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Supplementation of Forage Sorghum with Meal Concentrate and *Leucaena leucocephala* on Goat Performance with Particular Reference to Meat Essential Fatty Acid Contents

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Abstract

Forage sorghum, supplemented with meal concentrate or fresh leucaena on goat performance was studied, using 15 male crossbred Anglo-Nubian and Native goats. They were allocated into 3 treatments; Treatment 1: fresh forage sorghum with an amount of 2 % (as fed basis) meal concentrate of animal body weight; Treatment 2: fresh forage sorghum with an amount of 1 % (as fed basis) meal concentrate, and an amount of 1 % fresh leucaena of animal body weight, and Treatment 3: fresh forage sorghum with an amount of 2 % fresh leucaena of animal body weight, under the completely randomized design (CRD). The results showed that total dry matter intake was not significantly different among treatments. However, dry matter intake of forage sorghum was significantly different among treatments ($p < 0.05$), where the highest intake of roughage was found in treatment 3. Total crude protein intake was significantly different among treatments ($p < 0.05$), where the highest intake of crude protein was found in Treatment 1, affecting weight gain and average daily gain among treatments with significant difference ($p < 0.05$). The essential fatty acid contents of linoleic acid (C18:2 *n-6*; omega 6) and conjugated linoleic acid (C18:2 *cis-9, trans-11,* CLA) in the *Longissimus dorsi* muscle of goats were not significantly different while omega 3 fatty acid as linolenic acid (C18:3 *n-3;* omega 3) was significantly different among treatments ($p < 0.05$) where the highest amount (0.94 g/100 g fatty acid) was found in Treatment 3.

Keywords: Forage sorghum, meal concentrate, *Leucaena leucocephala*, goat, fatty acid

Introduction

Ruminant feeding with good quality pasture has been advocated to achieve low cost animal production. Accordingly, meat goat production can use good quality pasture to obtain an optimum daily gain. Therefore, pasture must be sufficiently provided to meet the growth requirement. In general, pasture from grass, commonly used for goat feeding, produces better growth performance when properly supplemented with meal concentrate. Forage sorghum, *Sorghum bicolor* (L.) Moench, is an alternative annual roughage used to feed animals during pasture shortage. It can be a profitably alternative roughage for meat goats because of its fast growth rate, high yield from several harvesting times, and drought tolerance. Forage sorghum may be used to produce fresh cut feeding, grazing, and silage feeding [1]. In general, it is first cut at 60 days after planting, with a continuous defoliation after 45 days of regrowth for 3 to 5 times after the first cut, and contains a protein content (8 - 10 %) similar to corn [2]. Tropical legume has also been introduced to supplement ruminants, as it has better nutritive values which can improve animal production. Leucaena (*Leucaena leucocephala*), a promising tropical tree legume with a

high protein content of 17 - 30 %, can be fed to ruminants without any harm in terms of fresh cut forage [3].

Lactating cows fed with fresh forage sorghum and legumes had significantly high daily dry matter intake and milk production [4,5]. Currently, feeding forages, naturally enriched with fatty acids, are important precursors in animal products. Ruminants have been found to have an increased essential fatty acids, conjugated linoleic acid (C18:2 *cis-9, trans-11;* CLA), in their milk and meat, because of a natural source of linolenic acid (C18:3 *n-3;* omega 3) content in forages [6]. Most studies have examined the use of plants, marine oils, vegetable oilseeds, and rumen protected substances (inert lipids) in diet in order to modify milk and meat fatty acid composition. However, these sources were of a high cost for animal production. The potential use of livestock products to deliver n-3 fatty acids has been the subject of intensive research [7]. Currently, forage lipids are the cheapest and safest sources of these fatty acids. They can provide long chain fatty acids in meat. Recent research has shown that grass contained higher concentrations of the fatty acid C18:3 *n-3* (49.15 % of fatty acid) than is contained in meal concentrate (1.86 % of fatty acid) [8].

It is hopefully known that consumer demand is now for food products of superior health quality, with meat products from forage being high in quality and safety [9]. There has been renewed interest in modifications related to essential fatty acids from the richest natural feed resources, which are believed to have several important human physiological functions, including immune-modulating with anti-carcinogenic and anti-artheriosclerosis agents, growth, and lean body mass promotion [10,11]. Forage sorghum feeding for goat production has aimed to use meal concentrate and leucaena for growth performance and for essential meat fatty acid content in terms of linoleic acid (C18:2 *n-6*; omega 6), CLA, and C18:3 *n-3*, in meat goats.

