Effects of Steam Treated Rice Straw-Based Diet on the Physico-Chemical Properties of Goats Longissimus Muscle

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Abstract

The present study was carried out to investigate the effects of steam treated rice straw-based diets on, physico-chemical properties of *longissimus* muscle of goat. Goats were assigned to rice straw treated with steam at 15.5 kgf/cm^2 for 120 Sec (STRS) and untreated rice (UTRS) straw-based diets. After 60 days all goats were slaughtered and 50 g of muscle *longissimus dorsi* (LD) was removed from left side of carcass for determination of meat quality and fatty acid profile. The results showed that the steam treated rice straw diet improved ($P < 0.05$) carcass yield and dressing % of goats as compared to untreated rice straw fed goats. Significantly higher protein and lower moisture was observed for meat of STRS group than UTRS, however the fat, ash contents, meat color and pH were not different between the groups. The TBARS values gradually increased in stored meat. The different diet did not affect the composition of fatty acids. Total saturated (∑SFA) monounsaturated fatty acids (∑MUFA) for UTRS and total polyunsaturated fatty acid (∑PUFA) for STRS group was higher ($P > 0.05$). It is concluded that the goats fed on treated straw diet (STRS) maintained carcass yield, dressing % and meat composition without negative impact on meat characteristics.

Novelty Of The Study

Straw is important agro-industrial byproduct with huge potential of nutrition which must be unlocked to utilize for the milk and meat producing animals. Different techniques which are used to enhance the availability of these important nutrients i.e., urea treatment but it causes toxicity. So, among new techniques, steam treatment is novel technique in this respect, which is used in this study.

Introduction

The use of cereal grains, wheat and barley straws have become a common practice for ruminant feeding (Al-Dalain et al. 2020) but grain based commercial supplements may not be economical for growing and finishing meat goats because high starch supplement in feed lead to decrease in pH and fiber digestibility (Mwangi et al. 2019). The fibrous by products such as cereal straws are a main component of the ruminant diet in tropical and subtropical areas during both cropping seasons and dry or winter periods (Ghasemi et al. 2014). It is, however, imperative that for increasing the productivity in the livestock sector, effective strategies should be designed to improve the efficiency of crop residues (Kurokochi and Sato, 2020).

Nevertheless, supplementation of feedstuffs along with crop residues may improve the nutritive value of crop residues or treatment with chemicals which enhance digestibility after partially solubilization of primary cell wall components (Safari et al. 2011). There is a large no of studies which show that steam treatment and steam explosion (SE) of stalks and straws, demonstrated the pliability of the steam explosion process and the probable conversion of forestry and agriculture residues into economically valuable commodities (Viola et al. 2008).

The consumers demand high quality and convenient meat products with natural flavor and taste (Karami et al. 2011). The unsaturated fatty acids contents in meat have importance related to the consumer's health (Paengkoum et al. 2013). It has been investigated that in the tissue of caprine and bovine fatty acid profile is being influenced by diet, age and production system (Dhanda *et al.* 1999). In meat, together with metal ions, heme proteins, and reactive oxygen species, highly peroxidizable poly unsaturated fatty acids (PUFA) may be considered prooxidant components and the risk of oxidation lift by increasing unsaturated fatty acids in meat. The free-radicals are involved in the oxidation of lipids that is a primary reason of shelf-life reduction and rancidity development in many kinds of meats (Luciano et al. 2011; Paengkoum et al. 2013).

However, different studies showed that residues of crop supplementing with other feed stuffs or increasing digestibility by using chemicals and/or feed taken after dissolving crusting substances (Cellulose, hemicellulose and lignin) that cause improvement in ruminant performance (Abebe et al. 2004). Very limited information is present regarding characteristics of carcass and meat quality of goats when reared on steam treated rice straw feeding. Hence, the aim of present study was to determine steam treated straw in order to search economical ration (growing and finishing) for meat-goat to minimize negative impact on the environment of rumen while feeding high-starch diets to ruminants.

