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Use of Steam Treated Sugarcane Pith in the Diet of Finishing Calves as a Replacement for Low Grain Corn Silage

Research Article

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ABSTRACT

The aim of the present experiment was to investigate the effects of using steam treated sugarcane pith (STSP) as a substitute for part of the corn silage in the diet of finishing calves on performance, optimal use of available food sources, and probably reducing the costs of production. Twenty-four Holstein male calves with a mean weight of 195 kg and 5 months old were assigned to three treatments included: 1) control diet, 2) and 3) diets containing 6% and 12% STSP, respectively. The performance characteristics of calves including weight gain, average daily gain, feed conversion ratio, feed efficiency, and digestibility of nutrients were measured. The final weight, total weight gain, average daily gain, feed conversion ratio, and feed efficiency were the same in all treatments ($P>0.05$). Consumption of nutrients, except ether extract, was not influenced by dietary treatments. The treatments caused no increase in digestibility of dry matter, neutral detergent fiber (NDF), acid detergent fiber (ADF) ($P>0.05$) and a significant increase in crude protein ($P<0.05$). The concentration of ammonia nitrogen, volatile fatty acids, and pH of rumen liquor, and blood glucose and blood urea nitrogen were not influenced by treatments. The chewing and rumination time adjusted for ADF intake was decreased in diets containing STSP ($P<0.05$). Therefore, the use of STSP as a replacement for part of corn silage in the diet of finishing calves did not have an adverse effect on performance and could be a proper alternative in the diet.

KEY WORDS blood parameters, chewing activity, digestibility, performance, rumen parameters.

INTRODUCTION

The microbial fermentation products like volatile fatty acids in the rumen of livestock, such as sheep and goats, which are only fed by roughages, produced more than 40% of their energy requirements. For food-producing animals, except for those fed manually with high concentrate diets, the rate and size of cell wall degradation are important factors affecting the consumption and availability of nutrient requirements for production. Dairy or beef cattle need to intake of high fodder with high digestion of the cell wall in the rangeland. In other parts of the world, where feed sources are limited, most animals only access low-quality by-products, which most of their composition is cell walls. Therefore, a slight change in the digestibility of these feeds can lead to a difference equivalent to the discrepancy between maintenance and low-production requirements (Chesson *et al.* 1995). Sugarcane bagasse pith is a by-product obtained after removing of hard skin from sugarcane bagasse. The sugarcane is also the residual product after the extraction of sugarcane juice, which is produced in Iran and throughout the world every year (Chaji *et al.* 2010). Several methods have been reported to improve the nutritional value of low-quality materials such as sugarcane

bagasse and cereal straw. These methods include the use of sodium hydroxide (Jackson, 1977; Osorio and Cruz, 1990), ammonia (Sundstol and Coxworth, 1984), steam (Castro *et al.* 1993; Liu *et al.* 1999; Chaji *et al.* 2010) alone or with the enzyme (Liu and Orskov, 2000) and ammonia (Horton *et al.* 1991). Different processes allow microorganisms to access cellulose structures and cell content (Osorio and Cruz, 1990).

Increased digestibility of cell wall (Pate, 1982) and dry matter (Chaji *et al.* 2010) had been reported by steam treated of bagasse (2 MPa, 2 minutes) or sugarcane pith (19 bar, 3 minutes), respectively. Horton *et al.* (1991) showed that the use of pelleted bagasse, up to 15% of the diet, did not reduce the performance of finishing cattle fed high grain diets. However, when these animals were fed with limited amounts of grain, and had *ad libitum* access to bagasse and pelleted Bermuda grass or corn silage (up to 100% of diet), the average daily gain and feed efficiency were significantly decreased in diets containing sugarcane bagasse. Replacement of steam treated sugarcane pith (19 bar, 3 minutes, 70% moisture) with 33, 66 and 100% wheat bran (maximum 12% ration) in the diet of the sheep, and feeding them at maintenance level, improved the digestibility of NDF and ADF, and had no effect on dry matter digestibility (Chaji *et al.* 2012).

There are little information and data about the effect of replacing STSP with part of forage in the diets of growing or finishing livestock on the performance and digestibility of nutrients. Most of the feeding experiments used the raw (untreated) or steam treated pith as the sole ingredient of diet or used chemical or other treatments to improve their feeding value and compare them with untreated bagasse. Therefore, the present experiment was conducted to study the effect of replacement of part of corn silage with steam treated sugarcane pith in finishing Holstein calves diet on finishing performance and digestibility of nutrients.

