Studies on the Utilization of Non-Protein Nitrogen and Agricultural By-Products as Feed for Native Cattle in the Republic of Korea

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Summary

Straw-bran-manure silage (SBMS), chopped rice straw or alkali treated straw pellets were added to a basal diet for growing native steers. The SBMS diet yielded the best results for feed intake, body weight gain, feed efficiency, digestibility and costs. Feeding SBMS to lactating Holsteins resulted in a higher feed intake than a corn silage based diet. Milk production and the chemical composition of milk were not influenced by SBMS. The level of moisture in SBMS influenced the microbial population and the contents of lactic and butyric acids in silage. The optimum level of moisture in SBMS was 50 % at which harmful microorganisms, such as ***Coliform*** and ***Salmonella***, disappeared within 20d of fermentation. The major ***Lactobacillus*** in the fermentation of SBMS was identified as ***Lactobacillus casei*** subspecies ***alatosus***. Straw-bran-manure silage can be regarded as a safe and economical roughage for the native cattle and lactating dairy cows.

I. Introduction

A severe shortage of feedstuffs is one of the major obstacles limiting animal production in the Republic of Korea. According to estimates, over 70 % of grain and grain by-products are imported annually for producing concentrate feeds. The treatment of animal wastes is becoming more important with increased animal populations in confinement feeding systems. A feasible approach is to produce feedstuffs from animal wastes because most animal wastes contain fairly large amounts of unused nutrients [1]. Traditionally, in the Republic of Korea, straw has been chopped and heated in water during the winter season, presumably to dissociate the indigestible lignin and silica from cellulose and hemicelluloses. The treatment of cellulosic materials with an alkali solution, such as sodium hydroxide, improves the nutritional value quite extensively, but it is not popular in rural areas for economic and practical considerations. Straw itself is a poor source of energy, nitrogen and minerals. Therefore, various additives have been used to improve the nutritive value of straw [2].

The possibility of feeding processed waste materials has been reported by the Korea Advanced Institute of Science and Technology and by others [3,4]. A new feed material called straw-bran-manure silage (SBMS) has been developed using rice straw and chicken manure. This silage is high in crude protein and is palatable to ruminants. The quality of the SBMS depends on lactic fermentation. The moisture content of the silage is a critical factor controlling lactic fermentation.

A series of experiments were carried out to evaluate the SBMS diet in comparison with diets of untreated rice straw, or alkali treated rice straw pellets on the performance of cattle and sheep native to the country. The effect of feeding SBMS was compared with corn silage on the milking performance of Holstein cows. Also, the fermentation pattern of SBMS was monitored at different moisture levels to determine the optimum moisture level that enhances the quality of the silage.

II. Materials and Methods

1. Effect of diet on feed intake and weight gain

Fifteen native steers with an average body weight of 130 kg were used in a 48 week experiment. The experimental animals were divided into three groups according to body weight and all the animals received concentrate feed (commercial feed) at the rate of 1% of their body weight. Three different roughages, SBMS, chopped rice straw and alkali treated pelleted rice straw (4% NaOH treatment) were given to the three groups of animals, respectively, at the rate of 2% of their body weight. Feed intake and body weight were measured bi-weekly.

2. Digestibility of the diets

Six Corriedale rams with a mean body weight of 30kg were used to measure digestibility in a 3 × 3 Latin square design of experiment. The treatments consisted of SBMS, untreated straw or alkali treated straw pellets. Animals were given concentrate feed and the experimental roughages at the same rate as mentioned in Section 2.1. Feeds were given ad libitum during the 15 d preliminary period and 90% of ad libitum intake was given during the 5 d collection period. Ruminal samples were taken via rumen fistule at 0, 3, 6 and 9 h post-feeding and pH determination was conducted immediately.

3. Effects of SBMS on milk yield

Ten Holstein cows were paired according to body weight and milk yield and randomly assigned to two treatment groups: SBMS and corn silage. The experimental rations were fed for 85 d, which consisted of a 15 d preliminary period and a 70 d experimental period. The experiment was replicated by the switching of the animals for another 85 d feeding period. The animals were fed either the SBMS or corn silage, in addition to concentrate and hay. The ratio of concentrate to roughages (hay plus either the SBMS or corn silage) was maintained at 4:6 on a dry matter (DM) basis throughout the experiment. The ration was given twice daily and hay was given once a day after the concentrate and the silages were consumed completely. Four Corriedale rams were used in a digestibility trial with experimental rations identical to the ones used in the dairy cattle experiment.