Materials And Methods

Steam treatment of rice straw

The rice straw was obtained from the agricultural field of Nanjing Agricultural University. The samples were chopped, and steam treated for 120 Sec at steam pressure of 15.5 kg f/cm^2 (STRS-2). The College of Engineering Nanjing Agriculture University designed the steam explosion machine and dried treated and untreated rice straws was transported to experimental farm.

Location and description of the study area

The experiment was conducted at the goat farm situated at Liuhe Animal Science Base of Jiangsu Academy of Agricultural Science, Zhuzhen, Nanjing, China. There is mean annual temperature of about 28°C (82 °F) in July, while -7°C (19°F) in January months respectively. Moreover, this area has an approximately 1,100 millimeters (43 inches) average rainfall, 117 rainy days and have almost 76% mean relative humidity.

Animals' management and feeding

The experiment was conducted according to the animal care and guidelines of the Animal Care Committee, Nanjing Agricultural University China. Ten Xuhuai goats (18.47±0.39 kg) were equally divided into two feeding groups and were assigned to untreated (UTRS) or steam treated (STRS) rice straw diets (Table 1) in a 60-day trial period, a 7 day adaptation period was provided to the goats prior to start of the trail. The goats were kept in a 15'×20' shed with height at center 10', side walls of chain link fencing 6', slatted floor, troughs used for feeding and a central alley. Goats were offered feed on *ad libitum* twice daily at 08:30 and 16:30 hour (h).

Meat sampling and carcass traits

At the end of 60 days trail all the goats were individually weighed and humanely slaughtered after an 18 h fasting. After slaughtering animals were hanged for skinning which was removed in order head (up to the atlanto-occipital joint) forefeet and hind feet up to the carpal-metacarpal joint and the tarsal-metatarsal joint respectively. The muscle samples were subsequently taken from left side of carcass. A sample of about 50gm from left side *longissimus dorsi* (LD) muscle was taken and at -20°C stored for further analysis. Fasted live and carcass weight were recorded immediately after slaughtering and the dressing percentage was calculated by dividing the carcass weight with live weight and expressed as a percentage (%).

Muscle pH and color

The digital pH meter (Hanna, Model HI9918, USA) was used to measure the pH values of meat samples. The pH value was recorded at 45 min of post-mortem as pH 45 min, and pH 24 h at 24 h of post-mortem on the muscle (*longissimus dorsi*) after equilibration to room temperature. The calorimeter (Konica Minolta, CR -400, Japan) was used to assess the color of muscles for lightness (L*), redness (a*) and yellowness (b*).

Chemical analysis of meat

Moisture contents of meat were estimated by the loss in weight of 3 g minced meat and the LD muscle samples were dried for 48 h in oven at 105°C. The dried samples were aged in a muffle furnace at 550 °C for 8h and the ash contents were recorded. Analysis of crude protein (CP) by using 1 g of sample following Kjheldahl method as detailed in the AOAC (2000). The total fat contents were determined from 5 g samples in a Soxhlet apparatus following a 6-cycle extraction with petroleum ether.

Measurement of lipid oxidation

The lipid oxidation was evaluated by measuring Thiobarbituric acid reactive substances (TBARS) by utilizing malondialdehyde (MDA) standard with the help of chemical diagnostic kit (Nanjing Jiancheng Bioengineering Institute, Nanjing, China) and values were expressed as nmol/mg protein.

Fatty acid profile

Muscle samples were taken gently, and external visible fat was removed. The samples were ground homogeneously to estimate fatty acid composition. The total lipids were extracted following the chloroform-methanol procedure. Extracted lipids were trans methylated into fatty acid methyl esters and isolated by Gas Chromatograph using a Shimadzu GC-2010 equipped with CP-WAX 30M I.D.0.32 mm capillary column. The nitrogen and hydrogen were used as carrier and fuel respectively whilst the air as a combustion-supporting gas were used at constant flow rate of 3, 47 and 400 ml/min, respectively. Spilt ratio was 1:10 and 1 µl was injected. The detector and injection port were maintained at 250 °C.

