Article

Effect of cotton gin trash supplementation as an unconventional feedstuff on feed intake and production characteristics of Mecheri sheep of India

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Abstract: The purpose of this study was to see how feeding cotton gin trash (CGT) as an alternative meal affected the growth performance, carcass features, and meat quality of Mecheri ram lambs. A growth performance trial was conducted with thirty-two weaned Mecheri ram lambs from four months to nine months (180 days) of marketing age and assigned into four groups (T_1, T_2, T_3 and T_4) of eight animals in each group. The lambs were fed with CGT at 0 (T_1), 25 (T_2), 50 (T_3) and 75 (T_4) per cent inclusion levels in the roughage portion at 60:40 roughage: concentrate ratio. All the group of animals were fed on dry matter requirement basis at four per cent of their body weight. The lambs fed with 75 (T_4) and 50 (T_3) per cent inclusion level of CGT showed significantly (P<0.01) higher total body weight gain (kg) than T_1 (14.54) and T_2 (15.05) groups. The average daily gain (g) of lambs in T_3 (99.24) and T_4 (105.51) were significantly (P<0.01) higher than T_1 (80.77) and T_2 (83.61) groups. Over the course of the 180-day trial period, there was no statistically significant difference in the average DMI (g) between the groups (P>0.05), however the lambs in T4 demonstrated higher feed efficiency (7.4) than the T1 (9.3) group. The slaughter studies revealed that the lambs in T_4 followed by T_3 group registered significantly (P<0.01) higher hot carcass weight, dressing percentage and Meat: Bone ratio than T_2 and T_1 group animals. The weights of the liver, spleen, head, stomach, and intestines empty were considerably (P<0.05) larger in the T3 and T4 groups than in the other groups, although there was no significant (P>0.05) difference in the weights of edible and inedible offals. Meanwhile, there were no significant variations (P>0.05) in pH, water holding capacity, shear force value, sensory characteristics, or proximate composition of meat across treatment groups. In accordance to the findings, CGT can be added up to 75% of the roughage component in sheep feed as an effective unconventional supplementation, as it improves body weight, feed efficiency, and carcass characteristics in Mecheri ram lambs.

Keywords: Cotton gin trash; Growth performance; Mecheri ram lambs; Carcass characteristics

1. Introduction

In India, there is a severe shortage of feeds and fodder for livestock as a result of the growth of both the animal and human populations and the reduction of arable land, which is made worse by natural disasters like floods and droughts. India has the largest population of livestock in the world while having only 2.29 per cent of the global land area. This puts a tremendous burden on the availability of land, water, and food resources. According to statistics, there is a shortfall of 11.24 per cent for green fodder, 23.4 per cent for dry fodder, and 28.9 per cent for concentrates over the entire country. As a result, there is a supply-demand mismatch for feed, that is having a counterproductive effect on livestock output.

In livestock farming, the use of alternative feed sources has expanded throughout time as a result of a persistent feed and fodder crisis driven on by a lack of grazing surface area. The use of unconventional feed resources (NCFR) in livestock nutrition plans is increasing everyday as a result of a limited availability of animal feeds, which is crucial in bridging the supply-demand gap. All feeds that are either not generally included in commercially produced livestock rations or have not historically been used in animal feeding are referred to be NCFRs. The NCFR usually contains a variety of feeds made from perennially grown crops as well as feeds with both animal and industrial origins. The main sources of these feeds are byproducts from forestry and agriculture. Such feeds are not used either as a result of the traditional beliefs of livestock owners or because they are less palatable and contain potentially harmful ingredients. It also happens that some unconventional feeds are traditionally provided to animals in one place but may not be used at all in another. In general, the by-products are generally less expensive and allowing farmers to save money by using a less expensive by-product than conventional feedstuffs and can be included as animal feed as long as they support acceptable animal performance [1,2].

During the monsoon season, India has enough of feed resources. The animals must, however, be kept on crop remnants or straws and industrial waste supplemented with some green fodder throughout the remainder of the year. These ingredients can be used to feed animals because they don't compete with those used for humans.

The Cotton, a pure cellulose staple fibre derived from the blossom of the cotton plant (Gossypium sp.), is the most often used natural fibre by humans [3]. The fibres that develop around the cotton seed are contained in the cotton boll. After the cotton is harvested, the fibres have to be separated from the seeds using a process called "ginning," and then they are packaged into bales for transport and usage in subsequent industries (such as spinning) [4]. Cotton ginning, in general, is an intersection between cotton cultivation and the industrial sector, which takes part in the process of separating of cotton fibres coming from cotton bolls. The cotton stalks, cotton gin trash (CGT), and cottonseeds are three important by-products generated during this process of extraction. Cotton stalks are the plant parts that remain in the cotton field after the cotton bolls have been harvested, and CGT is the waste generated during the cotton cleaning phases of the ginning process. Cotton seeds, on the other hand, have been extracted after ginning when the fibres are separated [5]. The CGT is a complex blend of woody cotton boll fragments, stalks, swirled cotton fibre leftovers, mulched leaves, soil, and dust particles [6]. The CGT was mostly disposed of by spreading it on the ground, composting it, feeding it to livestock, utilising landfill disposal methods, incineration, conversion of energy, creating pellets for fuel in heat stoves, construction materials and insulation [7]. The CGT has the potential to be used in livestock feed as an alternative protein, fat, and fibre source [8], and it is being used to meet the energy and protein requirements of sheep [9]. Although CGT is low in protein and energy, it is a good source of fibre and has the potential to be a more cost-effective solution for sheep farmers than traditional roughages [10]. The nutritional makeup of CGT, on the other hand, varied greatly [11].