4. Quality of SBMS

Rice straw, chopped into lengths of 5−7㎝, was treated with a 4% solution of NaOH (4 g NaOH in 100 ㎖ water per 100 g straw DM). The alkali treated straw was covered with vinyl film for two to three days. Wheat bran and hen manure were mixed with alkali treated straw at the rate of 30:20:50, respectively, on a DM basis, and the mixture was ensiled in a trench silo. Three experimental silages were prepared separately by adding tap water to fix the final moisture content of each SBMS preparation at 50%, 60% or 70%, respectively.

Samples were taken for evaluation of microbial activity at days 0,5,10,15,20,25,30 and 40 of fermentation. A 10 g sample was homogenized with 90 g sterilized distilled water for 1 min under aseptic conditions. The microbial populations were determined by the Pour Plate method using selective media, such as Rogosa agar for *Lactobacillus*, Wilson and Blair's sulphite media for *Clostridium*, violet red bile glucose agar for *Coliform* bacteria and S−S agar (Difco) for *Salmonella* and *Shigella*.

Morphological characteristics were determined under X600 magnification with a micrometer. Culture characteristics were estimated on the double layers of Rogosa agar. The lactic acid dehydrogenase method was used for the determination of D- or L-lactic acid production using specific D- or L-form enzymes, respectively. The basal medium used in the carbohydrate assimilation consisted of 10 g tryphticase, 5 g yeast extract, 5 g NaCl and distilled water to make 1 L. Various carbohydrates were added at the 1% level and the fermentation reaction was determined by measuring pH and gas production by a drum tube. The levels of individual volatile fatty acids (VFA) were determined by gas liquid chromatography.

Table 1. Feed intake and body weight gain of experimental native cattle in the Republic of Korea.

Item	SBMS	Untreated rice straw	NaOH treated rice straw pellets
Initial body weight	128.0	131.0	128.0
Final weight	429.2	361 8	400.2
Weight gain	301.2	230.8	272.0
Daily gain*	0.896	0.687	0.810
Index	100	77	90
Daily feed intake			
Dry matter	6.26	5.80	6.03
Concentrates	2.49	2.22	2.30
Roughage	3.77	3.58	3.73
Feed conversion	6.99	8.44	7.44

* Significant difference at $P<0.05$ between treatments.

Table 2. Cost-benefit analysis (unit of currency: won)

Item \ Treatment	SBMS	Untreated rice straw	NaOH treated rice straw pellets
Feed cost (FC)			
Concentrate	183 973	164 432	169 759
Roughage	137 341	54 054	188 111
Total	321 314	218 486	357 870
Gross income (GI)	1 114 440	853 960	1 007 140
GI−FC	793 126	635 474	649 270
Calf price	600 000	600 000	600 000
Balance	193 126	35 474	49 270

Note: Feed price :

Concentrate : 220 won/kg DM.
SBMS : 108.5 won/kg DM.
Rice straw : 45 won/kg DM.
Straw pellet : 150 won/kg DM.

Meat price : 3700 won/kg.

Table 3. Feed intake and digestibility of various rations by sheep

Item \ Ration	SBMS	Rice straw	Straw pellets
Total intake (g DM/d)	929.4	647.8	803.2
Roughage (g DM/d)	699.5	418.0	573.4
Digestibility			
Dry matter	62.7	50.7	54.5
Crude protein	74.4	63.1	51.9
Crude fibre	48.0	37.4	42.1
Ether extract	86.1	66.1	61.7
Nitrogen free extract	70.7	67.4	63.8
Digestible nutrients (%)			
Digestible crude protein	12.2	6.6	4.9
Total digestible nutrients	61.6	47.7	51.8

Table 4. Effect of corn silage and SBMS feeding on the milking performance of holstein dairy cows

Item	Corn silage	SBMS
Daily milk production	17.23	17.05
Milk fat	4.06	4.19
Milk protein	3.89	3.92
Lactose	5.27	5.17
Solids non-fat	10.36	10.35
Feed intake (DM)	17.12	18.27
Concentrate	6.82	6.82
Silage (wet)	30.0	30.0
Silage (DM)	8.31	9.32
Orchard grass hay	1.99	2.13
Feed cost / kg milk yield (won)	192	173
Index	100	90

Table 5. Digestibility by sheep of various nutrients in the experimental rations

Item \ Ration	Corn silage	SBMS
Digestibility (%)		
Dry matter	69.62	65.47
Organic matter	70.18	67.86
Crude protein	71.85	68.45
Crude fat	94.66	95.72
Crude fibre	53.02	62.12
Nitrogen free extract	72.48	64.86
Neutral detergent fibre	53.49	56.34
Acid detergent fibre	48.63	51.30
Cellulose	51.61	60.98
Digestible nutrients (%)		
Digestible crude protein	10.18	10.24
Total digestible nutrients	70.72	66.63