The fatty acids were calculated individually according to the relation of peak area to the total area. The fatty acids were denoted as the part of each individual fatty acid to the total of all fatty acids present in the sample. The combinations and ratios of fatty acids were calculated as desirable fatty acids (DFA), total saturated fatty acids (SFA), total unsaturated fatty acids (UFA), total monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), UFA/SFA and PUFA/SFA, respectively.

Statistical Analysi

The statistical analyses were performed by using software (SPSS 16.0 K for Windows, Chicago, IL) and the obtained data were expressed as the means ± SEM values. The mean values were compared by One-way analysis of variance technique and significant difference at ($P < 0.05$) among the means were found by Turkey's comparison test.

Results

Chemical composition and carcass traits of meat

The meat from the goats offered with steam treated rice straw (STRS) exhibited higher mean percentage of protein and lower moisture ($P \leq 0.05$) contents as compared to the meat of goats fed with untreated rice straw ration (UTRS). Similarly, the fat percentage was higher and ash contents were found lower in meat of the STRS group than UTRS group, however the differences were not significant between the groups (Figure 1).

The results regarding carcass traits are presented in Figure 2. The goats of STRS groups had a higher fasting body weight than goats of UTRS groups. Carcass yield and dressing percentage followed a similar trend where these were recorded higher ($P<0.05$) in STRS fed goats than those fed UTRS diet.

pH and Meat Color

The physical characteristics, i.e., pH and color of the meat are presented in Table 2. The results revealed that the pH of meat at 45min as well as at 24h remained unchanged ($P > 0.05$) between the UTRS and STRS groups. Moreover, the lightness (L*) and yellowness (b*) values were recorded higher and redness (a*) was lower in the STRS group as compared to the UTRS group, despite the lack of statistically significant differences.

Fatty acid profile

The effect of the diets on the composition of fatty acid of goat kids is presented in Table 3. Muscles from both STRS and UTRS groups contained oleic, palmitic and stearic fatty acids as most abundant fatty acids. The oleic and stearic acid were found higher in meat of UTRS goats, while the palmitic acid was higher in meat of the STRS group without any statically differences between the groups. However, SFA like capric, myristic, margaric and eicosanoic for UTRS group were higher and in consequence the total saturated fatty acids were also found higher (P>0.05) in UTRS group as compared to the STRS group. While lauric, pentadecanoic and behenic acids were higher (P>0.05) for STRS group. The palmitoleic (MUFA) and other polyunsaturated (PUFA) i.e. linoleic, linolenic and arachidonic were recorded higher in STRS group, resulting in higher total polyunsaturated fatty acid and unsaturated fatty acid proportion than UTRS group which further resulted in higher UFA:SFA and PUFA:SFA despite the lack of statistically significant differences. Whereas the stearidonic acid and total monounsaturated fatty acids were higher (P>0.05) in UTRS group. There was also no difference (P>0.05) for desirable (C18:0+UFA) fatty acids between the two groups.

Lipid oxidation

The results regarding the effects of straw feeding on lipid oxidation in fresh and stored meat of goats are presented in Figure 3. Slightly lower values of TBARS as units of malondialdehyde (MDA) were recorded in STRS than UTRS group in fresh and stored meat. However, the differences were not significant between the steam treated rice straw and untreated rice straw fed goats.

Discussion

Chemical composition of meat

High attraction towards goat meat production from farming of intact males is directed to the declining in demand for animal fat, therefore the uplifts in importance of red meat production and the requirement of large amount of animal protein (Solaiman *et al.* 2011). The carcass characteristics of farm animals particularly fat content are affected by feeding regime and level of forage, but principal variation is noticed between high concentrate to forage ratios when there is a change in dietary intake (Safari *et al.* 2011; Tahuk et al., 2021). The meat from treated straw fed goats in this study had lower moisture contents and higher fat with a higher protein percentage these finding are supported by research which demonstrated a lowered moisture in the goats, provided treated wheat straw-based diet with higher fat content (Safari *et al.* 2011). Moreover, Pi *et al.* (2005) reported a higher carcass trait in goats fed with treated and pelletized rice straw-based ration. They reported that the goat fed with treated straw-based ration had greater carcass and dressing percentage, likewise in present study the carcass weight and dressing percentage was seen higher in the goats fed treated straw. The lower performance in goats fed untreated rice straw possibly due to the lower digestion of nutrient such as neutral digestible fiber (NDF) which posed negative consequences on the feed intake and performance and this also align with (Vorlaphim et al., 2021). With the use of high forage diets weight of gastro-intestinal tract increases which may reflect to the reduction in dressing percentage (Papi *et al.* 2011). However, Dayani *et al.* (2011) shown conflicting results and reported that there was no difference in these carcass traits between the animals fed treated or untreated straw diets.

