, 1972). In the present study treated straw was stored at 15 °C or 25 °C. The present results showed there was more mould at 25 °C than at 15 °C; this was particularly so for water-alone and $Ca(OH)_2$-alone treatments (Table 1). Moisture is another important factor in the treatment of straw with $Ca(OH)_2$ and urea. Zaman and Owen (1990) found that 0.8 l water kg^{-1} straw DM was satisfactory for $Ca(OH)_2$ and urea treatment. Accordingly the present study was conducted using 0.8 l water kg^{-1} straw DM.

The ash content of the ensiled straws increased as the $Ca(OH)_2$ or NaOH level increased, but there was no change with urea treatment (Table 1). As expected, the calcium content of the straw increased with increasing levels of $Ca(OH)_2$, but the values were slightly lower than the theoretical values. This was perhaps caused by the insoluble nature of $Ca(OH)_2$ resulting in some of the chemical falling to the bottom of the bag. Temperature appeared not to affect the calcium content but the ash content was increased at 25 °C compared with 15 °C.

The nitrogen content was higher for urea-alone and urea+$Ca(OH)_2$ treatments compared with $Ca(OH)_2$ or NaOH treatments (Table 1). The retention of nitrogen in straw with urea-alone or urea+$Ca(OH)_2$ was lower than estimated. This is presumably because a large amount of nitrogen was lost to the atmosphere as ammonia (after breakdown of urea) from the urea-treated straw.

Table 1
Chemical composition and in vitro organic matter digestibility (OMD) of barley straw ensiled with calcium hydroxide and urea

		pH		Dry matter (DM) (g kg^{-1})		Ash (g kg^{-1} DM)		Calcium (g kg^{-1} DM)		Nitrogen (g kg^{-1} OM)		ADF (g kg^{-1} OM)		Hemicellulose (g kg^{-1} OM)		OMD (%)		Mould score[b]	
		Ensiling temperature (°C)																	
		15	25	15	25	15	25	15	25	15	25	15	25	15	25	15	25	15	25
Chemicals (g kg^{-1} straw DM)																			
$Ca(OH)_2$	Urea																		
0[a]	0	6.2	6.3	497	519	35	46	7	6	8	8	559	584	273	265	45.8	42.2	1	2
30	0	7.1	7.4	531	533	53	65	17	19	8	7	583	602	233	238	48.4	47.2	2	2
60	0	8.2	7.8	539	552	62	82	28	29	7	7	580	589	210	190	58.4	59.8	1	2
0	30	8.6	8.3	538	536	40	41	6	6	11	12	606	595	243	250	51.3	55.3	0	0
30	30	8.4	8.2	519	516	44	56	15	15	14	15	577	593	233	230	59.2	58.2	0	0
60	30	8.7	8.3	530	511	59	70	32	28	16	17	569	587	220	172	67.3	68.9	0	0
0	60	8.8	8.7	535	508	39	42	6	6	17	18	573	594	242	213	56.4	62.5	0	0
30	60	8.8	8.7	521	536	47	50	15	13	19	20	579	594	241	221	62.7	65.0	0	0
60	60	9.2	8.6	561	547	65	65	31	31	31	28	548	572	166	157	65.4	69.1	0	0
NaOH	Urea																		
30	0	7.8	7.7	513	527	69	67	6	7	8	8	585	595	181	203	67.5	63.0	0	0
60	0	8.6	9.2	498	553	93	87	6	6	8	7	594	601	128	149	75.9	72.9	0	0
Untreated straw		7.1	6.9	859	850	41	38	5	6	7	7	574	582	285	300	48.5	47.7	0	0
SED		0.25		28.9		4.0		–		1.4		9.6		16.4		1.03		–	

ADF, acid detergent fibre; SED, standard error of difference between two means.
[a] Straw wetted by water only.
[b] 0, no visible mould; 1, estimated 15% mouldy; 2, estimated 30% mouldy.