Table 6. Ruminal pH and VFA concentration at 3 and 6 h after feeding sheep various rations

Item \ Ration	SBMS		Untreated rice straw		NaOH treated rice straw pellets	
	3 h	6 h	3 h	6 h	3 h	6 h
pH value	6.12	6.16	6.19	6.25	6.50	6.53
Total VFAs (mM/L)	132.1	100.6	99.6	81.7	107.7	86.8
Individual VFAs (mM/L)						
Acetate	76.9	72.5	61.7	51.4	74.6	65.2
Propionate	33.8	31.2	25.3	19.4	24.7	21.8
Butyrate	17.1	14.1	8.7	7.7	6.3	5.9
Iso-valerate	1.0	0.8	0.9	0.6	0.4	0.3
Valerate	1.3	1.0	0.9	0.5	0.6	0.6

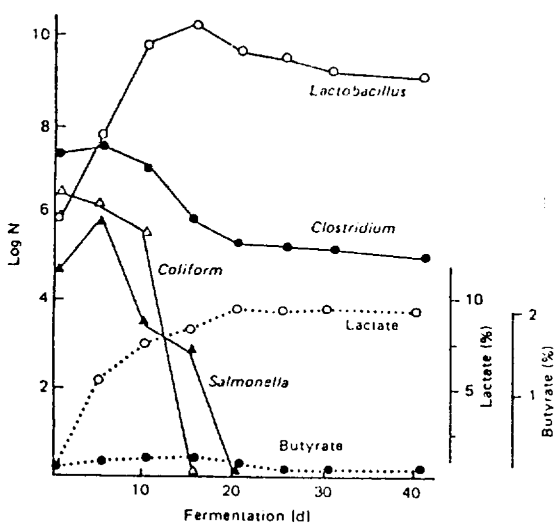

Fig.1. Change in microbial number, lactate and butyrate in 50% moisture silage during fermentation.

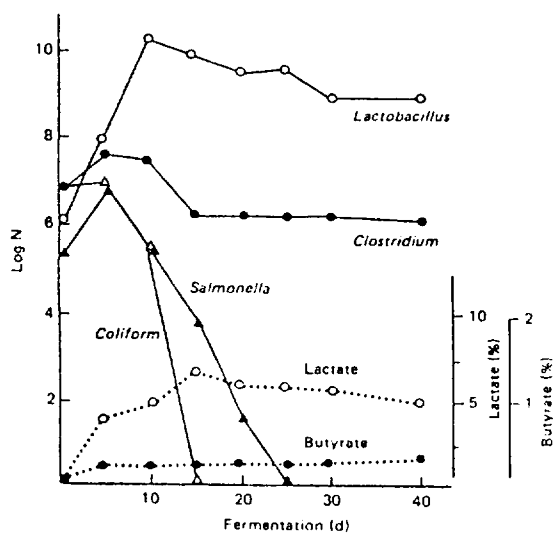

Fig.2. Change in microbial number, lactate and butyrate in 60% moisture silage during fermentation.

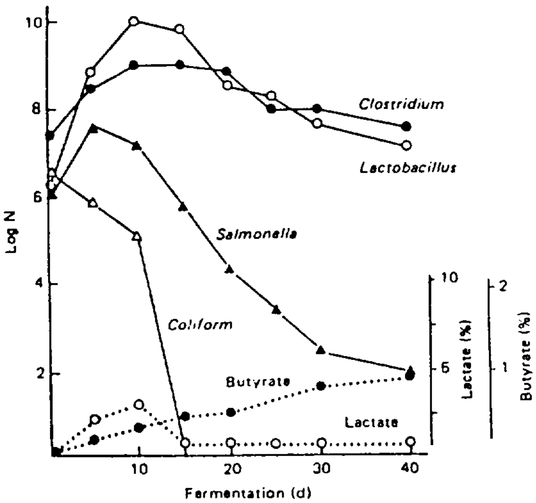

Fig. 3. Change in microbial number, lactate and butyrate in 70% moisture silage during fermentation.