MATERIALS AND METHODS

All experimental procedures were carried out in the Ferdowsi University of Mashhad and all animals were cared for and used according to the Agricultural Animals in Research and Teaching guidelines (FASS, 2010).

Animals and experimental treatments

In this experiment, twenty-four finishing Holstein male calves with an average weight of 195 kg with a mean age of 5 months were selected. The calves were randomly assigned to one of the three experimental treatments. Each treatment included six replicates. The diet of the calves was formulated based on standard requirements tables (NRC, 2001).

The forage to concentrate ratio was 25 to 75, containing: concentrate, corn silage, and steam treated sugarcane pith (Tables 1 and 2).

The experimental treatments were included 1) control diet (without STSP), 2) diets containing 6%, and 3) 12% STSP, respectively. The freshwater was always available to the animals. The experiment period was about 75 days (15 days of adaptation to feed and environment and 60 days for recording the data). During the whole experimental period, the animals were manually fed a total mixed ration twice a day at 8.00 a.m. and 8.00 p.m. The price of STSP and low grain corn silage was $ 12 and $ 19 per ton, respectively.

Performance experiment

The calves were weighed every 15 days after 12 hrs. starvation prior to morning meal during the 60-day period of the experiment. The daily feed consumption was measured by recording the amount of given and the feed residual during the experiment days. Finally, feed efficiency (FE, ratio of average daily gain to average dry matter intake), feed conversion ratio (FCR, ratio of average dry matter intake to average daily gain), average daily gain (ADG), and total weight gain were calculated.

Rumen fluid sampling and measurement of fermentation parameters

Sampling from rumen fluid was performed every 15 days and 3 hours after morning meal using a stomach tube. The pH of the rumen fluid samples was measured immediately using a pH meter (Metrohm 691, Switzerland) and then filtered with four-layer cheesecloth. In order to measure ammonia nitrogen, 10 mL of ruminal fluid was acidified with an equal volume of 0.2 M HCl and stored at -20 ˚C. Ammonia nitrogen was measured by spectrophotometry method (Brodrick and Kang, 1980). The rumen fluid volatile fatty acids (VFA) concentration were measured using the gas chromatography method (Ottenstein and Bartley, 1971).

Blood sampling

Blood samples were taken from the jugular vein every 15 days, 3 hours after the morning feed, and poured into tubes containing EDTA. Samples were centrifuged at 3500 rpm for 10 minutes, and then the plasma was separated and stored at -20 ˚C to measure glucose, (BUN) and triglycerides using an automatic analysis device (Auto analyzer BT Targa 3000, Biotectica Rome, Italy).

Digestibility of nutrients

Total fecal excretion of livestock was collected for 7 days from days 55 to 62, and after daily weighing, about 10% was stored in a freezer at -20 ˚C.

Table 1 Feed ingredients of diets used to feed finishing calves in the present experiment

Ingredients	Percentage of steamed sugarcane pith in diets		
	0.0	6.0	12.0
Corn silage	24.0	18.0	12.0
Steam treated sugarcane pith	-	6.0	12.0
Barley grain	38.0	38.5	39.0
Canola meal	10	10	10
Wheat bran	15	15	15
Beet pulp	10.5	9.9	9.3
Urea	1.1	1.2	1.3
Limestone	0.7	0.7	0.7
Mineral and vitamin premix[1]	0.5	0.5	0.5
Salt	0.2	0.2	0.2

[1] Composition per kg of premix: vitamin A: 600000 IU; vitamin D: 200000 IU; vitamin E: 200 mg; Antioxidants: 2500 mg, Ca: 195 g; P: 80 g; Mg: 21000 mg; Mn: 2200 mg; Fe: 3000 mg; Cu: 300 mg; Zn: 300 mg; Co: 100 mg; I: 12 mg and Se: 1.1 mg.

