CORN STEEP LIQUOR, A POTENTIAL SUBSTITUTE OF UREA FOR GROWING LAMBS

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ABSTRACT

The study was aimed to evaluate corn steep liquor (CSL), a by- product of corn starch processing, as a potential substitute of urea and its influence on nutrients intake, digestibilities and economics of weight gain for growing lambs. Five experimental diets, CSL0, CSL20, CSL40, CSL60 & CSL80, were formulated to replace urea by CSL at the rates of 0, 20, 40, 60 and 80% on the basis of N supply, respectively. Fifty growing lambs were divided into 5 groups of 10 animals each in a randomized complete block design. Maximum and minimum dry matter (DM) intakes were recorded for lambs fed diets containing highest (CSL80) and null (CSL0) concentration of CSL, respectively. Crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) intakes also followed the same trend. Digestibilities of DM, CP, NDF and ADF increased with ascending replacement of CSL to urea. Lambs fed CSL gained higher weight than those fed CSL0 diet. Maximum weight gain was recorded for lambs fed diet containing maximum concentration of CSL. Cost of feed per Kg live weight produced was slightly decreased if not being similar due to ascending replacement with CSL. However, feed conversion ratio showed the best value with CSL80, followed by CSL60 and CSL40 while the poorest with CSL0 and CSL10 ($P < 0.05$). The findings of the present study indicated significant increase in nutrients intake and weight gain without any adverse effects on growth performance of lambs when CSL was used up to 80% on N basis as replacement of urea.

***Key words**: Corn steep liquor, urea, nutrient utilization, growing lambs*

INTRODUCTION

In South Asian countries, reduced growth rate of growing ruminants is usually attributed to low quality of forage which characterized by low crude protein (CP), energy and digestibility **(Sarwar et al., 2002a)**. Ruminants getting only 62% of the required digestible CP, therefore, nitrogen (N) is considered the first limiting nutrient that reduces the animal growth through its adverse effect on the rumen microbial growth and subsequent ruminal fermentation **(Sarwar et al., 2002b)**. Reduced microbial growth directly affects ruminal volatile fatty acids (VFA) synthesis which fulfills more than 75% of energy needs of ruminants. The VFA synthesis is the main driving force behind a productive rumen microbial population and its impairment leads to reduced animal productivity and profitability **(Henning et al., 1993)**.

Reduced ruminal microbial activities can be restored by ensuring N availability by feeding urea, non-protein nitrogen (NPN) source, which is advocated for ruminant enhanced productivity. Urea feeding has been reported to improve ruminal fermentation in different classes of ruminants fed N deficient diets. Urea, under specific levels and with availability of suitable carbohydrate, is completely hydrolyzed to ammonia in the rumen and this ammonia is of vital significance for rumen microbes as more than 80% of them need ammonia for their growth **(Aharoni et al., 1991; Bryant and Robinson, 1962).**

Stimulating rumen microbe growth through urea supplementation offers a viable practice; however, it is inferior to dietary protein when measured in terms of animal performance **(Helmer and Bartley, 1971)**. This better response of dietary protein might be attributed to the fact that it is degraded in the rumen to produce peptides and amino acids in addition to ammonia. It has also been reported that rumen bacteria responsible for utilization of sugar and starch require amino acids or peptides for their growth **(Helmer and Bartley, 1971)**. Thus, feeding urea in combination with readily fermentable carbohydrate can help synchronize the ruminal availability of nitrogen from urea and carbon from carbohydrate. Thus combination of N and carbohydrate sources could improve ruminal fermentation, as ruminal fermentation in the absence of carbohydrate may intensify the chances of ruminal ammonia escape **(Khan et al., 2008).** This is not only a dietary N loss but it can increase the energy requirement of animal as excess ruminal ammonia is absorbed in blood circulation and is excreted as urea in urine and it costs about 7.2 Kcal ME/g N excretion of ammonia N from the body **(Tyrrell et al., 1970)**. Escape of higher concentrations of ammonia from rumen also multiplies the chances of animal death due to urea toxicity. These findings along with increasing cost of urea constrain the use of urea feeding to animals at farm level.