Meat color and pH

The fall in the pH rate and ultimate pH are major decisive of meat quality and are associated to the glycogen breakdown rate, while the meat color, is one of the most important parameter of consumer choice (Pi *et al.* 2005). The pH was found not effected with different feeding diets both groups of goats fed on UTRS and STRS maintained normal pH value (5.9–6.5). The similar findings have been reported by Safari *et al.*(2011a), stated that there was no difference in meat pH at 45 min or 24 h between the goats fed on treated wheat straw, untreated wheat straw, treated wheat straw with hay or untreated wheat straw with hay.

The meat color is dependent of many individual factors and their correlations, but the Chevon has higher redness and lower lightness than the lamb, mostly because of the lower intramuscular fat of goat carcass (Kannan *et al.* 2001). Abdullah and M usallam, (2007), showed that feeding regimen has no effect on color variables. The meat color characteristic was not found to be differed between the untreated and treated straw fed goats which in accordance with the findings of Pi *et al.* (2005) showed that the redness (a*), yellowness (b*) and lightness (L*) values of meat were not influenced by the treated or untreated rice straw-based diets. The results are parallel to the results in the native black goat of Jordan investigated by Abdullah and Musallam (2007).

Fatty acid profile

It has been described that the fatty acid profile of tissues is affected by diet (Abbasi *et al.* 2020). The values investigated for meat fatty acid contents in present study agreed with those noted for goats (Banskalieva *et al.* 2000). However, in our study the difference between treated and untreated rice straw fed goats for meat fatty acid had no significance. The prevalence of three abundant fatty acid i.e., palmitic acid, stearic acid and oleic acid accounted in the range of 75% to 78%, dominated by oleic acid which accounted 38% to 40% of total fatty acids, these finding are satisfied with values commonly established for goat (Atti *et al.* 2006). The higher oleic acid values (C18:1) may be attributed to the higher animal biosynthesis from stearic acid (C18:0) (Rule *et al.* 1997), it indicates that the straw feeding had no negative impact on oleic acid biosynthesis which had an improvement in meat quality. The proportions of the DFA's which include all unsaturated fatty acids and stearic acid, noted in this study were around 76% for both group that was in the range of (61–80%) as observed by Banskalieva *et al.*, (2000) for goat meat. Jaakamo *et al.* (2019) observed that the percentage of grass and concentrate in a diet affects PUFA. However, higher ($P>0.05$) amount of UFA and MUFA observed in STRS diets reflecting that the treated straw feeding had no negative impact on carcass unsaturated fatty acid characteristics.

Lipid oxidation

The mechanism of lipid oxidation starts after death immediately, as circulation of blood stops and metabolic processes are blocked, in results free radicals are produced which may cause the oxidation of meat pigments and generate rancid odors and flavors (Arshad *et al.* 2018). The MDA level for fresh and stored meat was not found affected by the treated and untreated straw feeding, however an accepted rise in MDA was recorded after one and two-week storage, in this study statistically diet was not a major effect, but it was the effect of aging and storage that reflected rise in oxidative values as the quality of meat did decrease over time, because the TBARS value of meat enlarge with storage (Franco *et al.* 2012).

Conclusion

The results of the present study suggested that it is possible that steam treated rice straw could effectively be used as partially replacement of roughage during dry periods as the goats fed on treated straw diet maintained similar carcass yield, dressing % and meat composition traits compared to those given the conventional diets, without a negative impact on meat characteristics. However, the fatty acid profile and oxidative stability were not found to be affected by the treatments therefore more research are needed to optimize the level of steam treated rice straw provided in the diet to obtain a balance between the production of meat and its nutritional quality.