Table 2 Chemical composition of experimental diets used to feed finishing calves

Chemical composition (g/kg DM)	Percentage of steamed sugarcane pith in diets		
	0.0	6.0	12.0
ME (Mcal/kg DM)	2.80	2.78	2.75
NDFom[1]	351	349	347
ADFom[2]	177	186	195
Ether extract	27.0	26.7	26.0
Crude protein	175.6	172.4	171.9
NFC	417	421	423
TDN	720.9	716.6	711.4
RUP[3]	31.28	30.28	29.28
RDP[4]	144.3	143.7	142.7
Ca	3.00	3.00	3.00
P	2.00	2.00	2.00

NDFom: neutral detergent fiber corrected for ash; ADFom: acid detergent fiber corrected for ash; RUP: rumen undegradable protein and RDP: rumen degradable protein.

At the end of the seventh day, after mixing daily samples of each animal, one sample was prepared to determine the composition of the nutrients. The nutrient digestibility of experimental diets was calculated according to the amounts of nutrients in feed, ort, and feces.

Chemical analysis

The chemical composition of the feed, ort, and feces were measured after drying (in an oven, at 90 ˚C for 24 hours, Memmert Germany) and milling with 2 mm sieve. Ether extract (Soxhlet method, Tecator, Sweden), dry matter (method 934.01-AOAC, 2005), ash (method 942.05-AOAC, 2005), crude protein (Kjeldahl method, FOSS Keldal Model 2300, Sweden), and acid detergent fiber (ADFom, method 973.18-AOAC, 1990; corrected for ash) were determined by standard method. Neutral detergent fiber (NDFom) was measured without sodium sulfate and amylase and was corrected for ash (Van Soest *et al.* 1991).

Statistical analysis

Data on weight gain and ammonia nitrogen samples was measured using the mixed procedure of SAS (2013) (version 9.4) using repeated measurement at the time. The initial weight was used as a covariate for final weight, because of the significant difference in initial weight at the beginning of the experiment.

RESULTS AND DISCUSSION

The performance of finishing calves fed with rations containing different levels of STSP is presented in Table 3. The final weight, total weight gain, average daily gain, feed conversion ratio, and feed efficiency were not different among the control diet, and treatments containing 6% and 12% of STSP (P>0.05). However, the feed conversion ratio (P=0.09) and feed efficiency (P=0.08) trends had improved in diets containing STSP.

Nutrient digestibility and feed intake are shown in Table 4. The consumption of dry matter and other nutrients, except ether extract (EE), was not affected by experimental rations; the EE consumption decreased with the increase of STSP in the diet. The digestibility of dry matter, NDF, ADF, and fat were not affected by treatments. Among the nutrients, the digestibility of crude protein in the diets containing STSP was significantly higher than the control diet (Table 4).

Table 3 Performance of finishing calves fed with diets containing steam treated sugarcane pith

Item (kg)	Percentage of steamed sugarcane pith in diets			SEM	P-value
	0.0	6.0	12.0		
Initial weight	188.4[a]	213.6[a]	185.2[b]	7.49	0.03
Final weight	263.4	287.4	257.3	8.17	0.41
Gain, days 0-30	41.6	38.4	41.6	3.06	0.88
Average daily gain, days 0-30	1.39	1.28	1.39	0.10	0.53
Gain, days 30-60	33.6	35.4	30.5	3.5	0.71
Average daily gain, days 30-60	1.12	1.18	1.02	0.3	0.61
Gain, days 0-60	75.2	73.8	72.1	3.45	0.88
Average daily gain, days 0-60	1.25	1.23	1.20	0.06	0.27
Feed conversion ratio[1], days 0-60	5.25	5.25	4.93	0.42	0.09
Feed efficiency[2], days 0-60	19.04	19.04	20.28	0.97	0.08
Average Dry matter intake, days 0-60	6.58[a]	6.46[a]	5.92[b]	0.13	0.04

[1] Ratio of average dry matter intake to average daily gain.
[2] Ratio of average daily gain to average dry matter intake.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 4 Feed intake and apparent nutrients digestibility of diets containing steam treated sugarcane pith fed to finishing calves