The Mecheri sheep are medium-sized animals with compact body and short hairs. It is primarily raised for mutton and has a greater dressing percent-age and good skin quality. As one of the well-adapted breeds, raising Mecheri sheep is becoming more popular among farmers, particularly young entrepreneurs starting into agriculture and associated areas [12]. In Mecheri sheep breeding tract (particularly in Karur and Tiruppur districts of Tamil Nadu, India), farmers are feeding Mecheri sheep with unconventional feed such as CGT as a roughage supplement mainly during forage shortage in summer months. Since, there is an abundant availability of CGT due to greater number of textile industries in aforesaid districts, the CGT is being utilized rampantly by the sheep farmers without scientific validation. Considering the above facts, the present study is taken up to assess

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the effect of CGT supplementation as a roughage source on feed intake, weight gain, carcass characteristics and meat quality of growing Mecheri ram lambs. This research will be beneficial for determining an acceptable amount of supplementation for improved profitability and efficient use of leftover unconventional feed for sheep rearing practises wherever it is easily available in the area.

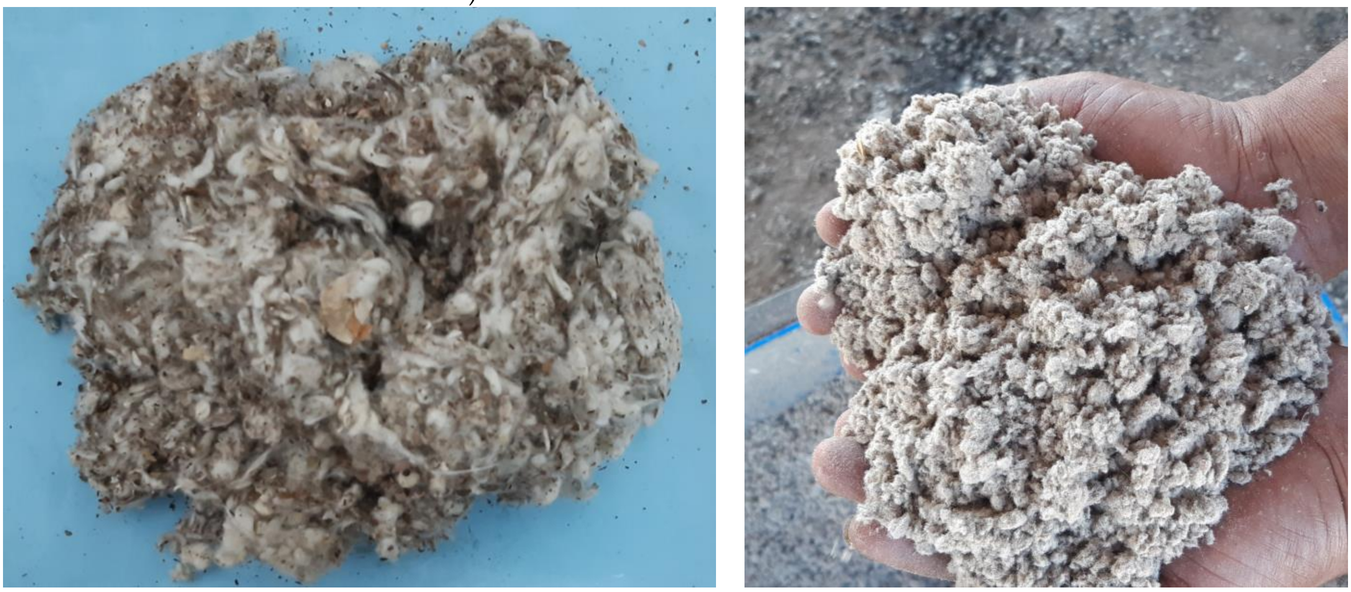
2. Materials and Methods

2.1. Description of the study area

The Mecheri Sheep Research Station, Pottaneri, Salem district, Tamil Nadu State in India, which is situated at a longitude of 77° 56'E and latitude of 11° 45'N, is where this study was carried out. The weather varies from semi-arid to sub-humid, and droughts happen frequently. The average maximum and lowest temperatures are 34.3°C and 21.9°C, respectively, with an annual rainfall of roughly 894 mm.