Declarations

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Conflict of interest

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Ethical statement

The study was approved by the institute ethics committee, and the trial/sampling procedure was carried out following ethical standards. The manuscript does not contain clinical studies or patient data.

Consent to participate

All the authors critically reviewed and read the manuscript as well as approved the contents.

Consent for publication

I assure that manuscript has not been previously published, is not currently submitted for review to any other journal and will not be submitted elsewhere before a decision is made by this journal.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability

Not applicable.

Authors contributions

WT and MN designed the project. The sampling, data collection, processing and interpretation of results were made by SA, NR and MN. The data analysis was made by MN, SA and manuscript was written and reviewed by NR, RMB and WT. All the authors read the manuscript and approved the contents.

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Tables

Table 1. Ingredients (g/kg) and chemical composition (%) of the experimental diets

Item (g/kg)	Diets	
	UTRS	STRS
Rice Straw	500.0	500.0
Corn	82.5	82.5
Middlings	75.0	75.0
Wheat Bran	72.5	72.5
Corn germ meal	50.0	50.0
Soybean meal	45.0	45.0
Dried distiller's grains	50.0	50.0
Cottonseed meal	25.0	25.0
Corn pellet	65.0	65.0
Molasses	15.0	15.0
Premix	20.0	20.0
Chemical composition, DM (%)		
DM	91.0	90.6
OM	83.7	85.3
Ash	16.3	14.7
CP	11.4	11.7
NDF	60.4	52.0
ADF	29.9	29.4

Table 2. pH and color traits of *Longissimus dorsi* muscle of goats fed untreated and steam treated rice straw based diets.

Item	Diets		SEM	P Value
	UTRS	STRS		
pH				
pH 45min	6.55±0.21	6.56±0.30	0.148	0.952
pH 24h	6.03±0.11	6.20±0.10	0.062	0.132
Color traits				
L* (Lightness)	33.3±2.8	33.8±2.50	0.634	0.606
a* (Redness)	18.3±1.8	17.5±1.90	0.439	0.083
b* (Yellowness)	2.10±0.06	2.14±0.08	0.202	0.785

Table 3. Fatty acid composition (%) of total lipids in *Longissimus dorsi* muscle of goats fed untreated and steam treated rice straw-based diets.

Fatty acid	Structure	Diets		SEM	*P Value*
		UTRS	STRS		
Capric	C10:0	0.060±0.01	0.056±0.01	0.005	0.365
Lauric	C12:0	0.112±0.08	0.180±0.07	0.077	0.568
Myristic	C14:0	1.790±0.43	1.347±0.06	0.176	0.150
Pentadecanoic	C15:0	0.251±0.02	0.312±0.05	0.020	0.098
Palmitic	C16:0	20.960±1.33	21.388±0.88	0.652	0.667
Margaric	C17:0	0.876±0.10	0.761±0.054	0.046	0.154
Stearic	C18:0	17.130±0.99	15.354±1.99	0.911	0.241
Eicosanoic	C20:0	0.055±0.01	0.039±0.01	0.006	0.124
Behenic	C22:0	0.049±0.01	0.064±0.01	0.006	0.132
Palmitoleic	C16:1	1.721±0.30	1.894±0.29	0.171	0.515
Oleic	C18:1	39.893±3.01	38.431±2.77	1.666	0.568
Linoleic	C18:2	11.547±1.06	13.733±1.63	0.795	0.124
Linolenic	C18:3	0.284±0.06	0.289±0.09	0.044	0.945
Stearidonic acid	C18:4	0.519±0.09	0.497±0.05	0.077	0.846
Arachidonic	C20:4	4.759±1.90	5.644±1.09	1.152	0.614
Total saturated	∑SFA	41.286±2.81	39.502±0.96	1.214	0.357
Total monounsaturated	∑MUFA	41.615±2.83	40.324±2.73	1.605	0.592
Total polyunsaturated	∑PUFA	17.109±2.75	20.162±3.60	1.847	0.307
Total unsaturated	∑UFA	58.724±2.78	60.486±1.29	1.197	0.357
Total desirable (C18:0+UFA)	∑DFA	75.8±1.81	75.8±1.14	0.875	0.992
UFA/SFA	∑UFA:∑SFA	1.43±0.15	1.53±0.06	0.069	0.346
PUFA/SFA	∑PUFA:∑SFA	0.415±0.08	0.510±0.09	0.053	0.277

