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Full Length Article

Effects of Replacing Whole-Plant Corn Silage with Whole-Plant Rice Silage and Rice Straw on Growth Performance, Apparent Digestibility and Plasma Parameters in Growing Angus Cross Bred Beef Cattle

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Abstract

The purpose of the current experiment was to check the outcome of replacing whole-plant corn silage (WCS) with whole-plant rice silage (WRS) and rice straw (RS) on growth performance, apparent digestibility and plasma parameters in growing Angus cross bred beef cattle. A total of 30 Angus hybrid bulls (body weight = 272.43 ± 21.80 kg) were divided into three groups and three dietary treatments were offered: WCS, whole-plant corn silage diet; WRS, whole plant rice silage and RS, rice straw diet. An equal amount of concentrate (1.76) was supplied to all experimental treatments. Results showed similar dry matter intake (DM) of WCS, WRS and RS ($P > 0.05$). Ether extract and crude protein (CP) intake was higher in animals which were on WRS feed, while the CP intake was lowest in animals which were on RS diet ($P < 0.05$). Highest acid detergent fiber (ADF) and neutral detergent fiber (NDF) intake was observed in bulls fed RS diet ($P < 0.05$). Lowest final body weights were observed in animals which were on RS diet ($P < 0.05$). Highest DM and CP digestibility were observed in bulls on WCS treatment ($P < 0.05$). In case of both ADF and NDF digestibility, highest ADF and NDF digestibility was seen in bulls which were on RS diet ($P < 0.05$). Lowest forage price and weight gain price per day was observed in animals which were on RS diet ($P < 0.05$). In conclusion, WRS can successfully replace WCS in growing beef cattle without impairing DM intake, weight gain and final body weight gain. © 2019 Friends Science Publishers

Keywords: Whole plant corn silage; Whole plant rice silage; Rice straw; Growth; Digestibility; Bulls

Introduction

The trend of ensiling of fodder is widely practiced in different countries and to ensure seasonal fodder availability, to store forage at a precise nutritional value, to expand the farmland utilization and to meet the nutritional requirements of high producing animals. Various studies have been conducted to evaluate the use of whole-crop cereal silages, for example sorghum, wheat, barely, alfalfa and maize in ruminant production (Kim *et al.*, 2016; Shibata *et al.*, 2016; Niu *et al.*, 2017; Chen *et al.*, 2018; Nazli *et al.*, 2018; Xia *et al.*, 2018c). In dairy production whole crop corn silage (WCS) is preferred and WCS is being used as a major component of feed (Chen *et al.*, 2018; Nazli *et al.*, 2018). However, the major consequence of inclusion of WCS in beef production is high cost of WCS which ultimately reduce the profit. Therefore, farmers in developing countries are focusing on the use of alternative crop silages to reduce the cost of beef production (Wei *et al.*, 2018; Rahman *et al.*, 2019; Viennasay *et al.*, 2019).

Rice crop silage is another trend in ruminant feeding system because modified verities of rice have been introduced in the filed with high energy yield per unit area and surplus production of rice and being used in the dairy and beef production (Ki *et al.,* 2009). Like other forage crops, whole crop rice is mostly used in ensiled form (Takahashi *et al.*, 2007; Ki *et al.*, 2009; Shibata *et al.*, 2016) and Ki *et al.* (2009) recommend the use of whole crop rice silage (WRS) in beef production because of its high contents of α-tocopherol. Similar with WCS, the major consequence of inclusion of WRS in beef production is also high cost of WRS. Therefore, farmers in developing countries are focusing on the use of crop residue to increase beef production and to reduce the cost of beef production (Wei *et al.*, 2018; Rahman *et al.*, 2019; Viennasay *et al.*, 2019). However, demand of beef meat is increasing in China (Zhang *et al.*, 2015; Muhammad *et al.*, 2016; Aziz-ur-

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Rahman *et al.*, 2017; Xia *et al.*, 2018a, b, b; Rahman *et al.*, 2019) and in 2050 beef consumption will rise by 119% to 1139.2 million tons (Sheng and Song, 2019). Keeping in veiw the demand of beef meat, rearing of beef animal on crop residue will not fulfill the requirement of animal and ultimately the demand of meat. Therefore, a study is needed to evaluate the production performance of beef cattle on WCS and WRS and crop residue i-e rice straw (RS) and economic benefits of feeding WCS, WRS and RS to beef cattle. According to our knowledge no study was conducted to evaluate the effect of replacing high price WCS with WRS and RS on growth performance, apparent digestibility and plasma parameters in growing angus beef cattle. We hypothesized by feeding WRS with concentrate will successfully reduce the cost of feed in beef production and performance of animals will not be compromised as compare to WCS, while RS will partially replace WCS.