Materials and methods

Forage sorghum management

Commercial forage sorghum, with low prussic acid, and which was drought tolerant [2], was planted on a paddock of a 0.16 ha experimental site located at the Faculty of Agricultural Technology, Phetchaburi Rajabhat University, Phetchaburi province. The paddock was cultivated to have a fine firm seedbed before sowing. It was sub-divided into 6 paddocks, each of approximately 0.26 ha. Forage sorghum seed was drilled in rows (35×10 cm^2) every week at a seedling rate of 18.75 kg/ha before the experiment began. It was topdressed with 187.50 kg/ha of N:P:K (15:15:15) fertilizer on the sowing date, and urea application on forage sorghum at 187.50 kg/ha was done 30 days after planting. Irrigation was applied when necessary to ensure optimal soil moisture conditions for plant growth. The first sorghum harvesting, at 15 - 20 cm above the ground, was done when the plant was 60 days old. Afterwards, a supply of irrigation and urea fertilizer at 187.50 kg/ha were applied for continuous defoliation (second cut) at 45 days of regrowth. The second cut forage sorghum, at 15 - 20 cm above the ground, was fresh cut daily for the trial.

Animal and diet

Fifteen crossbred Anglo-Nubian bucks (≥ 75 % Anglo-Nubian and Native), averaging 4 months old and of approximately 13 kg live weight, were assigned under the completely randomized design (CRD) of 3 treatments with 5 goats in each group; Treatment 1: fresh forage sorghum (*ad libitum*) supplemented with an amount of 2 % (as fed basis) meal concentrate of animal body weight, Treatment 2: fresh forage sorghum (*ad libitum*) supplemented with an amount of 1 % (as fed basis) meal concentrate and an amount of 1 % fresh leucaena of animal body weight, and Treatment 3: fresh forage sorghum (*ad libitum*) supplemented with an amount of 2 % fresh leucaena of animal body weight.

During the experiment, the second cut forage sorghum and leucaena (leaves and immature branch) grown on the experimental site were mechanically chopped at 2 - 3 cm long for the animals supplemented with commercial meal concentrate, containing soy bean meal, sunflower meal, mung bean meal, coconut meal, ground corn, cassava, rice bran, etc. plus small proportion of minerals, according to treatments. Meal concentrate and chopped leucaena were offered twice daily, in the morning and evening, after

removal of refusals; chopped forage sorghum was provided at any time of the day when it was almost empty. Feed intake was estimated as the difference between the daily feed offered and the residual uneaten feed, and feed samples were collected monthly for further analyses.

Each goat was individually housed in a pen 1.0 m wide and 1.5 m long under a tiled roof barn, and given free access to water and mineral block. They were fed for the entire 3 months from November 28, 2011, to February 28, 2012.

Sample collection and chemical analyses

Forage sorghum and leucaena were collected and analyzed for dry matter (DM) content, crude protein by Kjeldahl analysis, ether extract (EE) using Soxtec System with petroleum ether, ash using a muffle furnace at 550 °C for 3 h [12], neutral detergent fiber (NDF), and acid detergent fiber (ADF) [13]. Gross energy (GE) was determined using Oxygen Bombs [14]. The precursor of CLA, C18:2 and C18:3 in forage sorghum, leucaena, and meal concentrate samples were analyzed using a gas chromatograph (Chrompack CP 9001, CA, USA) equipped with a fused silica capillary column (50 m length, 0.25 mm ID) (Chrompack CPSIL88, CA, USA) [15,16].

Measurements

Feed intake was determined daily as the difference between feed offered and refusal collected. DM percentage of roughage and meal concentrate was used to calculate daily dry matter intake. Animal live weight was individually measured at the beginning and at the end of the experiment, using a 60 kg digital scale (CAS, DB-II) to determine weight change in terms of weight gain and average daily gain (ADG).

A technique [17] to assess the nutritional status of goats in relation to production was applied on the last day of the experiment. To accommodate this technique, morning feeding was delayed, and blood samples of 10 ml were taken from the jugular vein before feeding; this was repeated again separately 4 - 5 h after morning feeding. The samples were also heparinized, centrifuged, and stored at –20 °C for blood urea nitrogen (BUN) [18], blood glucose (BG) [19] and triiodothyronine (T_3) by electrochemiluminescence immunoassay (ECLIA, Roche Diagnostic, Indianapolis, IN, USA).