Corn steep liquor (CSL) is a major by product of corn starch processing. It is an inexpensive source of nitrogen, vitamins, amino acids, peptides and soluble nutrients **(Nisa et al., 2004).** It is viscous slurry with light to dark brown colour, having ensiled odour and acidic pH (3.5) due to considerable amount of lactic acid **(Sarwar et al., 2004)**. The product is practically free from fat, fibre and silica **(Wagner et al., 1983; Talpada et al., 1987; Gupta et al., 1990)**. It contains about 40% crude protein on dry matter basis, out of which more than 90% is in the form of amino acids and peptides. Biological trials on beef animals by using CSL as a liquid source of protein supplement have been reported to enhance animal performance **(Gill, 1997; Trenkle, 2002)**. Other studies suggest that it supports better weight gains and feed efficiency in steers kept on high roughage rations. Use of CSL as growth medium in microbiological studies for growth and maintenance of microbes also gives indirect information about absence of any macro / micro undesirable / harmful element for animals. The sole CSL can be good source of N and carbohydrates, indicating that it can replace a costly NPN source like urea from the diets of ruminant animals. However, literature regarding its potential to replace urea from the diets of ruminant animals is limited. Therefore, the present study was planned to examine the influence of replacing feed grade urea with CSL on nutrient utilization, weight gain and carcass characteristics in growing lambs.

MATERIALS AND METHODS

Diets and animals

Five isocaloric and iso-nitrogenous rations were formulated according to the requirements as prescribed by NRC (1985). The NPN shared the 1/3rd of the total crude protein content of diet. CSL replaced urea at the rate of 0, 20, 40, 60 & 80% on the basis of NPN supply by urea in rations CSL0, CSL20, CSL40, CSL60 & CSL80, respectively (Table 1). Sixty growing *Lohi* lambs with an average weight of 25 $\pm$ 3.10 kg per animal were divided into 5 groups of 10 animals each in a randomized complete block design. The remained 10 animals were maintained to counter any mortality, to avoid introduction of any variable in smooth execution of the study. The trial lasted for 90 days. First 20 days for adaptation while every alternate 10 days of remaining 70 days served as collection period.

Analysis

Daily feed consumption was recorded. Feed intake was recorded daily and their representative samples were taken for analysis. The lambs were weighed weekly. Faeces were collected daily, dried at 55 °C, bulked and mixed at the end of each collection period. Digestibility was determined by using total collection method (Sarwar et al., 1996). During collection periods, complete collections of faeces were made according to the procedure described by Williams et al. (1984). The faeces of each lamb were collected daily, weighed, mixed thoroughly and 20% of it was sampled and dried at 55 °C. At the end of each collection period, dried faecal samples were composted per lamb and 10% of the composted samples were taken for analysis. Urine samples were acidified with 50% H_2SO_4 and stored at -20°C for laboratory analysis

(Nisa et al., 2004).

Feed and faecal samples was analyzed for acid detergent fiber (ADF) and neutral detergent fiber (NDF) by the methods of Goering and Van Soest (1970) while dry matter (DM) and crude protein (CP) using Kjeldahal method described by AOAC (1990). Two animals were slaughtered from each treatment for evaluation of carcass characteristics (five primal cuts and percentage composition of fat, bone and lean of cuts) and meat quality (Kashan et al., 2005). Carcass weight and dressing percentage were determined by following the procedure described by Atti et al, (2004). Economics of using enzose as energy source without affecting the daily growth rate of animals and profitability was also calculated. Nitrogen balance was determined using equations described in NRC (2001).

Statistical analysis

The data were analyzed using a Randomized Complete Block Design. In cases of significance, means were separated by Duncan's Multiple Range Test (Steel and Torrie, 1984). The contrasts were determined by using the SPSS (version 10.0.1).