Materials and Methods

Ethics Statement

All procedures used in this experiment was conducted in accordance with the Chinese Guidelines for Animal Welfare. Experimental procedures performed in the current study was approved by the Hunan Agricultural University Institutional Animal Care and Use Committee (Changsha, China). Furthermore, all experiments protocols including animal handling were performed humanly and animal welfare were specially considered. We further confirmed that no harm or stress was given to animals during the experimental period. The nutritional requirement and fiber requirement exceed the recommended level to cope abnormal behavior related to deficiency of nutrition and fiber source.

Experimental Design, Animal Management and Diet

The experimental trial was performed at Hunan Tianhua Industrial Co., Ltd. (Loudi City, Hunan Province, China). In the current study, a total 30 Angus hybrid bulls (Xiangxi Yellow Cattle x Angus, body weight = 272.43 ± 21.80 kg) were divided into three groups in such a way that each group received one of three dietary treatments. The dietary treatments were: WCS, whole-plant corn silage diet; WRS, whole plant rice silage and RS, rice straw diet. An equal amount of concentrate was supplemented with above said forage sources. Concentrate was made according the nutritional requirements recommended by Nutritional Research Council (N.R.C.) of U.S.A. The amount was enough to maintain the minimum daily requirement of the animals. It was ensured that amount of concentrate was enough to maintain daily weight gain of half kg per day. During the experimental trial first ten days were considered as adaptation period and trail was finished after 70 days. Before the start of experimental trial all the animals were weighed and tagged for identification. De-worming and all necessary vaccines were performed before the start of experiment to ensure smooth running of experiment. Optimum standard housing condition were provided to animals by keeping in view the welfare of animals as stated in previous researches (Muhammad *et al.*, 2016; Aziz-ur-Rahman *et al.*, 2017; Jiang *et al.*, 2019).

The WCS was transported from Hunan Deren Animal Husbandry Co., Ltd. The Whole-plant rice was harvested at the milky ripe stage from Yueyang City, Hunan Province, China. A commercial harvester was used to harvest the Whole-crop rice and harvested whole-crop rice was wilted for one day before ensiling. The wilted whole rice crop was ensiled at Hunan Deren Animal Husbandry Co., Ltd site for 60 days prior to animal feeding. After opening of ensiled crops, both WCS and WRS were chopped with a commercial cutter to size of about 2-3 cm length before every feeding time throughout the experimental trial. Rice straw was supplied by Hunan Tianhua Industrial Co., Ltd. A 1.75 Kg of concentrate per day per cattle was offered to each animal. Silages were offered *ad-libitum* and the feed intake was recorded every day. Chemical composition of experimental diet along with concentrate ingredient profile is presented in Table 1. The feeding time to the experimental animals were twice a day *i.e.*, at 8:00 and 14:00 and 5 to 10% orts was ensured throughout the experimental trial. Fresh drinking water was also ensured throughout the trail.

Sample Collection

Intake of silages and RS were determined daily by subtracting the residual with offered feed. For digestibilities trail, acid-insoluble ash (AIA) was used as internal marker. Acid insoluble ash was mixed in the diet six days prior to animal digestibility trail to acclimatized animals on AIA. Mixing of internal marker was done in the concentrate. Digestibility trail was conducted at d-56 to d60 of the experimental period. A total of six animals per treatment was used during the digestibility trail. Animal were shifted in the special metabolic cages before 10 days of the digestibilities trial to acclimatize the new environment. During the collection of samples for digestibility, fecal samples were collected from the rectum of each animal for time point *i.e.*, 6:00, 12:00, 18:00, and 24:00. The feed, and orts samples were also collected on the same days of digestibility trail to calculate the exact feed intake. Collected sample of feed, ort and fecal were dried at 65°C in hot air oven. Sample were place in oven until the constant weight of the samples were obtained. Dried samples were further grinded by grinding mill with a 1-mm screen, and then stored at -20°C for further proximate analysis, neutral detergent fiber (NDF), acid detergent fiber (ADF) and AIA determination. The AIA values of the diets, orts and feces were analyzed following the method described by previous researcher Keulen and Young (1977), with the formula described by Zhong *et al.* (2008):

$$D = [1 - (Ad \times Nf) / (Af \times Nd)] \times 100$$

Where Ad (g/kg) and Af (g/kg) represent the AIA of the diet and feces, respectively and Nd (g/kg) and Nf (g/kg) represent the nutrient contents of the diet and feces, respectively.