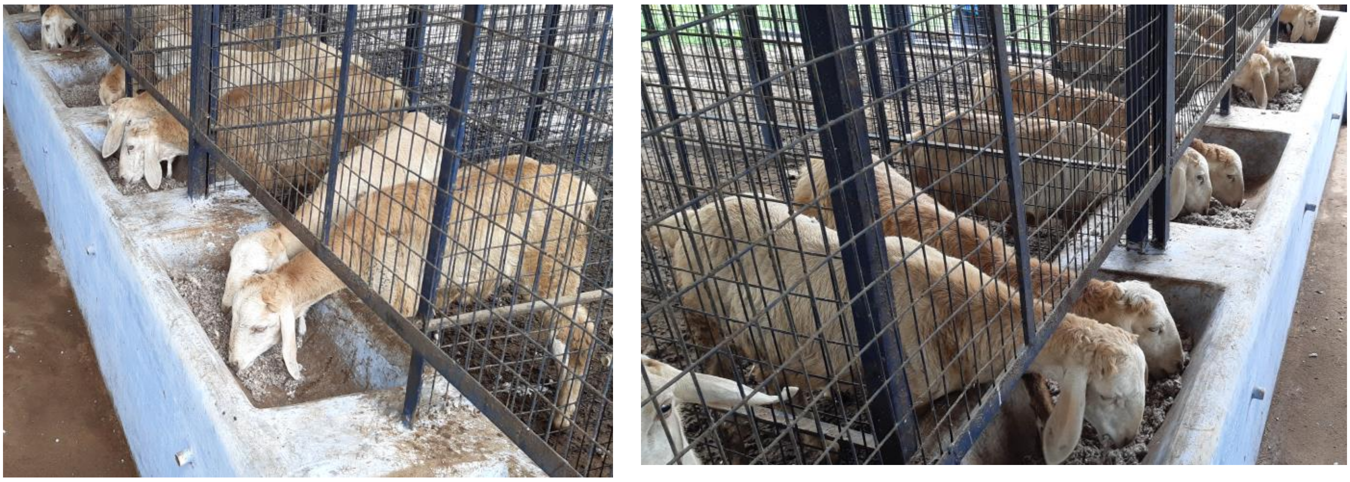
2.2. Experimental animals

A total of thirty-two weaned Mecheri ram lambs at 3-4 months age of uniform body weight were selected and assigned into four groups (T_1, T_2, T_3 and T_4) of eight animals in each group. In T_1 T_2, T_3 and T_4 groups, the roughage portion (Sorghum stover) of the diet was replaced with CGT at 0, 25, 50 and 75 per cent respectively. In all four treatment groups, the basal diet used for the experiment was based on 60:40 roughage: concentrate ratio. All four groups were raised using an intensive management approach, and their individual body weights were fed at 4% of their respective dry matter requirements (Figures 1 and 2).



(a) (b)

Figure 1 (a) and (b) Industrial cotton gin trash fed to the trail animals



(a) (b)

Figure 2. (a) and (b) Feeding of cotton gin trash in experimental animals

The chemical composition (%) of sorghum stover, CGT and concentrate mixture used in the experimental diet is presented in Table 1. The sorghum stover, CGT and concentrate feed were analysed for moisture, dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), calcium and phosphorus [13] and the total as well as acid insoluble ash were estimated by standard procedures [14, 15] and the results were expressed as percentage on dry matter basis. The fibre fraction in CGT samples was analyzed using prescribed procedure [16].

Table 1. The chemical composition (%) of sorghum stover, CGT and concentrate mixture used in the experimental diet (% dry matter basis).

Nutrients (%)	Sorghum stover	Cotton gin trash	Concentrate Mixture[a]
Dry matter	93.89	91.51	88.81
Crude protein	6.99	15.72	18.35
Crude fibre	33.56	31.96	9.57
NDF	64.80	65.44	20.07
ADF	48.50	51.34	6.57
Ether extract	2.46	4.58	1.96
Total ash	6.04	6.58	9.12
Calcium	1.52	1.59	1.20
Phosphorus	0.60	0.42	1.08
Gorss energy, MJ/kg[b]	15.74	17.03	15.05

NDF: neutral dietergent fibre, ADF: acid detergent fibre; [a]Maize 48.40 %, Deoiled rice bran 30.00 %, Soyabean meal 18.00 %, Salt 0.50 %, Calcite 2.50 %, Sodium carbonate 0.50%, Trace mineral mixture 0.10% (Vitamin A 8250 IU, Vitamin D3 12000 IU and Vitamin K 1mg per kg). [b] Calculated value.

The Table 2 lists the components and chemical make-up of the experimental diets administered to Mecheri ram lambs that included various amounts of CGT.

Table 2. Ingredients and chemical makeup of experimental diets fed to Mecheri ram lambs at various CGT levels.

	Treatment groups			
	T_1 (0%)	T_2 (25%)	T_3 (50%)	T_4 (75%)
Ingredient (%)				
Sorghum stover	60.00	45.00	30.00	15.00
Cotton gin trash	0.00	15.00	30.00	45.00

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Concentrate mixture[a]	40.00	40.00	40.00	40.00
Chemical composition (%)				
Dry matter	91.86	91.50	91.14	90.78
Crude protein	11.53	12.84	14.15	15.46
Crude fibre	23.96	23.72	23.48	23.24
NDF	46.90	47.00	47.10	47.19
ADF	31.72	32.14	32.57	32.99
Ether extract	2.26	2.58	2.89	3.21
Total ash	7.27	7.35	7.40	7.50
Calcium	1.39	1.4	1.41	1.42
Phosphorus	0.79	0.76	0.74	0.71
Gorss energy, MJ/kg[b]	15.46	15.66	15.85	16.04

NDF: neutral dietergent fibre, ADF: acide detergent fibre. [a]Maize 48.40 %, Deoiled rice bran 30.00 %, Soyabean meal 18.00 %, Salt 0.50 %,Calcite 2.50 %, Sodium carbonate 0.50%, Trace mineral mixture 0.10% (Vitamin A 8250 IU,Vitamin D3 12000 IU and Vitamin K 1mg per kg). [b]Calculated value.

In all the four groups, the animals were given an adaptation period of 15 days before the commencement of trial. The experimental animals in each group were housed separately with partition made by chain links. The feeder and water trough were also given separately for each animal so that feed intake and left over for each animal could be measured accurately. Animals were fed three times a day (morning, afternoon and evening) and fresh drinking water was always made available in the water trough. The CGT was fed according to the group allocation, and each time it was thoroughly cleaned and any extraneous particles were removed before feeding. To avoid dust, the CGT was soaked in water before being offered to the experimental animals as moist feed. From weaning to 180 days, the animals were weighed individually using an electronic weighing scale at biweekly intervals before administering feed and water in the morning. The average daily gain, dry matter intake, and feed efficiency were also estimated.

2.3. Slaughter studies

At the end of nine months of age, six lambs from each group with a total of 24 lambs were selected randomly and slaughtered to assess the effect of CGT feeding on the carcass characteristics. Prior to slaughtering, all 24 animals were given free access to water but weren't given feed for 12 hours. The animals were slaughtered with principles of the declaration of Helsinki and the stripping, legging, dressing and evisceration protocol were performed by adopting the standard procedure [17]. The pre-slaughter weight (PSW), carcass length, dressing percentage and other carcass parameters were collected and the dressing percentage was computed by subtracting hot carcass weight from PSW and was expressed as a percentage of PSW. The area of the *Longissimus dorsi* muscle was measured with the help of parchment paper and the Bureau of Indian Standard [18] method was followed in cutting wholesale cut parts.