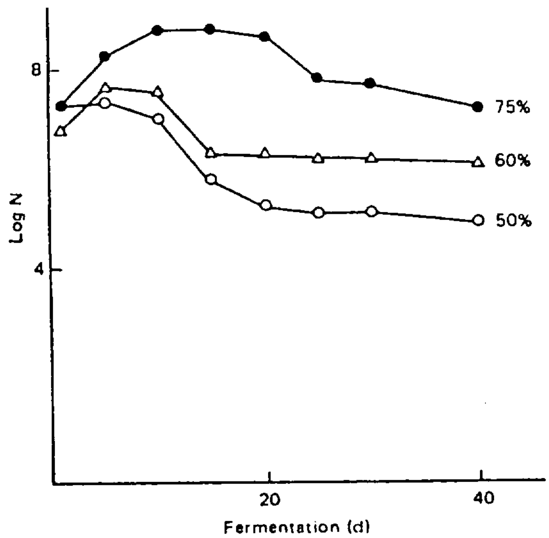

Fig. 5. Clostridia profile according to moisture.

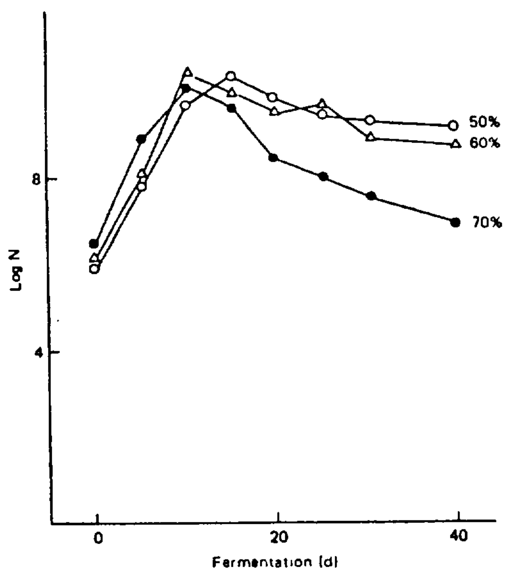

Fig. 4. Lactobacillus profile according to moisture.

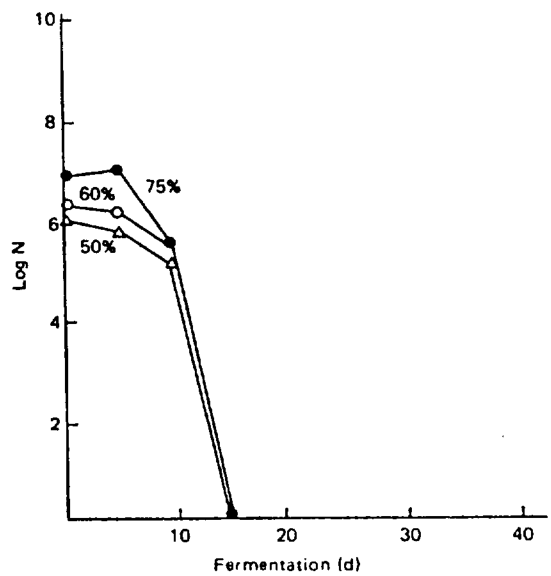

Fig. 6. Coliform bacteria profile according to moisture.

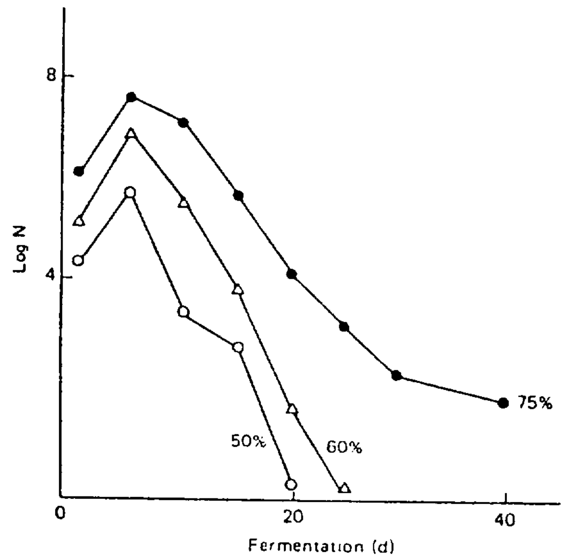

Fig.7. Salmonella profile according to moisture.

Ⅲ. Results and Discussion

The feed intake and performance of experimental animals are summarized in Table Ⅰ. Most animals reached the marketable body weight by the end of the experimental period. The SBMS group of animals showed the highest feed intake and, consequently, the highest body weight gain, followed by the animals fed the NaOH treated rice straw pellets. Animals receiving the untreated rice straw showed the lowest feed intake and body weight gain. The SBMS group showed a 14.8 % and 2.7 % improvement in feed efficiency over the untreated straw and straw pellet groups, respectively.