For determination of blood metabolites, blood was collected from each animal at d 61 of experimental period before the morning feeding. Blood was collected (approximately 10 mL) *via* syringe from the jugular vein into tubes contained Na-heparin. Collected blood samples were centrifuged at 3,000 × g for 20 min at 4°C to collect plasma, separated into three aliquots and frozen at -20°C for subsequent biochemical index analyses.

Economic Benefits

The price of concentrate, WCS, WRS, and RS were 3, 0.6, 0.6 and 0.5 RMB per Kg, respectively. Price of each component of feed per day was calculated by the cost of intake of each component over entire day. Weight gain price was calculated by cost of all component feed required for per kg weight gain.

Chemical Analysis

Proximate analysis of feed, orts and fecal samples were determined by the following the procedure of Association of Official Analytical Chemists (A.O.A.C., 1990). The OM content was calculated using the following formula:

100- the percentage of ash

Ankom Fibre Analyser (Ankom Technology, Fairport, N.Y.) was used to determine the fractions of NDF and ADF in feed, orts and fecal samples. For determination of NDF and ADF official method of Vansoest *et al.* (1991) was followed. Crude protein determination was carried out following the procedure of Kjeldahl (A.O.A.C., 1990; method 990.03). All proximate analysis procedure along with NDF and ADF determination was completely or partially followed by standard methods as described in previous studies (Li *et al.*, 2014; Wang *et al.*, 2016; Hussain *et al.*, 2018a, b; Sharif *et al.*, 2018; Zhang et al., 2018).

The plasma biochemical indicators, such as total glycerin (TG), total cholesterol (TC) and total protein (TP), were examined by using an automated biochemistry analyser (BS-200 Mindray, Wuhan, China). Albumin (ALB), low density lipoprotein (HDL), high density lipoprotein (LDL), plasma urea nitrogen (BUN), glucose (GLU) and free Fatty Acids (FFA) were examined using commercial test kits (Andygene, Beijing, China) as used by previous researcher (Rehman *et al.*, 2019a, b).

Statistical Analysis

Statistical analyses were carried out using S.A.S. software (S.A.S. Institute Inc., Cary, U.N., U.S.A.). Data within each treatment group were checked for normality using PROC UNIVARIATE NORMAL. Differences of means in different treatments were tested using Duncan's multiple range test and considered statistically significant at $P < 0.05$.

Results

Intake and Growth Performance

Results of effects of replacing WCS with WRS and RS on growth performance is presented in Table 2. Results showed that intake of silages and RS were similar among the experimental diets ($P > 0.05$). The amounts of concentrate intake were similar among all the animals. Overall dry matter (DM) intake was not changed by experimental treatments ($P > 0.05$). Nutrient intake differs due to experimental diets ($P < 0.05$). Crude protein intake was maximum in animals were on WRS feed, while the crude protein intake was lowest in animals which were on RS diet ($P < 0.05$). Similarly, ether extract intake was higher in animals were on WRS feed, while the ether extract intake was lowest in animals which were on RS diet ($P < 0.05$). Highest NDF intake was observed in animals which were on RS diet ($P < 0.05$), while the NDF was similar in WCS and WRS diet ($P > 0.05$). Similarly, ADF intake was observed in animals which were on RS diet ($P < 0.05$), while the ADF intake was similar in WCS and WRS diet ($P > 0.05$). Lowest final body weights of the animals were observed in animal which were on RS diet ($P < 0.05$). However, replacing WCS with WRS and RS decrease the average daily body weight gain in animals which were on RS diet ($P < 0.05$), while the weight gain of WCS and WRS were similar ($P > 0.05$).