2.4. Meat quality studies

2.4.1. Physicochemical and sensory properties

The pH of sheep meat was determined by adopting the standard method [19] and the water holding capacity of fresh meat samples was assessed by adopting the filter paper press method [20]. In addition, the shear force value was taken by subjecting 1cm x 1cm thick meat sample to Warner Bratzler Shear (Stable Micro System Ltd., TA HD plus, UK) and taking the average of three values. The *longissimus dorsi* muscle was cooked properly, the meat samples were served to technically sound taste panel members with a score card of nine-point descending scale to assess the flavour, juiciness, and tenderness.

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Finally, the overall acceptability was assessed by calculating the average of the flavour, juiciness and tenderness given by the taste panel members.

2.4.2. Proximate composition and fatty acid analysis

The Proximate composition like moisture, protein and fat in the *Longissimus dorsi* muscle were estimated using standard procedure [13]. Furthermore, the total ash was calculated [14] and the results were reported as a percentage of dry matter. In the *Longissimus* dorsi muscle, fatty acids such as Myristic acid, Palmitic acid, Stearic acid, Oleic acid, Linoleic acid, Linolenic acid, Arachidic acid, Behenic acid, Eicosapentaenoic acid, Docosahexaenoic acid, and Palmitoleic acid were measured. The meat was frozen for 12 hours at 5^{o}C before lipid extraction [21] and the fatty acid profile was evaluated using conventional procedure [22].

2.5. Statistical analysis

The obtained data were compiled and statistically analysed; the various parameters were submitted to analysis of variance procedures [23] appropriate for a completely randomised design using the SPSS software version 17.0 [24], and the means were compared [25] for significance.

3. Results

3.1. Chemical composition of dietary treatments

The results indicated (Table 2) that the dry mater and crude fibre per cent was higher in T_1 followed by T_2, T_3 and T_4 experimental groups respectively. Conversely, the T_4 group had the highest levels of crude protein, NDF, ADF, ether extract, gross energy (MJ/kg), total ash, and calcium per cent, followed by the T_3, T_2, and T_1 groups. The T_1 group had the highest percentage of phosphorus (0.79), followed by the T_2, T_3, and T_4 experimental groups. The lambs were thoroughly monitored during the trial period, and no health problems associated with treatment diets were noted.

3.2. Dry matter intake and growth performance

During the whole 180-day trial period, the mean dry matter (g/day) consumed by the animals in the T_1, T_2, T_3, and T_4 groups was 734.08, 731.17, 759.64, and 766.86 respectively (Table 3). Though the mean dry matter intake (g/day) of lambs in the T_4, T_3, and T_2 groups was higher than in the T_1 group, there was no statistically significant ($P>0.01$) difference between them. However, the lambs fed with 75% (T_4) CGT in roughage had a significantly ($P<0.05$) higher body weight (31.63 kg) than that of T_2 (27.66 kg) and T_1 (27.18 kg) groups but was not significantly ($P>0.05$) different from T_3 (30.48) treatment group. Similarly, T_3 had a considerably ($P<0.05$) higher body weight than T_1 but was not significantly different ($P>0.05$) from the T_2 treatment group.

Table 3. Growth performance and dry matter intake of Mecheri ram lambs at different levels of CGT.

Item	Cotton gin trash inclusion levels in roughage					
	T_1 (0%)	T_2 (25%)	T_3 (50%)	T_4 (75%)	SEM	p-value
Number of observations	8	8	8	8		
Initial body weight, kg	12.64 ± 0.74	12.61 ± 0.60	12.61 ± 0.63	12.64 ± 0.55	0.30	1.000
Final body weight, kg	27.18^a ± 1.25	27.66^{ab} ± 0.98	30.48^{bc} ± 0.85	31.63^c ± 1.00	0.59	0.012
Total gain, kg	14.54^a ± 0.98	15.05^a ± 0 .98	17.86^b ± 0.71	18.99^b ± 0.99	0.55	0.004
Average daily gain, g /day	80.77^a ± 5.46	83.61^a ± 5 .45	99.24^b ± 3.95	105.51^b ± 5.48	3.07	0.004

DMI, g /day	734.08 ± 35.17	731.17 ± 25.42	759.64 ± 31.59	766.86 ± 21.50	14.02	0.764
Feed efficiency, kg/kg gain	9.30 ^{b}± 0.61	8.96^{ab} ± 0.57	7.74^{ab} ± 0.46	7.40^{a} ± 0.39	0.28	0.039

Means bearing different superscripts in the same row differ significantly (P<0.05). DMI: dry matter intake.

The total weight gain in 180 days of trial period from the initial body weight were 14.54, 15.05, 17.86 and 18.99 kg in T_1, T_2, T_3 and T_4 groups respectively. It showed that T_4 and T_3 had significantly (P<0.01) higher total body weight gain (kg) than T_2 and T_1 treatment groups. The average daily gain (ADG) of lambs in T_4 and T_3 were 105.51 g and 99.24 g respectively and it significantly (P<0.01) higher than T_2 (83.61 g) and T_1 (80.77 g) groups. The study revealed that the lambs fed with CGT at 75 and 50 per cent level of roughage portion had shown significantly (P<0.01) higher average weight gain than the lambs fed with 25 per cent CGT and control group. The T_1, T_2, T_3, and T_4 groups had overall feed efficiency of 9.30, 8.96, 7.74, and 7.40 kg/kg growth respectively and there was a significant (P<0.05) difference in feed efficiency between the T_4 and T_1 groups alone.