Figures

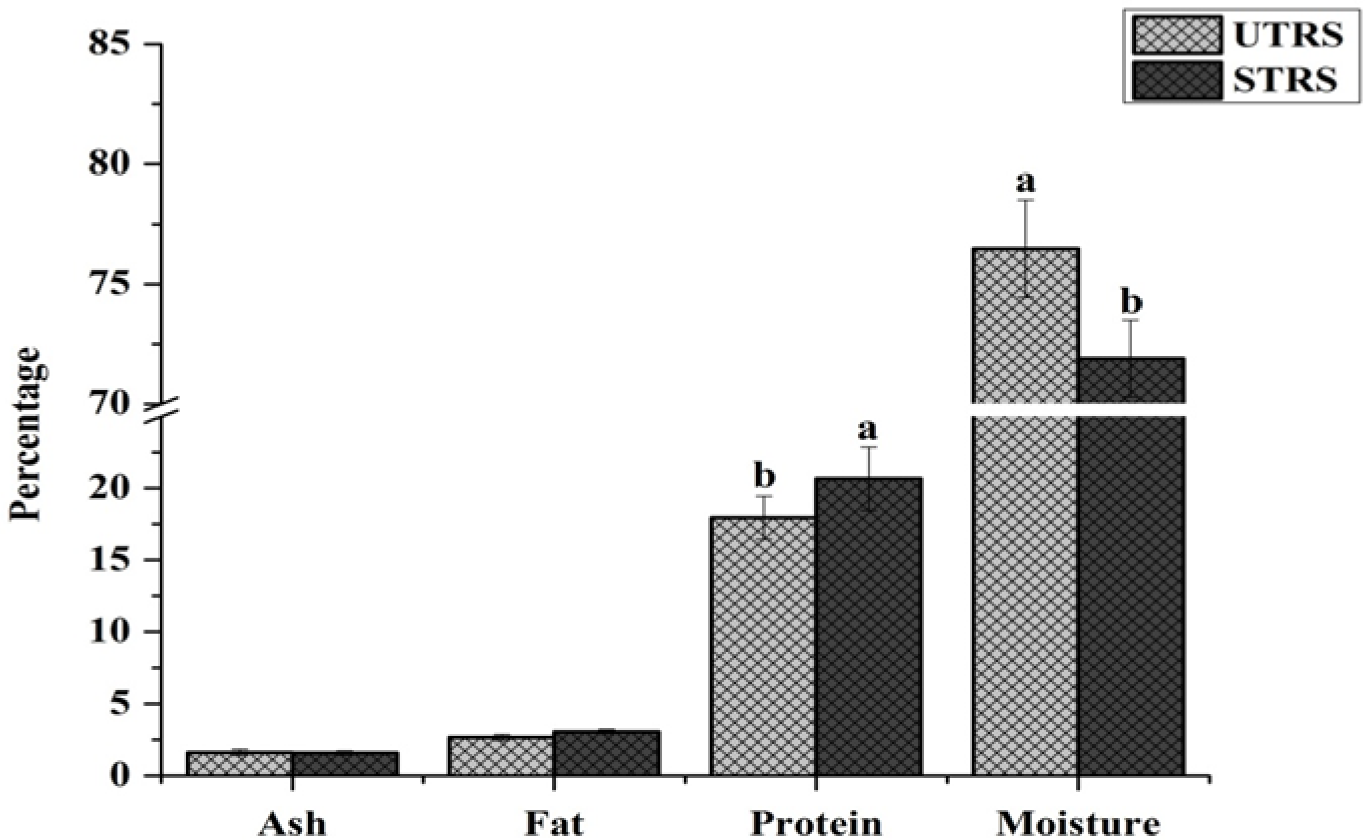

Figure 1

Chemical composition (%) of Longissimus dorsi (LD) muscle of goats fed untreated and steam treated rice straw-based diets. abValues with different letters are significantly different (P<0.05).