Item	Percentage of steamed sugarcane pith in diets			SEM	P-value
	0.0	6.0	12.0		
Average nutrients intake, kg/day					
Dry matter	6.91	6.48	5.63	0.37	0.087
NDFom	2.51	2.45	2.48	0.071	0.81
ADFom	1.29	1.28	1.49	0.074	
Crude protein	0.84	0.93	0.94	0.031	0.06
Ether extract	0.22[a]	0.20[b]	0.14[c]	0.006	0.0001
Apparent digestibility, g/kg					
Dry matter	688.2	709.7	697.2	20.5	0.76
NDFom	579.5	605.1	595.1	25.6	0.44
ADFom	460.5	480.6	507.1	31.8	0.60
Crude protein	716.3[b]	759.5[a]	768.7[a]	11.5	0.007
Ether extract	893.4	906.0	888.8	8.60	0.37

NDFom: neutral detergent fiber corrected for ash and ADFom: acid detergent fiber corrected for ash.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

The concentration of rumen liquor ammonia nitrogen, total VFA, acetate, propionate, butyrate, and pH of the calves were not affected by the experimental diets (Table 5).

Chewing activity, eating and rumination of calves was not affected by the experimental diets (Table 6). The eating time corrected for dry matter, NDF, and ADF intake was not affected by the experimental treatments. Rumination and chewing time corrected for ADF intake was affected by the experimental diets, which was lower in the diet containing 12% STSP than the control diet. Blood glucose and blood urea nitrogen concentrations of finishing calves were not affected by the experimental diets (Table 7). There was no difference in finishing performance characteristics when replacing STSP, as a low price by-product ($ 12 and per ton) of the food industry, with corn silage ($ 19 per ton); these results are one of the positive aspects of this experiment. In an experiment, rations containing steam treated (2 MPascal for 2 minutes, equivalent to 22 bar) sugarcane bagasse (60% diet of calf calves) were replaced with the cotton hull, raw bagasse, steam treated sugarcane bagasse pellet, ammoniated steam treated sugarcane bagasse pellet, corn silage or Bermuda grass (Horton *et al.* 1991). In their experiment, replacing the steam treated sugarcane bagasse with different forms of processed bagasse had no effect on the ADG and final weight of calves. However, these characteristics were significantly lower during the replacement of the steam treated sugarcane bagasse with Bermuda grass and corn silage (Horton *et al.* 1991). In that study, replacing steam treated sugarcane bagasse with peanut shells did not show any significant effect on carcass weight, ADG, and FCR of finishing calves (Horton *et al.* 1991). The superior chemical composition and low fiber content, along with more digestibility of corn silage (65%) and Bermuda grass (53%) resulted in better weight gain and FCR in these diets compared to the steam treated sugarcane bagasse (Horton *et al.* 1991).

Table 5 The rumen fermentation parameters in finishing calves fed with diets containing steam treated sugarcane pith

Item	Percentage of steamed sugarcane pith in diets			SEM	P-value
	0.0	6.0	12.0		
pH	6.42	6.32	6.41	0.06	0.78
Ammonia nitrogen	19.28	19.15	20.13	1.71	0.12
TVFAs, mmol	118.4	119.1	120.40	5.10	0.18
Acetate, mmol/100 mmol	55.8	58.0	61.0	4.34	0.16
Propionate, mmol/100 mmol	33.6	32.7	31.5	1.90	0.20
Butyrate, mmol/100 mmol	23.4	22.8	22.2	2.86	0.29
Valerate, mmol/100 mmol	3.3	3.5	3.7	0.11	0.08
Isovalerate, mmol/100 mmol	2.3	2.1	2.0	0.14	0.11
Acetate:propionate	1.66	1.77	1.93	0.20	0.33

TVFAs: total volatile fatty acids.
SEM: standard error of the means.

Table 6 The chewing activity (min/day) in finishing calves fed with diets containing steam treated sugarcane pith

Item	Percentage of steamed sugarcane pith in diets			SEM	P-value
	0.0	6.0	12.0		
Eating	191	211	181	23.54	0.66
Ruminating	421	355	315	46.34	0.30
Chewing	612	566	496	39.69	0.16
Eating per kg DMI	27.7	33.6	35.1	5.97	0.34
Eating per kg NDFI	76.08	88.61	73.75	11.85	0.64
Eating per kg ADFI	147.7	169.3	130.0	24.75	0.56
Eating/chewing (%)	31.2	37.3	36.5	5.67	0.64
Ruminating per kg DMI	61.0	54.57	54.28	6.06	0.46
Ruminating per kg NDFI	167.81	143.14	125.34	16.71	0.24
Ruminating per kg ADFI	325.8^{a}	273.8^{ab}	204.8^{b}	26.72	0.02
Ruminating/chewing (%)	68.8	62.7	63.5	5.66	0.65
Chewing per kg DMI	88.7	88.2	89.4	6.59	0.60
Chewing per kg NDFI	243.9	231.7	199.1	14.56	0.12
Chewing per kg ADFI	473.5^{a}	443.1^{a}	334.8^{b}	26.82	0.008
Chewing per 24 hr.[1] (%)	42.5	39.3	34.4	2.76	0.16