3.3. Carcass characteristics

The Carcass characteristics of Mecheri lambs as influenced by CGT feeding at different levels are presented in the Table 4. The lambs in T_4 group showed significantly (P<0.05) higher pre-slaughter weight than T_2 and T_1 groups but not significantly (p>0.05) different from T_3 group. The hot carcass weight (kg) of lambs in T_4 and T_3 treatment groups were significantly (P<0.01) higher than T_2 and T_1 groups. When compared to the T_2 and T_1 groups, the lambs in the T_4 group had a substantially (P<0.01) greater dressing percentage (50.78%) but were not significantly (P>0.05) different from the T_3 (49.37 %) group. Similarly, the Meat: Bone ratio in the T_4 group was considerably (P<0.01) larger than in the T_2 and T_1 groups and the T_4 and T_3 groups had significantly (P<0.01) larger loin eye area (cm2) than T_2 and T_1 groups. Caudal fat was significantly (P<0.05) higher in the T4 group than the T2 group, but not statistically (P>0.05) different from the T3 and T1 groups. The weight of edible offals, such as the liver and spleen, was significantly (P<0.05) higher in the T4 group than the T1 group. The weight (kg) of inedible offals such as the head and stomach with the intestines empty was considerably (P<0.05) larger in lambs from the T4 treatment group than in lambs from the T2 and T1 treatment groups, but not statistically (P>0.05) different from the T3 treatment group. It was discovered that lambs in the T4 group produced more loin yield than T_2 and T_1 groups but not significantly (P>0.05) different from T_3 group. Whereas, the lambs in T_4 and T_3 groups showed significantly (P<0.05) higher leg percentage than T_2 and T_1 groups.

Table 4. Carcass characteristics of Mecheri ram lambs fed with different levels of CGT.

Parameters	Cotton gin trash inclusion levels in roughage					
	T_1 (0%)	**T_2 (25%)**	**T_3 (50%)**	**T_4 (75%)**	**SEM**	**P value**
n	6	6	6	6		
Pre-slaughter weight, kg	27.15^{a} ±1.23	27.58^{a} ±1.52	30.75^{ab} ± 0.83	31.70^{b} ± 1.09	0.69	0.032
Hot carcass weight, kg	12.92^{a} ± 0.58	13.18^{a} ±0.77	15.22^{b} ± 0.70	16.12^{b} ± 0.69	0.43	0.009
Dressing Percentage	47.60^{a} ± 0.48	47.75^{a} ± 0.41	49.37^{ab} ±1.02	50.78^{b}± 0.55	0.41	0.008
Carcass length, cm	68.50 ± 1.34	68.83 ±1.58	71.33 ±1.31	72.33 ±1.41	0.74	0.185
Meat: Bone ratio	2.53^{a} ± 0.04	2.54^{a} ± 0.06	2.63^{ab} ± 0.04	2.76^{b} ± 0.03	0.03	0.006
Loin eye area, cm^2	12.28^{a} ± 0.17	12.40^{a} ± 0.28	13.36^{b} ± 0.37	13.76^{b} ± 0.22	0.36	0.002
EDIBLE OFFALS						
Liver, kg	0.39^{ab} ± 0.03	0.37^{a} ± 0.02	0.46^{bc} ± 0.02	0.48^{c} ± 0.03	0.02	0.026

Heart, kg	0.11 ± 0.01	0.10 ± 0.01	0.13 ± 0.01	0.13 ± 0.01	0.01	0.191
Kidney, kg	0.08 ± 0.01	0.08 ± 0.01	0.09 ± 0.01	0.10 ± 0.01	0.01	0.215
Spleen, kg	0.05^{a} ± 0.00	0.06^{ab} ± 0.01	0.07^{ab} ± 0.01	0.08^{b} ± 0.00	0.01	0.030
Testicle, kg	0.27 ± 0.02	0.25 ± 0.02	0.28 ± 0.01	0.29 ± 0.03	0.01	0.599
Omental fat, kg	0.24 ± 0.04	0.24 ± 0.05	0.34 ± 0.05	0.36 ± 0.09	0.03	0.321
Caudal fat, kg	0.24^{ab} ± 0.02	0.22^{a} ± 0.01	0.26^{ab} ± 0.01	0.29^{b} ± 0.02	0.01	0.043
Kidney fat, kg	0.15 ± 0.02	0.15 ± 0.03	0.20 ± 0.04	0.22 ± 0.04	0.02	0.349
IN-EDIBLE OFFALS						
Blood, kg	1.08 ± 0.09	1.14 ± 0.09	1.28 ± 0.05	1.33 ± 0.09	0.04	0.153
Head, kg	1.73^{a} ± 0.03	1.74^{a} ± 0.04	1.86^{ab} ± 0.05	1.93^{b} ± 0.07	0.03	0.041
Skin, kg	2.91 ± 0.17	2.92 ± 0.16	3.10 ± 0.17	3.21 ± 0.11	0.08	0.460
Feet, kg	0.73 ± 0.03	0.72 ± 0.03	0.78 ± 0.01	0.79 ± 0.01	0.01	0.048
Stomach and intestine full, kg	6.97 ± 0.30	7.17 ± 0.55	7.57 ± 0.18	7.88 ± 0.19	0.17	0.259
Stomach and intestine empty, kg	1.58^{a} ± 0.07	1.61^{a} ± 0.10	1.77^{ab} ± 0.03	1.86^{b} ± 0.09	0.04	0.048
Trachea and lungs, kg	0.43 ± 0.07	0.44 ± 0.03	0.52 ± 0.02	0.52 ± 0.02	0.02	0.244
WHOLE SALE CUTS						
Fore quarter (%)	55.20 ± 0.49	54.02 ± 0.74	54.17 ± 0.76	55.94 ± 0.40	0.33	0.125
Neck & shoulder	25.98 ± 0.12	25.35 ± 0.17	25.23 ± 0.27	25.17 ± 0.38	0.14	0.125
Breast & fore Shank	16.00 ± 0.14	15.78 ± 0.21	15.46 ± 0.23	15.38 ± 0.15	0.10	0.101
Rack	13.14 ± 0.23	13.30 ± 0.60	13.70 ± 0.37	13.93 ± 0.42	0.21	0.554
Hind quarter (%)	44.80 ± 0.49	45.99 ± 0.74	45.84 ± 0.76	44.06 ± 0.40	0.35	0.125
Loin	12.69^{a} ± 0.15	12.71^{a} ± 0.10	13.04^{ab} ± 0.14	13.17^{b} ± 0.11	0.07	0.029
Legs	32.11^{a} ± 0.42	32.49^{a} ± 0.51	33.94^{b} ± 0.57	34.07^{b} ± 0.33	0.28	0.014

Means bearing different superscripts in the same row differ significantly (P<0.05).