Feed Digestibility

Results of nutrient digestibility are showed in Table 3. In case of nutrient digestibility results, DM digestibility was changed by experimental diets ($P < 0.05$). Highest DM digestibility were seen in bulls which were receiving WCS experimental diet ($P < 0.05$), while the lowest DM digestibility was observed in animals which were on RS diet ($P < 0.05$). Organic acid digestibility was high in animals which were on WCS ($P < 0.05$), while the lowest OM digestibility was observed in animals which were on WRS diet ($P < 0.05$). While in case of CP digestibilities, highest CP digestibilities was observed in animals which were on WCS diet and the lowest CP digestibility was observed in animals which were on RS diet ($P < 0.05$). Ether extract digestibilities was not influenced by experimental diets ($P > 0.05$). In case of both ADF and NDF digestibility, dietary treatments affected the digestibility ($P < 0.05$). Highest ADF and NDF digestibility was observed in animals which were on RS diet as compared to other treatments ($P < 0.05$).

Table 1: Chemical composition of experimental diets (% DM basis)

Items	Concentrate supplement[1]	Whole crop corn silage	Whole crop rice silage	Rice straw
Organic matter	92.96	92.03	87.00	87.34
Dry matter	87.93	26.30	36.00	88.81
Crude protein	14.09	7.52	9.34	5.72
Ether extract	3.11	6.50	8.82	3.81
Neutral detergent fiber	18.05	71.48	60.41	87.23
Acid detergent fiber	6.23	46.29	41.52	85.27

[1]The ingredients composition of concentrate supplement was: Corn 57%, Soybean meal 25%, Wheat bran 13%, Limestone 1%, NaCl 1%, $NaHCO_3$ 1%, CaHPO4 1%, Premix 1%. Every kilogram of mineral–vitamin premix contained the following: 8000 IU Vitamin A, 1200 IU Vitamin D3, 40 IU Vitamin E, 15.85 mg Cu, 88.68 mg Fe, 63.05 mg Mn, 59.99 mg Zn, 9.04 mg Mg, 0.21 mg Se, 0.83 mg I, 0.16 mg

Table 2: Effects of replacing whole-plant corn silage and whole-plant rice silage with rice straw on growth intake and growth performance of beef cattle

Items	Dietary treatment			SEM	*P*-value
	[1]WCS	[2]WRS	[3]RS		
Intake					
Forage dry matter intake (kg)	4.50	4.68	4.93	0.143	0.494
Concentrate dry matter intake (kg)	1.76	1.76	1.76		
Overall dry matter intake (kg)	6.26	6.44	6.69	0.142	0.494
Crude protein	0.59^{b}	0.67^{a}	0.53^{b}	0.018	0.001
Ether extract	0.35^{b}	0.46^{a}	0.25^{c}	0.025	<0.001
Neutral detergent fiber	3.53^{b}	3.06^{b}	4.62^{a}	0.199	<0.001
Acid detergent fiber	2.19^{b}	1.99^{b}	4.31^{a}	0.230	<0.001
Growth performance					
Initial body weight (kg)	270.80	271.90	274.60	5.629	0.966
Final body weight (kg)	327.59^{a}	332.04^{a}	304.79^{b}	6.736	0.049
Average daily weight gain (kg)	0.95^{a}	1.00^{a}	0.67^{b}	0.048	0.002

[1]whole crop corn silage
[2]whole crop rice silage
[3] rice straw
Different superscript letter in the same row represent the significant difference

Table 3: Effects of replacing whole-plant corn silage and whole-plant rice silage with rice straw on apparent digestibility of beef cattle

Items	Dietary treatment			SEM	*P*-value
	[1]WCS	[2]WRS	[3]RS		
Apparent digestibility of nutrients (%)					
Dry matter	56.19^{a}	50.82^{b}	51.93^{b}	0.695	<0.001
Organic matter	53.95^{a}	47.98^{c}	50.10^{b}	0.754	<0.001
Crude protein	60.80^{b}	68.92^{a}	57.74^{c}	1.301	<0.001
Ether extract	52.23	51.83	54.76	0.789	0.285
Neutral detergent fiber	53.79^{b}	49.93^{c}	56.19^{a}	0.759	<0.001
Acid detergent fiber	50.79^{b}	45.81^{c}	54.52^{a}	0.767	<0.001

[1]whole crop corn silage
[2]whole crop rice silage
[3] rice straw
Different superscript letter in the same row represent the significant difference

However, lowest ADF and NDF digestibilities was observed in animals which were on WRS diet ($P < 0.05$).

Blood Metabolites

The results of effects of replacing WCS and WRS with RS on blood metabolites are presented in Table 4. Results revealed that experimental treatments did not influence the blood metabolites ($P > 0.05$). Blood plasma TG were similar among all experimental treatments ($P > 0.05$). Similarly, blood plasma TC, ALB, HDL, LDL, BUN, GLU, and FFA were similar among all treatments ($P > 0.05$).