To assess the essential fatty content in meat goats, the goats from each group were slaughtered [20]. Meat samples were collected from the *Longissimus dorsi* muscle and extracted according to a modification method of Folchet and Metcalfe [21,22]. The randomly selected samples (approximately 5 g) were homogenized with 90 ml of a mixture of chloroform and methanol at a ratio of 2:1. The slurry was filtered using Whatman filter paper no.1. The filtrate was collected into a separatory funnel and 20 ml of deionized water was added. After standing at room temperature for 1 h, the liquid mixture was separated into 2 parts. The bottom one was collected and evaporated at 40 °C for 5 min using a rotary evaporator. The remaining part was flushed with N_2 gas and stored at –20 °C until methylation.

Fatty acid methyl esters (FAME) were prepared using the procedure described by Ostrowskaet [23]. The extracted fat (30 mg) was placed into a reaction tube, and then 5 ml of 0.5 mol/L sodium hydroxide in methanol and1 ml of C17:0 in hexane as an internal standard (2 mg/ml) were added to the tube. The mixture was heated at 100 °C for 10 min in a water bath and then cooled at room temperature. Two ml of 14 % BF_3 in methanol were added, and the mixture was heated again at the same temperature and time. Ten ml of saturated sodium chloride and 5 ml of hexane were then added to the tube. The mixture was placed at room temperature for 30 min to allow the liquid to separate into 2 parts. The top one, containing hexane, was collected into a vial for analyses using a gas chromatograph [23] (Chrompack CP 9001, CA, USA) equipped with a fused silica capillary column (50 m length, 0.25 mm ID) (Chrompack CPSIL88, CA, USA). Injector and detector temperatures were 270 and 280 °C, respectively. The conditions for the column temperature to separate the fatty acid profile started at 50 °C and was increased at 20 °C/min to 140 °C. The temperature was held at 140 °C for 5 min, and continued to increase at 4 °C/min to 190 °C, which was held for 15 min. Then, the temperature was increased at 10 °C/min to 210 °C, which was held for 6 min. *Cis*9, *trans*11- CLA, and *trans*10, *cis*12-CLA isomers (Sigma, USA) were used to identify and quantify each CLA isomer. Other fatty acid standards were obtained from Supelco Co. (18918, USA).

Statistical analysis

All data were statistically analyzed by Completely Randomized Design using the analysis of variance according to the statistical method [24], where significant differences among treatments were assessed by Duncan's new multiple range test at a 95 % confidence interval.

Results and discussion

Nutritive values of feeds

Chemical compositions of feeding treatments are shown in **Table 1**, where forage sorghum contained DM, crude protein, EE, ash, GE, NDF, and ADF of 23.65, 9.68, 1.37, 10.41 %, 4,175.9 kcal/kgDM, 49.10, and 33.74 %, respectively, while DM, crude protein, GE, NDF, and ADF of leucaena were 31.95, 14.69 %, 4,605.27 kcal/kgDM, 35.25, and 28.80 %, respectively. The CLA precursors as essential fatty acid contents of linoleic acid (C18:2 *n-6*) and linolenic acid (C18:3 *n-3*) in forage sorghum, leucaena, and meal concentrate (**Table 2**) were 12.04, 15.67, and 31.54 g/100 g fatty acid, respectively, and 40.41, 48.13, and 2.19 g/100 g fatty acid, respectively.

Since the forage sorghum fed to goats in this study had been harvested from the second defoliation at 45 days after the first cut, the contents of crude protein (CP), NDF, and ADF at 9.68 %, 49.10, and 33.74 % (**Table 1**), respectively, meant it was a good quality forage for ruminants [25]. As forage sorghum and leucaena are indicated as good quality roughage, there is a disadvantage in the hemicellulose derived from the difference between the NDF and ADF contents [26]. Since hemicellulose is the most complex of plant polysaccharides, its digestibility is closely associated with lignin, possibly causing low ruminal rates of passage and a low availability of protein and energy for animal performance [27].