RESULTS AND DISCUSSION

Nutrient intake and digestibilities

A linear increase in feed consumption was noticed with gradual replacement of urea by corn steep liquor (Table 2). Maximum and minimum dry matter intake was recorded in lambs fed CSL80 and CSL0, respectively. Similar trends were noticed on CP, ADF and NDF intakes. There was significant increase in DM and other nutrients digestibilities with gradual replacement of urea by CSL (Table 2). The N intake also increased in lambs by graded replacement of urea by CSL (Table 3). Lambs fed CAL60 and CSL80 had higher N balance than those fed of CSL0, CSL20 and CSL40 diets.

Increasing trend of nutrients intake by gradual replacement of urea with CSL might be attributed to ascending availability of peptides and some amino acids on the cost of ammonia due to hydrolysis of CSL rather than exclusive availability of ammonia in lambs fed on urea alone. CSL is a concentrated thick and complex mixture of carbohydrates, amino acids, peptides, organic compounds, inorganic ions, and myo-inositol phosphates derived from wet corn milling (Nisa et al., 2004). It contains some fermentable energy which on hydrolysis yields keto acids and the release of rumen ammonia nitrogen with keto acids might have synchronized the availability of nitrogen (N) and carbon units in rumen for enhanced microbial proliferation leading to improved feed degradation. In rumen, adequate and gradual supply of nutrients by replacing urea by CSL boosts up microbial synthesis which might have increased feed intake because increased microbial efficiency has also been linked to increased feed intake (Haddad et al., 2005). The efficient capture of dietary nitrogen and the synthesis of microbial protein by the rumen microbial population both require a balanced supply of both nitrogen and energy. When supply becomes unbalanced, losses of nitrogen as ammonia occur across the rumen wall and this is subsequently lost as urea in urine. Beever and Siddons (1986) suggested that N losses arising from ammonia absorption from the rumen are a consequence of the imbalance that exists between the degradation rates of ammonia-producing herbage N, and energy yielding organic matter, the so-called asynchrony in supply of energy and nitrogen. Some researchers have shown that bacterial growth and fermentation in the rumen are optimized when the rates of fermentation of starch and protein are synchronized (Nocek and Russell, 1988; Hoover and Stokes, 1991). Furthermore, sugar and starch degrading bacteria require ammonia, amino acids or peptides, while cellulolytic bacteria utilize ammonia as the chief N source (Russell et al., 1992). This indicates that amino acid and peptides also play an important role in the N supply of rumen micro-organisms. In lambs receiving CSL80 diet, the N requirements are met in the form of rumen ammonia, peptides and amino acids which might have accelerated microbial growth and subsequently fermentation as well. This implied that the structural carbohydrates (cellulose and hemicellulose) will be more extensively fermented as evident by increased ADF and NDF digestibilities in the present study. The addition of CSL at ascending levels in the present study might have enhanced rumen microbial count (Nisa et al., 2008) and per unit enzyme production due to availability of N in diverse forms (ammonia N, peptides and amino acids) and keto acids (carbon skeleton) leading to increased nutrient digestibilities (Sarwar and Nisa, 1999; Sarwar et al., 2004). The marked increase in N balance for lambs fed CSL60 and CSL80 was due to increased intake of these rations. Availability of ammonia N, peptides and amino acids along with fermentable energy source in CSL60 and CSL80 diets might have geared up rumen microbial multiplication and enzyme synthesis leading to improved crude protein degradability at ruminal level and microbial protein proportion at post ruminal level

Growth performance

Lambs fed CSL80 gained significantly more weight than those fed CSL0 diets (Table 3). The increased weight gain in lambs fed CSL60 than those fed CSL40 was statistically not significant. . As replacement rate by CSL increased weight gain was increased to came to the maximum in lambs fed CSL80. Cost of feed per Kg live weight produced was higher in lambs fed CSL0 diet than those fed on CSL80 diet; meanwhile feed conversion ratio was better in lambs fed diets containing higher concentration of CSL as replacement of urea.