3.4. Meat quality

3.4.1. The Physicochemical and sensory characteristics

There was no significant alterations (P>0.05) were seen between treatment groups in the longissimus dorsi muscle's physicochemical and sensory properties (Table 5), including pH, water holding capacity (%), and shear force value (kg/cm2). Similar to this, there was no significant change (P>0.05) in the sensory qualities of the Longissimus dorsi muscle in Mecheri ram lambs fed with various amounts of CGT, including appearance, flavour, juiciness, tenderness, and overall acceptability.

Table 5. The Physicochemical and sensory characteristics of *Longissimus dorsi* muscle in Mecheri ram lambs fed with different levels of CGT.

Parameters	Cotton gin trash inclusion levels in roughage					
	T_1 (0%)	T_2 (25%)	T_3 (50%)	T_4 (75%)	SEM	P value
Number of observations	6	6	6	6		
Physicochemical properties						
pH	6.42 ± 0.16	6.57 ± 0.66	6.53 ±0.12	6.23 ± 0.11	0.63	0.246
WHC*, %	59.44 ± 1.44	57.29 ± 1.57	59.62 ± 1.89	60.61± 1.76	0.82	0.566
Shear force value, kg/cm^2	4.82 ± 0.17	4.85 ± 0.59	4.91 ± 0.10	4.88 ± 0.10	0.54	0.947
Sensory characteristics						
Appearance	7.50 ± 0.5	7.33 ± 0.21	7.33 ± 0.21	7.33 ± 0.33	0.16	0.970
Flavour	7.50 ± 0.43	7.00 ± 0.37	7.50 ± 0.34	7.67 ± 0.42	0.19	0.657
Juiciness	7.17 ± 0.31	7.00 ± 0.37	7.67± 0.33	7.33 ± 0.21	0.15	0.485

Tenderness	6.50 ± 0.43	6.33 ± 0.42	7.33 ± 0.33	7.00 ± 0.26	0.19	0.229
Overall acceptability	7.33 ± 0.21	7.33 ± 0.21	8.00 ± 0.26	7.33 ± 0.33	0.13	0.206

Means bearing different superscripts in the same row differ significantly (P<0.05).* WHC: water holding capacity

3.4.2. The proximate and fatty acid composition

The proximate and fatty acid composition indicated (Table 6) that the per cent moisture, protein, fat and total ash of longissimus dorsi muscle in Mecheri ram lambs were not significantly (P>0.05) different among treatment groups. The percent EPA (C22:5) in T_2 groups was substantially (P<0.05) greater than in T_3 and T_4 groups but not significantly different from T_1 group. Furthermore, the saturated fatty acid (SFA) levels in the T_3, T_4, and T_2 groups were substantially (P<0.01) greater than in the control group. In contrast, the proportion of mono-unsaturated fatty acids (MUFA) in the T_1 group was substantially (P<0.05) greater than in the T_3 and T_4 treatment groups but not significantly different from the T_2 group. There was no significant difference in polyunsaturated fatty acids (PUFA) or the PUFA/SFA ratio between the treatment groups.

Table 6. The proximate and fatty acid composition (%) of *Longissimus dorsi* muscle in Mecheri ram lambs fed different levels of CGT.

Parameters	Cotton gin trash inclusion levels in roughage					
	T_1 (0%)	T_2 (25%)	T_3 (50%)	T_4 (75%)	SEM	P value
Number of observations	6	6	6	6		
Proximate composition (%)						
Moisture	73.70 ± 0.11	74.97 ± 0.20	74.07 ± 0.28	73.64 ± 0.11	0.05	0.185
Protein	23.19 ± 0.19	22.49 ± 0.20	21.92 ± 0.25	22.08 ± 0.25	0.06	0.391
Fat	0.68 ± 0.01	0.78 ± 0.04	0.93 ± 0.03	0.79 ± 0.02	0.01	0.143
Total ash	0.95 ± 0.03	1.06 ± 0.01	1.07 ± 0.01	0.86 ± 0.06	0.01	0.273
Fatty acid composition (%)						
Myristic (c14:0)	1.5^a ± 0.11	2.12^b ± 0.13	2.25^b ± 0.1	1.84^{ab} ± 0. 17	0.17	0.005
Palmitic (c16:0)	23.19 ± 0.43	25.24 ± 0.50	25.88 ± 0.37	25.22 ± 1.10	0.75	0.056
Stearic (c18:0)	18.62^a ± 0.39	20.37^b ± 0.94	21.38^b ± 0.45	20.95^b ± 0.36	0.70	0.019
Oleic acid (c18:1)	38.83^b ±1.20	35.8^{ab} ±1.49	34.36^a ±1.53	32.81^a ± 0.85	1.52	0.025
Linoleic (c18:2)	8.93 ± 0.64	8.96 ± 0.28	9.44 ± 0.82	10.45 ± 0.98	0.72	0.442
Linolenic (c18:3)	0.42 ± 0.06	1.05 ± 0.77	0.29 ± 0.04	1.35 ± 1.09	0.65	0.644
Arachidic (c20:4)	0.31 ± 0.13	0.1 ± 0.01	0.11 ± 0.02	0.12 ± 0.03	0.07	0.141
Behenic (c22:0)	4.05^b ± 0.41	2.84^a ± 0.23	2.2^a ± 0.23	3.11^{ab} ± 0.38	0.40	0.008
EPA (c22:5)	0.60^{ab} ± 0.08	0.80^b ± 0.13	0.42^a ± 0.06	0.35^a ± 0.07	0.11	0.018
DHA (c22:6)	0.40 ± 0.05	0.44 ± 0.11	0.35 ± 0.07	0.17 ± 0.02	0.08	0.083
Palmitoleic (c16:1)	2.40 ± 0.20	2.44 ± 0.10	2.20 ± 0.16	1.95 ± 0.21	0.18	0.231
Saturated fatty acids (SFA)	47.40^a ± 0.31	50.58^b ± 1.19	51.77^b ± 0.71	51.13^b ± 0.92	0.53	0.008
Mono unsaturated fatty acids (MUFA)	41.24^b ±1.23	38.25^{ab} ± 1.54	36.58^a ±1.58	34.77^a ±1.01	0.80	0.020
Poly unsaturated fatty acids (PUFA)	10.69 ± 0.88	11.37 ± 0.84	10.62 ± 0.84	12.46 ±1.15	0.46	0.492
PUFA/SFA	0.23 ± 0.02	0.23 ± 0.02	0.21 ± 0.01	0.25 ± 0.03	0.01	0.576