CP content in forage sorghum was kept above the minimal range (around 7 %) [28] needed for the normal requirements of ruminal protein levels for cellulolytic bacterial activity [29]. Therefore, the ruminants required forage with at least 7 percent crude protein (as a percentage of dietary dry matter) for maintenance, 10 - 14 percent protein for growth, and 15 percent protein for lactation [29]. NDF and ADF contents were low which would have affected animal intake due to their better fiber digestion [29]. Meal concentrate and leucaena were supplemented, to provide protein and energy to meet animal requirements for better growth performance [30]. However, the protein content of 14.69 % in chopped leucaena was lower than the normal range of 17 - 30 % [3], possibly due to an outbreak of psyllid during the dry season months, affecting lower leaf and more mature brown stem content quality [31].

Table 1 Chemical composition of forage sorghum and leucaena provided to the goats.

Items	DM (%)	CP (%)	EE (%)	Ash (%)	NDF (%)	ADF (%)	GE (cal/gDM)
Forage sorghum	23.65	9.68	1.37	10.41	49.10	33.74	4,175.94
Leucaena	31.95	14.69	2.19	7.31	35.25	28.80	4,605.27
Meal concentrate	93.20	15.40	5.99	9.81	-	-	4,255.28

DM = Dry matter, CP = Crude protein, NDF = Neutral detergent fiber, ADF = Acid detergent fiber, GE = Gross energy

Forage plants are generally high in polyunsaturated fatty acids (PUFA), particularly C18:2 *n-6* and C18:3 *n-3* fatty acids, but mainly in C18:3 *n-3* fatty acid [32,33]. The current results show that forage sorghum and leucaena had a higher content of C18:3 *n-3* than there was in meal concentrate, approximately by 22 times (**Table 2**), whereas meal concentrate had a higher content of C18:2 *n-6* than there was in forage sorghum. However, both the C18:2 *n-6* and C18:3 *n-3* fatty acids in forage sorghum and leucaena are precursors of these beneficial fatty acids in meat [34].

Table 2 Fatty acids as linoleic acid and linolenic acid in the experimental feeds.

Items	C18:2 *n-6* (linoleic acid) (g/100 g fatty acid)	C18:3 *n-3* (linolenic acid) (g/100 g fatty acid)
Forage sorghum	12.04	40.41
Leucaena	15.67	48.13
Meal concentrate	31.54	2.19

Feed intake and live weight gain

As forage sorghum and leucaena were fed to the animals, there was no adverse effect of toxicity from either hydrocyanic acid or mimosine. The commercial forage sorghum used in this experiment contained low level of prussic acid at 120 ppm which was under the toxic level at 600 ppm [2]. Moreover, Thai crossbred goats have natural ruminal *synergistes jonesii*, mimosine derivatives in the form of 3-hydroxy-4(1H)-pyridone (DHP) degrading bacteria [35]. Total dry matter intake and total dry matter per percent of body weight were not significantly different among the treatments, as shown in **Table 3**. Daily dry matter intake of forage sorghum in Treatment 1 was significantly lower (277.50 gDM) than those in Treatments 2 and 3 (328.26 and 357.83 gDM, respectively, $p < 0.05$). Goats in Treatment 1 received the highest amount of meal concentrate, which had a substitution effect on the rumen capacity of less forage sorghum intake, while more forage sorghum and leucaena intake was found in goats fed less meal concentrate in Treatments 2 and 3. It may be explained that the animals in Treatment 1 received higher amounts of meal concentrate (399.90 g/d), which would decrease ruminal gut fill [27]. However, total dry matter to body weight (%BW) was not significantly different among treatments. at 3.75, 3.77 and 3.86 %BW, respectively, which are at the normal standard of 3 - 4 % of body weight in dry matter [36].

Table 3 Dry matter intake (DMI) and protein intake of goats fed with different feeding treatments.