Increased weight gain in lambs fed on diets containing ascended replacement of CSL to urea was due to higher nutrients intake. Provision of fermentable carbohydrates, peptides and amino acids in addition to supplying ammonia upon hydrolysis, CSL might have enhanced rumen microbe synthesis and enzyme production leading to better rumen fermentation and volatile fatty acids production consequently ensuring sufficient energy availability at cellular level. Better rumen fermentation increases microbial multiplication and microbial flow to the post ruminal receptors of microbial protein and amino acids. Increased volatile fatty acids and post ruminal ammonia supply might have enhanced energy and amino acid availability for muscle accretion and thus weight gain. Bacterial crude protein (BCP) can supply from 50% of essential metabolizable protein required by beef cattle and efficient to synthesis BCP critical to meet the protein requirements of growing beef animals, economically (Spicer et al., 1986). While reduced weight gain in lambs fed CSL0 might be attributed to an inadequate supply of keto acids or imbalance/asynchrony between keto acids and rumen ammonia or both. Furthermore, better feed conversion in lambs fed high level of CSL due to increased nutrients utilization and better rumen environment. Moreover, improved rumen fermentation in lambs fed diets containing increased CSL might refer to enhanced volatile fatty acid production or post rumen supply of amino acids or both due to better feed utilization by efficient rumen microbial activities.

Carcass characteristics

Pre-slaughter weight, warm carcass and dressing percentage remained significantly unchanged across all diets. Skin, heart, liver, kidney and heart weights also followed the same trend when urea was replaced with CSL for growing lambs. Half carcass separable primal cuts in lambs also remained unaltered in all diets and the same was true for lean, fat and bone proportions of these respective cuts. The non significant effects on carcass quality reflect the suitability and potential of CSL as a suitable ingredient to replace urea. Furthermore, encouraging effects of CSL also imitate the absence of any undesirable constituent of this complex mixture which may impart detrimental effects on animal performance and carcass quality.

CONCLUSION

The Significant increase in nutrients intake and weight gain without any detrimental effects on dressing percentage and carcass quality reflect the suitability and potential of CSL as suitable economical feed ingredients to replace urea in the diet of growing lambs. The improved rumen performance by CSL replacement suggests possible future testing for increasing levels of CSL replacement of total protein requirement than that allowed by urea.

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Table 1: Ingredients and chemical composition of experimental diets containing corn steep liquor as replacement of urea for growing lambs.

Ingredients [%]	Experimental Diets[1]				
	CSL0	**CSL20**	**CSL40**	**CSL60**	**CSL80**
Corn grains	27.00	27.30	28.30	29.40	30.40
Wheat straw	20.00	20.00	20.00	20.00	20.00
Corn steep liquir	0.00	3.60	7.20	10.80	14.30
Urea	2.50	2.00	1.50	1.00	0.50
Canola meal	2.00	2.00	2.00	2.00	2.00
Sunflower meal	2.50	2.50	2.50	2.50	2.50
Corn gluten 60%	0.00	0.90	2.20	3.70	5.20
Rice polishing	8.00	8.00	8.00	8.00	7.00
Maize bran	16.00	14.70	11.30	8.70	6.00
Maize oil cake	16.00	13.00	11.00	7.90	6.10
Maize oil	1.00	1.00	1.00	1.00	1.00
$NaHCO_3$	2.00	2.00	2.00	2.00	2.00
DCP	2.00	2.00	2.00	2.00	2.00
NaCl	1.00	1.00	1.00	1.00	1.00
Chemical composition (%)					
Dry Matter	91.25	89.69	88.22	86.73	85.31
Crude Protein	18.20	18.21	18.18	18.18	18.18
Total Digestible Nutrients	70.80	69.80	69.90	69.80	69.70
Neutral Detergent Fiber	29.70	28.53	28.03	27.89	27.11
Acid Detergent Fiber	17.76	17.49	17.30	16.87	16.01