Means bearing different superscripts in the same row differ significantly (P<0.05). EPA: Eicosapentaenoic Acid. DHA: Docosahexaenoic Acid; SFA = c14:0+c16:0+c18:0+c22:0; MUFA = c16:1+c18:1; PUFA = c18:2+c18:3+c20:4+c22:5+c22:6.

4. Discussion

4.1. Dry matter intake

The CGT or cotton ginning thrash , is a low-cost and abundant source of lignocellulosic material and the effective appreciation of CGT benefits both the economy and the environment. This ginning by-product is made up of burs and stem fragments, immature cottonseed, lint, leaf fragments, and soil and has nutritional value and can be used as roughage feed for ruminant livestock as it has same nutritious content as low-quality grass hay [11]. The current study on supplementation with different levels of CGT revealed that the dry matter intake increases with increasing levels of CGT at 25, 50, and 75% of roughage, but the average dry matter intake and total dry matter intake were not significantly (P>0.05) different among treatment groups during the 180-day trial period and it agreed with earlier report and they [26] reported that the increased levels of CGT boosted feed consumption due to its palatability. It is also supported by another study [27] and found that increasing peNDF (physically effective fibre) in high grain diets can increase dry matter intake, which could explain the lack of a significant difference in dry matter intake between treatment groups as well as increased weight gain in the T3 and T4 groups due to 50 and 75% inclusion levels of CGT in roughage portion of diet, respectively.

4.2. Growth performance

At the 180th day of the trial period, the overall weight gain in the T_1, T_2, T_3, and T_4 groups was 14.54, 15.05, 17.86, and 18.99 kg, respectively. It was found that lambs provided 75 and 50% CGT in roughage had considerably higher total body weight gain than lambs fed with 25 and 0 % CGT. Feeding CGT at 10 and 20% inclusion levels in the total diet improved performance in Shugor desert lambs [26], with weight gains of 7.78 and 9.98 kg in 6 weeks of feeding trial, and the weight gain may be attributable to higher feed intake with rising CGT level due to its palatability. Similarly, another study [10] observed that steers fed a CGT-based diet had higher dry matter intake, average daily growth, and heavier ultimate body weights than steers fed a control diet without CGT.

A similar pattern to that of body weight was observed in average weight gain for lambs fed with various levels of CGT. The ADG of lambs increased as the degree of CGT increased in the T_2 (83.61 g /day), T_3 (99.24 g /day), and T_4 (105.51 g /day) groups and several authors have documented [26, 28,29] an increase in ADG of lambs fed CGT at higher levels. The cotton-plant-material (CPM) blocks containing CGT resulted in higher average daily growth in beef cattle [30]. In contrast, average daily gains of 163, 182, 186, and 138 g/day in fattening at 0, 25, 40, and 55% in desert lambs fed CGT were reported [31] and concluded that the ADG tended to be higher for lambs fed diets containing CGT at levels lower than 55% and that it could be used to replace up to 40% of a conventional concentrate lamb fattening diet without adverse effects on performance or nutrient utilisation. In the current study, the maximum inclusion level of CGT was only 45 per cent in the total ration in T_4 group vis-à-vis 75 per cent replacement of CGT in roughage portion and found similar good result in ADG. It has been found that CGT may be used efficiently as a source of fibre, fat, and protein without negatively impacting growth performance [10]. Furthermore, increased crude protein and gross energy levels in T_3 and T_4 experimental diets may be ascribed to higher inclusion levels of CGT. In the current study, lambs exhibited improved feed efficiency with increasing levels of CGT at 25, 50, and 75 % roughage proportion and the earlier studied [31, 26] found similar higher feed efficiency in desert lambs fed CGT at different levels. The CGT with larger particle size helps to maintain a fibre mat in the rumen, which allows feed retention time to increase, ultimately increasing digestion of feed in the rumen [32], and this could be the reason for better digestibility and nutrient utilisation, which resulted in better feed efficiency of 7.40 and 7.74 kg/kg gain in T4 and T3 groups in comparison to lambs in T2 (8.96 kg/kg gain) and T1 (9.3 kg/kg gain) groups.

4.3. Carcass characteristics

According to the results of the current investigation, lambs given 50 and 75 percent CGT of the roughage potion displayed improved carcass weight and dressing percentage than the control group. Similar to this, steers [10] consuming the CGT-based diet had heavier hot carcass weights (396 kg) and higher dressing percentages (62.7%) than steers ingesting the control diet without CGT (382 kg and 62.2%). The dressing percentage in the current study was similar to that seen in lambs of several sheep breeds, such as Assaf lambs (50.6%) [33], Zandi lambs (50.6%) [34], and cross-bred lambs (50%) [35].