[1] Chewing per total of eatig + ruminating + rest= 1440 minute.
DMI: dry matter intake; NDFI: neutral detergent fiber intake; ADFI: acid detergent fiber intake.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 7 The concentration of some blood parameters in finishing calves fed with diets containing steam treated sugarcane pith

Item (mg/100 mL)	Percentage of steamed sugarcane pith in diets			SEM	P-value
	0.0	6.0	12.0		
Glucose	91.2	93.4	92.51	4.54	0.86
Blood urea nitrogen	11.3	11.4	13.0	0.51	0.09
Blood urea	24.1	24.4	24.8	1.09	0.09
Triglyceride	213.7	218.9	216.0	5.4	0.08

SEM: standard error of the means.

Perhaps the reasons for the significant difference between the performance of calves fed with sugarcane bagasse in comparison to corn silage or Bermuda grass in the experiment of Horton *et al.* (1991), compared to the present experiment, where the difference between diets containing corn silage and STSP was not significant, can be examined in several respects. First, Horton *et al.* (1991) had used sugarcane bagasse, which had less nutritional value than STSP used in this experiment (Chaji *et al.* 2007). The amount of lignin, NDF, and ADF in STSP, compared to bagasse was about 4%, 22%, and 3% lower, which resulted in better digestibility and increased performance of animals that intake it (Chaji *et al.* 2007). Secondly, in the present experiment, STSP was 6% and 12% in rations, while in the experiment of Horton *et al.* (1991), bagasse consisted of up to 60% of the rations. In other words, bagasse formed the main portion of the feed.

Consistent with the results of present experiment, the use of 0, 10, 20, and 30 percent of urea treated sugarcane bagasse in rations of beef calves had no effect on the final weight, ADG, and total weight gain compared to the control diet (raw bagasse), while the FCR improved (Ahmed Ibrahim, 2010). Replacing sugarcane bagasse with raw bagasse in the diet of finishing calves had no effect on the final

weights, the ADG, and the FCR (Rabelo *et al.* 2008). The replacement of 4, 8, and 12 percent of the barley straw diet with STSP in the ration of lactating Saanen goats improved the production and composition of milk (Chaji *et al.* 2007).

With the increasing amount of STSP in the diet, EE consumption was decreased. The reduction of EE intake was due to lower EE content of diets containing STSP (Table 2), and less consumption from these diets (Tables 3 and 4).

By replacing 13 and 17 percent steam treated bagasse (12.75 bar, 8 minutes) with milo forage, equal 38, and 52 percent of whole rations, the digestion of nutrients decreased (Medeiros and Machado, 1993). However, replacing 26% steam treated bagasse with raw sugarcane bagasse had no significant effect on the digestibility of nutrients, while it led to an increase in feed intake (Medeiros and Machado, 1993).

There was no significant difference in the apparent digestibility of organic matter, crude protein, NDF, ADF, cellulose, and lignin between raw bagasse and steam treated sugarcane bagasse. However, pelleting and ammonia treatment of steam treated sugarcane bagasse resulted in a significant reduction in the digestibility of these nutrients (Horton *et al.* 1991); these results disagree with our results. Pate (1982) fed steam treated bagasse (19 bar, 4 minutes) of up to 56% DM in diets and reported a significant increase in the digestibility of crude fiber, ADF, NDF, cellulose, and dry matter of diet, compared to the same level of raw bagasse in the diet. When Campbell *et al.* (1973), fed the sheep steam treated bagasse, the digestibility of crude protein slightly decreased compared to raw bagasse.

The replacement of 4, 8, and 12 percent barley straw with steam treated sugarcane pith (STSP) in the diet of lactating goats did not influence the digestion of dry matter, organic matter, NDF, ADF, crude protein, while the digestibility of nutrients improved in diets containing STSP (Chaji *et al.* 2007).