[1]CSL0, CSL20, CSL40, CSL60 & CSL80 diets contained corn steep liquor as replacement of urea at the rate of 0, 20, 40, 60 and 80% on the basis of nitrogen supply by corn steep liquor, respectively

Table2: Effect of varying level of corn steep liquor when replaced with urea on nutrients intake and their digestibilities in growing lambs

Parameters	Diets[1]					
	CSL0	CSL20	CSL40	CSL60	CSL80	SE
Nutrients intake (g/day)						
Dry matter	951[c]	999[bc]	1042[b]	1078[ab]	1116[a]	25.43
Crude protein	173.08[c]	181.92[bc]	189.43[b]	195.98[ab]	202.89[a]	4.58
Neutral detergent fiber	282.45[a]	285.01[a]	292.01[ab]	300.65[ab]	302.55[a]	6.60
Acid detergent fiber	168.99[b]	174.72[a]	180.27[a]	181.86[ab]	178.67[c]	3.99
Nutrient digestibilities (%)						
Dry matter	61.20[c]	61.81[bc]	62.11[b]	63.45[ab]	64.61[a]	1.2
Crude protein	70.01[c]	70.42[bc]	70.81[b]	71.33[ab]	72.98[a]	1.42
Neutral detergent fiber	52.41[c]	52.62[bc]	53.84[b]	54.25[ab]	54.89[a]	1.13
Acid detergent fiber	48.21[c]	48.45[bc]	49.51[b]	50.12[ab]	51.85[a]	0.84

Means in a row with different superscripts differ significantly ($P < 0.05$)

[1]CSL0, CSL20, CSL40, CSL60 & CSL80 diets contained corn steep liquor as replacement of urea at the rate of 0, 20, 40, 60 and 80% on the basis of nitrogen supply by corn steep liquor, respectively

Table3: Effect of varying level of corn steep liquor when replaced with urea on nitrogen dynamics in growing lambs

Nitrogen (g/d)	Diets[1]					
	CSL0	CSL20	CSL40	CSL60	CSL80	SE
Intake	27.69^{c}	29.11^{bc}	30.31^{b}	31.36^{ab}	32.46^{a}	4.01
Faecal outgo	13.01	13.21	13.32	13.79	14.32	1.33
% of intake	46.98	45.38	43.95	43.97	44.12	0.71
Apparent absorption	14.68^{c}	15.9^{bc}	16.99^{b}	17.75^{ab}	18.14^{a}	2.12
% of intake	53.02	54.62	56.05	56.03	55.88	0.81
Urinary outgo	0.14^{c}	0.15^{bc}	0.16^{b}	0.17^{ab}	0.18^{a}	0.48
Balance	14.54^{c}	15.75^{bc}	16.83^{b}	17.40^{ab}	17.96^{a}	0.27

Means in a row with different superscripts differ significantly ($P < 0.05$)

[1]CSL0, CSL20, CSL40, CSL60 & CSL80 diets contained corn steep liquor as replacement of urea at the rate of 0, 20, 40, 60 and 80% on the basis of nitrogen supply by corn steep liquor, respectively

Table-4 Effect of varying levels of corn steep liquor when replaced with urea on growth performance of growing lambs

Parameters	Diets[1]					
	CSL0	CSL20	CSL40	CSL60	CSL80	SE
Wt. gain (g/day)	149^{d}	156^{c}	165^{bc}	173^{b}	189^{a}	4.22
Cost (Rs) of feed to produce one kg live weight	104	103	104	103	104	3.09
Feed Conversion Ratio	6.41^{a}	6.42^{a}	6.31^{ab}	6.30^{b}	5.94^{c}	0.18

Means in a row with different superscripts differ significantly ($P < 0.05$)

[1]CSL0, CSL20, CSL40, CSL60 & CSL80 diets contained corn steep liquor as replacement of urea at the rate of 0, 20, 40, 60 and 80% on the basis of nitrogen supply by corn steep liquor, respectively