This loss of nitrogen has also been reported by Jayasuriya and Pearce (1983) in urea-treated rice straw. They concluded that the loss of nitrogen would be during treatment, at opening the silo and during oven-drying of the sample. However, the present study showed that, in the presence of $Ca(OH)_2$, the percentage loss of nitrogen was small, probably because of lower hydrolysis of urea which inhibited loss of nitrogen in the form of ammonia.

Alkali treatment solubilizes the hemicellulose content of straw (Theander, 1981) thereby resulting in a reduced concentration of hemicellulose and NDF. Hence, measuring the hemicellulose and NDF content helps to assess how effective treatment with $Ca(OH)_2$ and urea has been. NaOH treatment reduced the hemicellulose content of straw more than the other treatments (Table 1). Hemicellulose values decreased with increasing level of $Ca(OH)_2$ kg^{-1} straw DM. Among the mixtures of $Ca(OH)_2$ and urea treatment it was reduced to a greater extent by treatment with 60 g $Ca(OH)_2$+60 g urea kg^{-1} straw DM. The ADF content of straw remained nearly constant across the treatments.

For comparable amounts of chemical applied, NaOH treatment improved OMD in vitro to a greater extent than $Ca(OH)_2$, urea or mixtures of $Ca(OH)_2$ and urea (Table 1). This has also been reported by other workers (Gonzalez Santillana, 1977; Nwadukwe, 1979). Compared with the untreated controls, the water-alone treatment depressed digestibility. The results of the present experiment have shown that $Ca(OH)_2$, urea and temperature interact to improve the digestibility (Table 2). Table 2 shows that the *F*-values for the main effects of urea and $Ca(OH)_2$ are much bigger than the values for temperature, and those for the interactions and the main effects and interactions are highly significant. Hadjipanayiotou (1984) also reported the interaction of $Ca(OH)_2$ and urea after treating barley straw with $Ca(OH)_2$ and urea in an ensiling system. However, the mixtures of $Ca(OH)_2$ and urea, either 60 g $Ca(OH)_2$+30 g urea or 60 g $Ca(OH)_2$+60 g urea kg^{-1} straw DM, gave better improvement in digestibility (20% units) compared with untreated control (Table 1). Verma (1981) also

Table 2
Analysis of variance table showing the effect of urea, $Ca(OH)_2$, storage temperature and their interactions on in vitro OMD (%) in treatment of barley straw

Source of variation	d.f.	Mean square	*F*	Significance
Urea (U)	2	844.15	534.98	***
$Ca(OH)_2$ (Ca)	2	732.57	464.27	***
Temperature (T)	1	29.56	18.73	***
U×Ca	4	34.46	21.84	***
U×T	2	30.09	19.07	***
Ca×T	2	7.59	4.81	*
U×Ca×T	4	8.65	5.49	**
Replicates	2	4.87	3.09	NS
Error	34	1.58		

* $P<0.05$; ** $P<0.01$; *** $P<0.001$; NS, not significant.
d.f., degrees of freedom.

found significant improvement in digestibility (using the nylon bag technique) of wheat straw after treatment with 60 g $Ca(OH)_2$ + 60 g urea kg^{-1} straw DM.

Compared with NaOH, $Ca(OH)_2$ is a weaker alkali and therefore less effective in improving digestibility, although this can be partially overcome by applying a sufficient quantity of $Ca(OH)_2$ and allowing adequate time for it to act upon the straw (Owen et al., 1982). It would seem that ensiling treated straw could be a suitable method for conservation and utilization of straw because ensiling the treated straw means there is an extension of the reaction time, and this led in the case of $Ca(OH)_2$ to an increase in the effectiveness of the chemical.

4. Conclusions

The hypothesis of the present study was based on the assumption that mould growth in $Ca(OH)_2$-treated straw could be prevented by adding urea, the urea being converted to ammonia and the latter acting as a mould preventer. It can be concluded from the present study that 30 g urea kg^{-1} straw DM would be able to prevent mould development on straw treated with 60 g $Ca(OH)_2$ kg^{-1} straw DM using 0.8 l water kg^{-1} straw DM.

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