Table 4: Effects of replacing whole-plant corn silage and whole-plant rice silage with rice straw on plasma biochemical parameters of beef cattle

Items	Dietary treatment			SEM	*P*-value
	[1]WCS	[2]WRS	[3]RS		
Total glycerides（mmol/L）	0.17	0.19	0.19	0.006	0.258
Total cholesterol （mmol/L）	4.91	4.86	4.70	0.107	0.716
Total protein（g/L）	74.24	74.06	68.43	1.626	0.265
Albumin（g/L）	38.78	35.94	34.02	1.158	0.253
High density lipoprotein（mmol/L）	1.16	1.15	1.27	0.059	0.682
Low density lipoprotein（mmol/L）	0.32	0.32	0.31	0.011	0.893
Blood urea nitrogen（mmol/L）	13.81	12.81	12.14	0.432	0.299
Blood glucose（mmol/L）	4.51	4.73	4.59	0.174	0.894
Free fatty acids （μmol/L）	0.32	0.29	0.25	0.015	0.159

[1]whole crop corn silage
[2]whole crop rice silage
[3] rice straw
Different superscript letter in the same row represent the significant difference

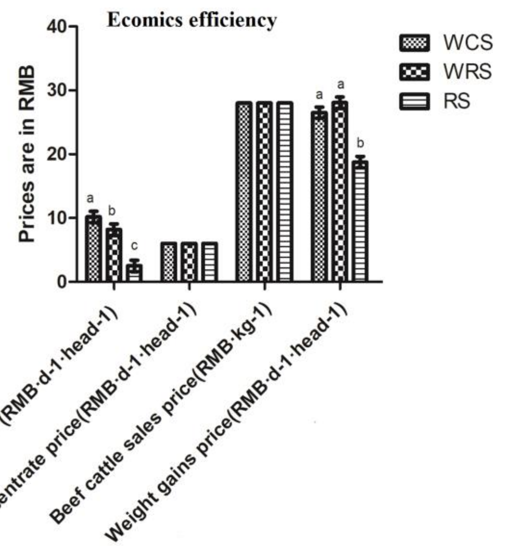

Fig. 1: Effects of replacing whole-plant corn silage and whole-plant rice silage with rice straw on economic efficiency of beef production. Error bars represents standard error means. Different small letter represents significance difference. WCS, WRS and RS represents whole crop corn silage, whole crop rice silage and rice straw respectively

Economics Efficiency

Results of economic efficiency of dietary treatments are presented in Fig. 1. Results revealed that forage price were influence by experimental treatments ($P < 0.05$). Forage price was higher in animals which were on WCS, while the lowest forage price was observed in animals which were on RS diet ($P < 0.05$). In term of weight gain price of animals, treatments affected the weight gain price of animals ($P < 0.05$). Higher weight gain price was observed in animals which were on WCS and WRS as compared to animals which were on RS ($P < 0.05$).