Table 5: Effect of varying levels of corn steep liquor when replaced with urea on Carcass characteristics in growing lambs

Parameters	Diets[1]					
	CSL0	CSL20	CSL40	CSL60	CSL80	SE
Pre-slaughter wt (kg)	37.65	39.20	38.29	39.04	38.72	0.67
Warm carcass wt (kg)	18.59	19.06	18.98	19.24	18.87	0.33
Dressing Percentage	49.38	48.65	49.55	49.28	48.77	0.64
Skin wt (kg)	2.51	2.57	2.70	2.75	2.56	0.10
Feet wt (kg)	1.65	1.76	1.60	1.70	1.79	0.09
Heart wt	0.18	0.19	0.20	0.18	0.20	0.01
Liver wt (kg)	0.61	0.65	0.74	0.58	0.56	0.06
Kidney wt (kg)	0.11	0.12	0.13	0.13	0.13	0.01
Lung wt (kg)	0.50	0.49	0.51	0.59	0.49	0.03

Means in a row with different superscripts differ significantly (P < 0.05)

[1]CSL0, CSL20, CSL40, CSL60 & CSL80 diets contained corn steep liquor as replacement of urea at the rate of 0, 20, 40, 60 and 80% on the basis of nitrogen supply by corn steep liquor, respectively

Table-6 Effect of varying levels of corn steep liquor when replaced with urea on half carcass separable primal cuts in growing lambs

Parameters	Diets[1]					
	CSL0	CSL20	CSL40	CSL60	CSL80	SE
Neck	1.75	1.88	1.83	1.87	1.75	0.08
Shoulder	3.52	3.72	3.60	3.73	3.68	0.09
Breast	3.25	3.54	3.49	3.42	3.65	0.18
Loin	4.11	4.14	4.00	4.19	3.80	0.10
Leg	5.97	5.76	6.07	6.03	5.99	0.26

Means in a row with different superscripts differ significantly (P < 0.05)

[1]CSL0, CSL20, CSL40, CSL60 & CSL80 diets contained corn steep liquor as replacement of urea at the rate of 0, 20, 40, 60 and 80% on the basis of nitrogen

supply by corn steep liquor, respectively

Table7: Effect of varying levels of corn steep liquor when replaced with urea on primal cuts and their composition (% of lean, fat and bone) in growing lambs

Parameters		Diets[1]					
		CSL0	CSL20	CSL40	CSL60	CSL80	SE
Neck	Lean	62.19	63.76	63.51	63.19	64.45	1.36
	Fat	7.30	7.85	8.01	7.91	7.69	0.18
	Bone	30.51	28.39	28.48	28.90	27.86	1.28
Shoulder	Lean	63.66	63.88	64.55	63.46	64.06	1.43
	Fat	6.85	6.38	7.26	6.63	6.41	0.98
	Bone	29.49	29.75	28.19	29.91	29.53	0.88
Breast	Lean	55.21	54.68	55.44	55.73	56.35	0.59
	Fat	14.21	14.59	14.59	14.25	13.38	0.93
	Bone	30.58	30.74	29.98	30.03	30.28	0.72
Loin	Lean	62.76	60.90	61.55	62.64	61.25	0.54
	Fat	10.75	11.28	11.23	10.09	10.73	0.77
	Bone	26.49	27.83	27.23	27.28	28.03	0.74
Leg	Lean	67.65	67.79	67.49	68.33	68.09	0.94
	Fat	11.35	11.71	11.68	13.39	16.03	1.37
	Bone	21.00	20.50	20.84	19.75	20.53	0.68

Means in a row with different superscripts differ significantly ($P < 0.05$)

[1]CSL0, CSL20, CSL40, CSL60 & CSL80 diets contained corn steep liquor as replacement of urea at the rate of 0, 20, 40, 60 and 80% on the basis of nitrogen supply by corn steep liquor, respectively