A limited amount of research on the influence of CGT feeding on carcass characteristics in lambs have been published and the dressing percentage tested gave higher outcomes (50.78%) than prior investigations [36,37], which revealed dressing percentages of 46.52% and 46.18% in Mecheri lambs across various feeding experiments. The hot carcass weight (kg) and dressing percentage increased with increasing pre-slaughter weight of treatment groups fed with higher CGT incorporation levels in roughage portion of the feed (25, 50, and 75%). Similarly, carcass length, meat-to-bone ratio and the loin eye area (cm2) found in the current study were higher than the earlier results observed in Mecheri lambs [36,37] as well as in Nellore cross bred lambs of India [38]. It showed that the experimental diets for the T_4 and T_3 groups had more crude protein than the T_1 and T_2 treatment groups, which may have contributed to these higher outcomes. Similar higher outcomes in Assaf lambs fed with higher crude protein level in the feed was also reported [33].

The weights of the liver, spleen, head, and stomach with intestine empty (kg) in the T_4 and T_3 groups were significantly ($P<0.05$) higher than in the other groups, and the findings were close to the range considered to be conventional for Mecheri lambs sheep and consistent with previous study [37] and they observed higher weights of edible organs such as liver, stomach with intestine empty, and head in Mecheri lambs fed with 1.5 percent concentrate supplementation. Furthermore, these results were equivalent to those reported in Zandi lambs offered a higher amount of cotton seed [34]. In terms of the percentage of whole sale cuts between the fore and hind quarters, there was no noticeable difference between treatment groups, and similar findings were observed in Mecheri [36] and Nellore cross bred lambs [38].

4.4. Meat quality

4.4.1. The Physicochemical and sensory characteristics

The lambs fed CGT at various levels had *Longissimus dorsi* muscles with pH values ranging from 6.42 to 6.57 and the percentage of CGT inclusion level had no discernible impact on these values. These results were close to the range considered to be conventional for sheep meat [39, 40] and the current figures concur with those obtained in earlier studies with the reported values of 6.65 [41] and 6.58 [42] in Ile de France lambs. The water holding capacity (WHC) of the sheep meat in the current study ranged from 57.29 to 60.61 % and was unaffected by feeding CGT at various levels. These values were comparable to those found in different sheep breeds (60.45%) [40], (57.08%) [41] and (60.99%) [43]. The shear force value (kg/cm2) of lambs' *Longissimus dorsi* muscle varied from 4.82 to 4.91 kg/cm2, with no significant difference ($P>0.05$) between treatment groups. A shear force of up to 5 kgf/cm2 is considered tender in sheep flesh [44], hence the meat from the lambs in this study can be considered tender. The results of this investigation on meat sensory evaluation showed that the CGT incorporation level had no impact on the pH, WHC, or shear force values of the muscles, which are quality indicators strongly associated to the meat sensory qualities. It could be concluded that feeding CGT to lambs had no negative effects on the sensory qualities of the meat from Mecheri ram lambs.

4.4.2. The proximate and fatty acid composition

The proximate analysis of *Longissimus dorsi* muscle samples showed that there was no significant difference ($P>0.05$) in the proximate composition among treatment groups. It could be inferred that feeding of 25, 50 and 75 per cent levels of CGT in the roughage

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portion of the feed did not cause any adverse effects on the proximate composition of meat samples. The results of the present study concurred with earlier reports [45, 37] in Mecheri lambs. However, there was lack of previous findings on effect of feeding CGT on the proximate composition of meat in lambs. The proximate composition such as fat (0.78 to 0.93 Vs 2.86 to 2.94 per cent) and ash level (0.86 to 1.06 per Vs 1.13 to 1.18 per cent) in the current study were lower than that found in Assaf lambs [33] fed with crude protein at different levels in the feed but the protein percentage shown higher in Mecheri lambs fed with various levels of CGT (21.92 to 22.49 Vs 19.5 to 19.6 per cent). This may due to higher pre-slaughter and carcass weight of Assaf lambs in compared to Mecheri lambs during slaughter. Whereas, the protein content in the current study were comparable to the value reported in Nellore cross bred lambs [38] and also found higher fat and ash per cent than the lambs fed with CGT. Inclusion of CGT in the feed of lambs increased the myristic and stearic acids in the treatment groups when compared to control group. At the same time, it reduced oleic and behenic acids in the treatment groups compared to control group. However, it has not caused any significant difference in the levels of palmitic, linoleic, linolenic, arachidic, DHA and palmitoleic acids among treatment groups. The results of present study are in accordance with previous study [46] and they reported that Oleic acid in MUFA, palmitic acid in SFA and linoleic acid in PUFA are the most prevalent fatty acids.

It was also observed that the saturated fatty acids (SFA) were significantly higher in lambs fed with CGT (T_3, T_4 and T_2 groups) than the control group. This might be mainly due to biohydrogenation process in the rumen [47, 48]. In contrast, the proportion of mono-unsaturated fatty acids (MUFA) in the control group was considerably greater than in the T_2, T_3, and T_4 treatment groups. It may be connected to the MUFA content of control animals' roughage diet [49]. There were no significant variations in polyunsaturated fatty acids (PUFA) or the ratio of PUFA to SFA (PUFA/SFA) between treatment groups. The ratio of PUFA and SFA (PUFA/SFA) of the present study ranged within the ratio of 0.10 and 0.26 as reported in the earlier studies in sheep meat [47, 50]. However, there are no prior studies on the impact of CGT on the fatty acid composition of meat from Mecheri lambs.

5. Conclusions

According to the study's findings, Mecheri ram lambs can be given CGT as a substitute for roughage sources to boost growth performance. The results show that increasing body weight increase, feed efficiency, and carcass characteristics in Mecheri ram lambs by including up to 75% CGT in the roughage portion of the feed. To ascertain the impact of feeding CGT at levels higher than 75% inclusion in the roughage section of sheep feed, more research needs to be done.

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Data Availability Statement: The data will be available to the needy scientist as per the MDPI transparent policy.

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