Discussion

Dry matter intake of forage, concentrate and overall DM intake was similar in all animals fed WCS, WRS or RS. Similar intake of DM of forage and overall DM intake in current study could be explained by theory adjusted voluntary feed intake of animals in relation to a physiological demand (metabolic regulation) (Papi *et al.*, 2011; Joy *et al.,* 2014; Muhammad *et al.*, 2016). Similar amount of concentrate was offered to animals among all dietary treatments in current study which exceed their NRC recommended requirements, therefore animals adjusted their forage intake to cope the negative effect of the excess concentrate. It has been reported that higher concentrate level caused acidosis in animals and animals forage intake increased (Faleiro *et al.*, 2011; Muhammad *et al.*, 2016; Aziz-ur-Rahman *et al.*, 2017). Therefore, it could be assumed that similar concentrate level encouraged animals to take similar amount of forage irrespective to forage type in current study. In case of nutrient intake, higher CP intake was observed in animals which were on WRS diet. Higher CP intake of WRS could be explained by similar forage DM intake of all experimental diets and higher CP contents of WRS as compare to WCS and RS (Table 1). In current study, NDF and ADF intake was similar in WCS and WRS. Our findings are in consistent with results of Ki *et al*. (2009) who stated that NDF and ADF intake were similar in dairy animals which were fed either WCS or WRS. Similar findings have also been reported by Takahashi *et al.* (2007). Takahashi *et al.* (2007) stated that Holstein cows showed similar NDF and ADF intake when Sudangrass hay was replaced by WCS in the diets of Holstein cows. However, in the current study RS diet NDF and ADF intake was higher as compared to other dietary treatments. The significant increase in the NDF and ADF intake with RS as compared to WCS and WRS in current study was due to the RS high NDF and ADF contents (Table 1). Higher NDF and ADF intake can be easily justified by similar DM intake of all experimental animals with WCS, WRS and RS treatments and RS had higher level NDF and ADF. Before the start of the experiment animal were randomly assigned to one of three treatments and the results of initial body weight after statistical analysis showed no difference among the experimental treatment (Table 2). Statistical results of initial body weight represent that randomization of animals in the current experiment was done appropriately to avoid bias among the experimental diets. Results of final body weight after statistical analysis explored that experimental treatment experimental treatment significantly changed the average daily weight gain and final body weight. No difference in initial difference in average daily weight gain and final body weight had given more accurate indicator for growing bull performance. As anticipated, animals which were on WCS and WRS experimental diets had the higher average daily gain and final body weight gain which were very close to growing beef cattle of other breed fed with 80% concentrates as described by previous researcher (Kum and Zahari, 2011). In the current study the average weight gain of Angus cross bred animal @ 0.95 Kg/day and 1 Kg/day on WCS and WRS experimental diets was also better compared with other beef cattle breed which were reared on feedlot system; Simmental-KK (750 g/day), Limousin-KK (750 g/day) Charolais-KK (816 g/day) (Johari and Jasmi, 2009). The animals which were on WCS and WRS experimental diet shoed weight increase and represents higher weight gain as compared to RS in current study which agreed the findings of previous researcher (Nazli *et al.*, 2018). Based on final body weight and average daily weight gain, it could be hypothesized that Angus cross bred beef cattle could be reared on crop waste like RS and can give positive average daily weight gain although this average weight gain will be low compared to conventional WCS and WRS diet.

Whole corn silage diet significantly increased the DM and organic matter digestibility, providing more available digestible nutrient that can increase the average daily weight gain (Table 2). Corn silage OM and DM higher digestibilities has been reported by previous researcher over other forage or ensiled forage and crop residues (Kum and Zahari, 2011; Wang *et al.*, 2016; Nazli *et al.*, 2018; Xia *et al.*, 2018a, c). Nazli *et al.* (2018) reported that WCS has more DM or OM digestibility over RS. Similarly, corn silage DM digestibility has been reported higher than Napier grass diet (Khaing *et al.*, 2015). Even though the DM and OM digestibility was higher in WCS but WRS had more CP digestibility. The higher CP digestibility in WRS treatment could be explained by higher CP contents in WRS (Table 1). Interestingly, higher NDF and ADF digestibilities was observed in RS in current study which could be explained by higher NDF and ADF retention time. It has been reported that fiber digestibility increases with longer retention time of feed in the rumen (Yansari, 2017). Retention time is affected by level of intake of the animal (Yansari, 2017) and in current study intake was similar among all the dietary treatments and hence increased NDF and ADF digestibilities was due to higher retention time of RS as compare to WCS and WRS.

Recently, high yielding rice varieties has been introduced in the field which increased the per acre yield of rice and now rice crop are being used in the ruminant production especially in ensiled form (Ki *et al.*, 2009). Forages for ruminates production are costly and ensiling of surpluses rice crop is reducing dependency on the costly forages (Ki *et al.*, 2009). Results of current study revealed that the replacing WCS with WRS decrease the price of forage and dependency on conventional forages in beef production which support the results of Ki *et al*. (2009). Interestingly, replacing of both WCS and WRS with RS further decrease the forage cost in beef production. Furthermore, current findings revealed that the price per day body weight gain was similar for both WCS and WRS, however the price of per day weight gain was lower in animals which were on RS. These findings support our hypothesis that the inclusion of RS in diet of beef animals will reduce the cost of beef production but RS inclusion in diet will not meet the growth rate of animals reared at WCS and WRS diet.

Conclusion

Replacing whole crop corn silage with whole crop rice silages had no negative impact on intake, weight gain and final body weight of growing animals. However, replacing of whole plant corn silage decrease the body weight gain and final body weight of the animals. Furthermore, replacing of whole crop corn silage with whole crop rice silage decrease the price of forage in beef production.

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