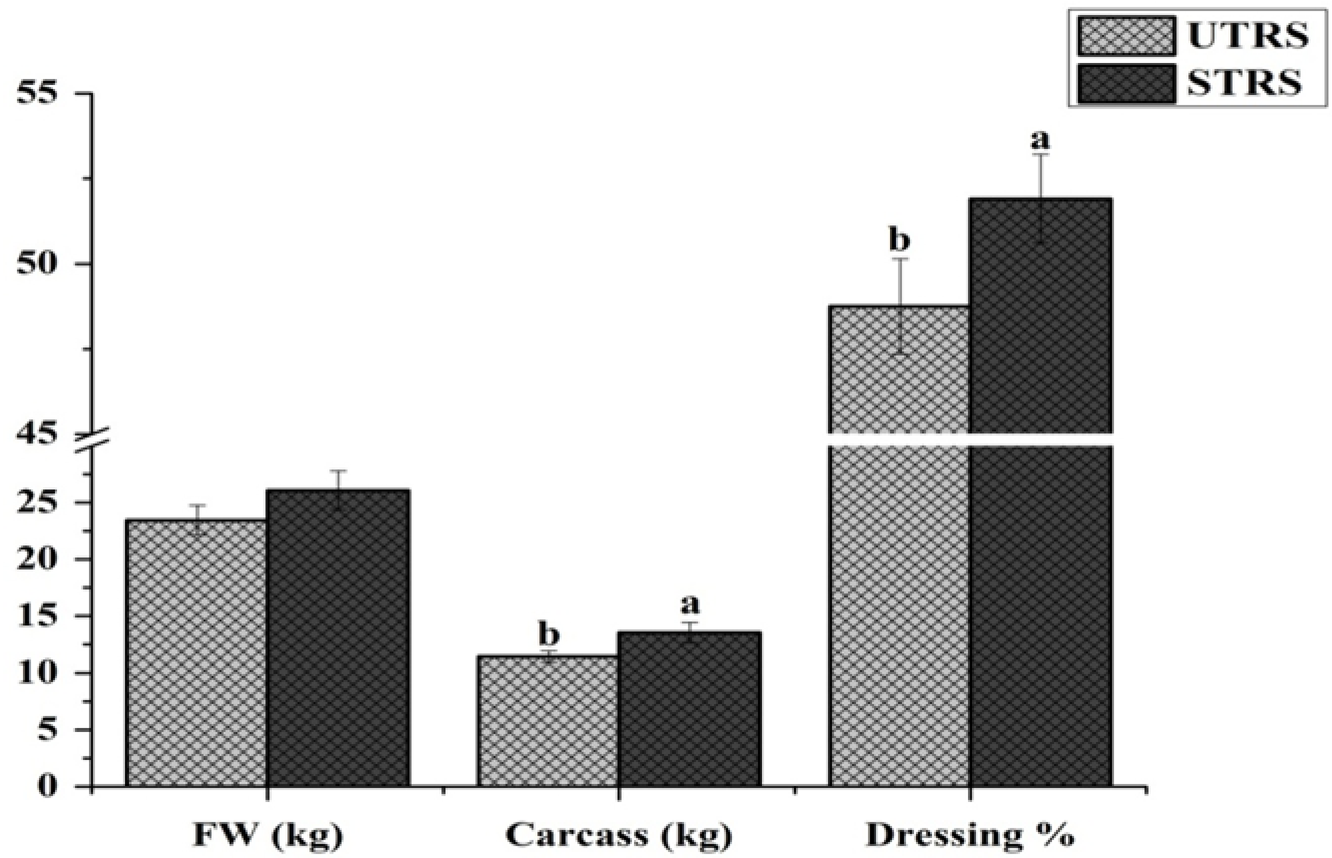

Figure 2

Final body weight (FBW), Carcass yield and Dressing percentage of goats fed untreated and steam treated rice straw based diets. abValues with different letters are significantly different (P<0.05).