Replacing 40, 80 and 120 g/kg wheat bran with STSP in a ration of sheep fed at maintenance did not influence the consumption of dry matter, organic matter, and NDF (Chaji *et al.* 2012). There, the replacement of wheat bran with STSP in the ration of sheep did not affect the digestibility of dry matter, organic matter, and protein, while the digestibility of NDF and ADF increased (Chaji *et al.* 2012). The amount of NDF (41.2% and 55%, respectively) and ADF (14.5% and 50.5%, respectively) in wheat bran was lower than steam treated sugarcane pith. Therefore, it was expected that the digestibility of fibers to be higher in diets containing wheat bran; however, because of the lower passage rate of rumen liquor in the diets containing STSP compared to wheat bran diets, the digestion of fiber was improved in diets containing STSP (Chaji *et al.* 2012).

In the present experiment (Table 4), replacement of STSP with corn silage caused an insignificant increase in the digestibility of dry matter, NDF, ADF, and a significant increase in crude protein. One of the possible reasons for increasing the digestibility of the nutrients may be attributed to the lower consumption of dry matter by an increase in the level of STSP in the diet (Table 3). As low dry matter consumption reduces the passage rate of liquor from the rumen, the rumen retention time increases, and more opportunities are created for the digestion of nutrients, especially the cell wall where the rumen is the main site for digestion (Chaji *et al.* 2012). The concentration of ammonia nitrogen and pH of rumen liquor in the calves fed with STSP was not affected by the experimental diets (Table 5). The forage to concentration ratio and the amount of fiber in the diet, influenced the VFA profile, the concentration of acetate, propionate, butyrate, and the acetate to propionate ratio, etc. (McDonald *et al.* 2010). The forage to concentration ratio (Table 1) and the amount of NDF and ADF of diets (Table 2) and their intake (Table 4) were not different. Therefore, the VFA concentration was not changed. The concentration of VFA correlates with the pH of the rumen (McDonald *et al.* 2010), and there were no differences among treatments for the concentration of VFA (Table 5). Therefore, it might have been the reason for no change in rumen pH among treatments.

Consistent with the results of present experiment, the replacement of 4, 8, and 12 percent of barley straw with STSP in the ration of lactating Saanen goat did not affect the rumen pH and concentration of ammonia nitrogen (Chaji *et al.* 2007).

Ammonia nitrogen concentration and rumen pH of male lambs fed diets containing 40, 80, and 120 g/kg STSP as a replacement with wheat bran, were not influenced, these results are consistent with our results. However, an increase in the amount of STSP in the ration resulted in an insignificant increase in the pH and ammonia (Chaji *et al.* 2012).

The chewing activity of calves was not affected by the experimental diets. Consistent with the results of the present experiment, the replacement of 4, 8, and 12 percent barley straw with STSP in the ration of lactating goats did not influence the chewing activity, rumination, and eating time, individually or corrected for dry matter and NDF intake (Chaji *et al.* 2007).

Blood glucose and urea nitrogen concentrations of finishing calves were not affected by the experimental diets. There is a high correlation between glucose and propionate production in the rumen (McDonald *et al.* 2010) and between BUN and concentration of the rumen ammonia nitrogen (Davidson *et al.* 2003). Since there were no significant differences in the concentration of rumen ammonia

nitrogen or propionate among the treatments (Table 5), the concentration of BUN and glucose were the same.

The increasing amount of STSP in the diet of lactating goat as a replacement for barley straw did not affect the concentration of blood ammonia nitrogen, while the concentration of blood glucose was linearly increased (Chaji *et al.* 2007).

CONCLUSION

Consequently, the use of steam treated sugarcane pith as a replacement (both 6% and 12%) for part of corn silage in the diet of finishing calves did not have a negative effect on the performance, nutrient digestibility, rumen, blood parameters, and chewing activity, but could be a proper alternative to it in the diet. The STSP is much cheaper compared to corn silage and it is abundant in many areas, especially in the southern regions of Iran and other parts of the world. Therefore, its using, to the extent that it was used in the present experiment (12% of the diet), can reduce the production costs. In addition, it leads to the optimal use of feed sources derived from the agricultural and food industries.

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