The cost-benefit analysis of the experiment is presented in Table Ⅱ. In spite of the higher feed intake in the SBMS diet, the cost of SBMS is lower than the straw pellet diet because of the high production cost of the straw pellets. It is apparent that the SBMS feeding is cost beneficial in terms of net profit due to the lower feed cost and higher performance of the animals. The results of metabolism studies with sheep are presented in Table Ⅲ. They showed a similar trend as observed in the cattle trial in terms of feed intake. The digestibility of ration components in Table Ⅲ clearly shows that SBMS is more readily digested than the others. The DM digestibility of the SBMS diet was 15.1 % and 23.7 % more than the straw pellet and the untreated straw diets, respectively.

The increased digestibility of the SBMS and rice straw pellet diets might be explained by NaOH treatment and the possible mechanism was reviewed. The rupture of intermolecular hydrogen bonds in the cellulose by the NaOH solution may have led to an increase in digestibility. The cellulose would have swelled in water and led to an overall decrease in the crystallinity [5].

Table Ⅳ shows the effect of feeding SBMS or corn silage on daily feed intake, milk production and the chemical composition of milk between the SBMS and corn silage diets. The digestibility and ruminal fermentation of various nutrients in sheep are presented in Tables Ⅴ and Ⅵ, respectively. Apart from fibre, the digestibility of SBMS showed somewhat lower values than corn silage. The lower score of nutrient content and digestibility for the SBMS diet was made up by lower production costs as compared with corn silage (35.2 %). The pH value of rumen fluid in animals given the SBMS diet was lower and total VFA concentration higher than those on the other diets, supporting the view that the SBMS diet was comparatively superior to the others.

The increased consumption of silage in

Table 7. Identification study of lactobacillus

Characteristics	Species	L−1	L−2	Results of Mills and Lessel [7]
Morphological characteristics	Gram RX	Positive	Positive	Positive
	Shape	Rod	Rod	Rod
	Size (μm)	0.8−1.5	0.8−1.0	0.6−1.4
	Colour	White	Yellow	White
Culture characteristics	Opacity	Opaque	Opaque	—
	Elevation	Raised	Raised	—
	Surface	Smooth	Smooth	Smooth
	Edge	Undulate	Entire	—
Lactic acid production	D-form	Negative	Positive	Negative
	L-form	Positive	Positive	Positive
Carbohydrate assimilation	Arabinose	−	+	−
	Cellobiose	+	+	+
	Galactose	+	+	+
	Glucose	+	+	+
	Glucose	+	+	+
	Lactose	−	+	+
	Maltose	+	+	+
	Mannose	+	+	+
	Melibiose	−	−	−
	Rhamnose	−	−	−
	Ribose	+	+	+
	Trehalose	+	+	+

ruminants might be explained by the ensiling effect. The most practical method of handling manures was to ensile either alone or with other ingredients, such as straw and other fibrous residues[1]. Lactic acid production was increased during ensiling, and this might be a basis for the increased palatability of SBMS[6]. The change in microbial population during the 40 d fermentation for the moisture treatments, 50, 60 or 70%, are presented in Figs 1,2 and 3, respectively. The number of *Lactobacillus* increased very rapidly in all treatments during the first ten days of fermentation. The number of *Lactobacillus* showed a negative correlation to butyric acid and a positive correlation to lactic acid, suggesting that the number of *Lactobacillus* mainly influences the fermentation pattern. The number of *Lactobacillus* was negatively correlated to *Clostridia*, as shown in Figs 4 and 5. Pathogenic microorganisms, such as *Coliform* bacteria, disappeared within 15 d of fermentation in all treatments. However, the rate of decline of *Salmonella* depended on moisture content, as shown in Figs 6 and 7. Therefore, the low moisture silage was more desirable over the other two as evidenced by the higher *Lactobacilli* population and lactic acid content, and the lower *Clostridia* population and butyric acid content.

An identification study of *Lactobacilli* was conducted on 50% moisture silage taken on day 20 of fermentation. Two major strains were identified and tentatively designated L-1 and L-2. The results of the identification study showed that L-1 was ***Lactobacillus casei*** subspecies ***alactosus***, while L-2 was unidentified, as shown in Table Ⅶ. ***Lactobacillus casei*** subspecies ***alactosus*** was the main fermentation organism producing L-lactic acid to improve the quality of silage. The identification parameters of the *L. casei* subspecies ***alactosus*** strain were the same as those in the results of Mills and Lessel [7].

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