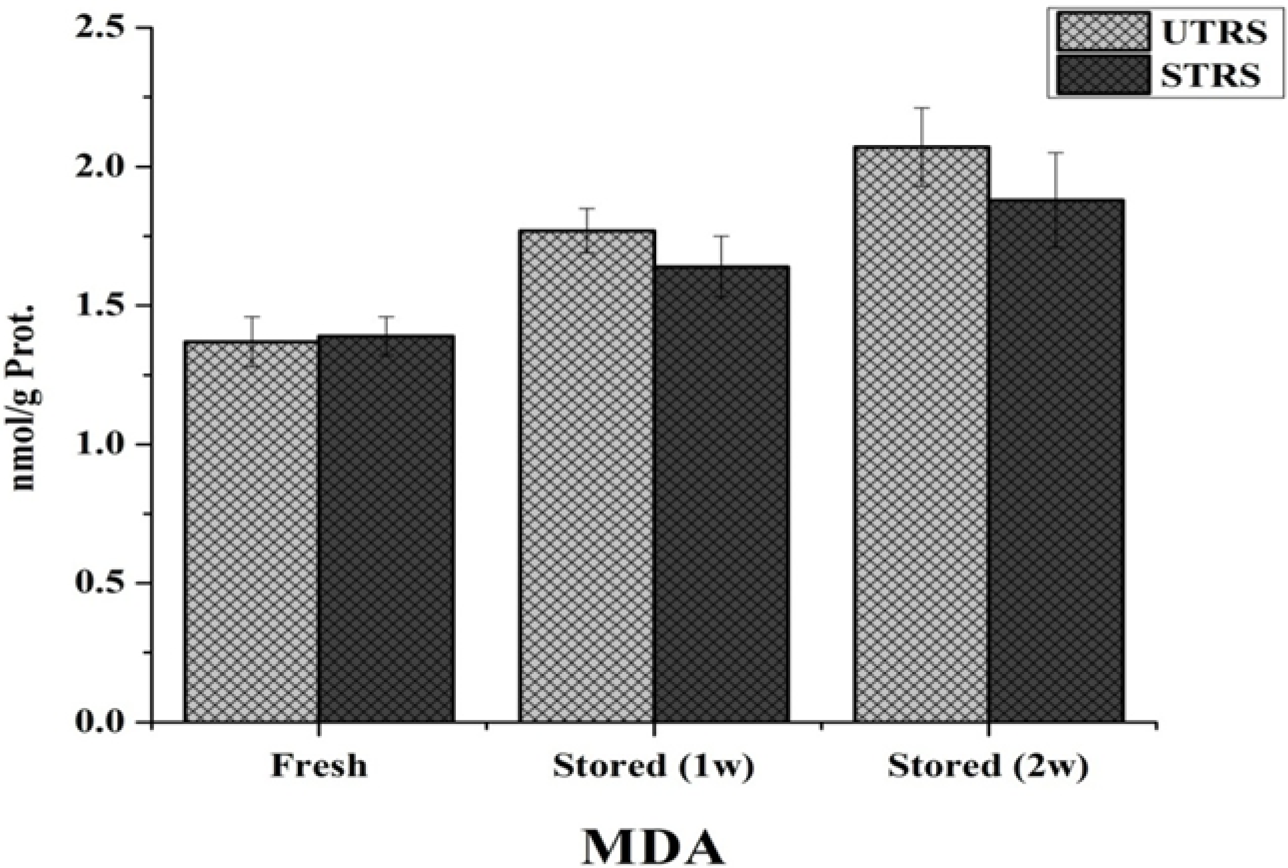

Figure 3

Malondialdehyde (MDA) contents of goat meat fed untreated and steam treated rice straw based diets. abValues with different letters are significantly different (P<0.05); 1w = 1 week, 2w = 2 weeks