Feed intake	Treatments		
	Treatment 1	Treatment 2	Treatment 3
Dry matter intake (g/day)			
Forage sorghum	277.50 ± 33.95^{b}	328.26 ± 26.15^{ab}	357.83 ± 63.43^{a}
Meal concentrate	399.90 ± 12.57^{a}	201.12 ± 2.87^{b}	-
Leucaena	-	160.66 ± 13.51^{b}	311.40 ± 17.29^{a}
Total	677.40 ± 30.69	690.07 ± 22.10	668.36 ± 72.38
R:C ratio[1]	41:59	71:29	100:0
Dry matter intake (%BW)			
Forage sorghum	1.54 ± 0.23^{b}	1.78 ± 0.20^{ab}	2.04 ± 0.36^{a}
Meal concentrate	2.20 ± 0.19^{a}	1.10 ± 0.03^{b}	-
Leucaena	-	0.90 ± 0.08^{b}	1.84 ± 0.16^{a}
Total	3.75 ± 0.28	3.77 ± 0.20	3.86 ± 0.47
Crude protein intake (g/day)			
Forage sorghum	26.86 ± 3.29^{b}	31.78 ± 2.53^{ab}	34.55 ± 6.18^{a}
Meal concentrate	61.70 ± 1.94^{a}	31.03 ± 0.44^{b}	-
Leucaena	-	23.60 ± 1.98^{b}	45.75 ± 2.54^{a}
Total	88.57 ± 3.01^{a}	86.41 ± 2.19^{ab}	80.30 ± 7.55^{b}

[a,b]Mean values within a row indicated with different superscripts are significantly different ($p < 0.05$).
[1]Ratio of roughage to meal concentrate.

Total crude protein intake was significantly different among treatments, at 88.57, 86.41, and 80.30 g/d, respectively ($p < 0.05$). The animals in Treatment 3 received leucaena as a protein supplement to replace meal concentrate. However, more NDF and ADF intake from leucaena and forage sorghum would have a detrimental effect on rumen digestion, due to the slow rate of passage of roughage in the rumen [36,37] possibly affecting poor growth performance. Therefore, meal concentrate and leucaena would contribute to increase protein content and energy for better growth performance. Although the protein content in leucaena was close to that in meal concentrate, leucaena itself contains more cell wall content in the forms of NDF and ADF, which extended ruminal digestion times [36].

Total live weight gain and ADG were significantly different among treatments, as shown in **Table 4** ($p < 0.05$). The animals in Treatment 1 were fed high amounts of meal concentrate enriched with high protein and energy contents, resulting in better growth rate, while goats in Treatment 2 received a combination of meal concentrate and leucaena had similar growth to those in Treatment 1. A higher ratio of roughage in **Table 3**, affecting more NDF and ADF content from forage sorghum and leucaena, would depress ruminal protein digestion, affecting lower growth performance [29,30]. It is well documented that crude protein intake is for maintenance and growth, so high crude protein intake, with less NDF and ADF content from a lower ratio of roughage (**Table 3**), could increase better digestion and higher ADG of goats in Treatments 1 and 2 [36]. However, the lowest growth rate of goats in Treatment 3 was from the highest ratio of roughage (**Table 3**), possibly causing poor digestion of a high protein intake [36].

Although ADG of goats in Treatment 3 (64.21 g/d) was lower than those in the goats supplemented with meal concentrate, such growth rates were better than the ADG (13 g/d) from goats receiving poor quality grass from public pasture [20]. If the animals had been fed with better quality feed from leucaena, their performance would have been improved.

Table 4 Live weight gain and average daily gain (ADG) of goats fed different feeding treatments.

Growth performance	Treatments		
	Treatment 1	**Treatment 2**	**Treatment 3**
Initial live weight (kg)	13.12 ± 0.93	13.32 ± 1.26	13.42 ± 1.19
Final live weight (kg)	22.14 ± 1.71[a]	22.10 ± 1.01[a]	19.52 ± 0.79[b]
Live weight gain (kg/hd)	9.02 ± 1.58[a]	8.76 ± 1.69[a]	6.10 ± 1.58[b]
ADG (g/hd/d)	94.91 ± 16.68[a]	92.21 ± 17.87[a]	64.21 ± 16.72[b]

[a,b]Mean values within a row indicated with different superscripts are significantly different ($p < 0.05$).

Blood parameters

Blood glucose (BG) concentrations (**Table 5**) before feeding (60.60 - 68.20 mg/dl) and 4 h after feeding (62.40 - 78.40 mg/dl) were not significantly different among the feeding treatments. BG concentration is determined for energy utilization from feed, through ruminal microbial activity which digests carbohydrates and produces volatile fatty acids. In particular, propionic acid is changed to glucose as an energy source in the liver, which is indicated by blood glucose in a normal range between 50 - 75 mg/dl [38]. The results of this study were in the normal range of BG, representing a sufficient energy derived from feed provided to the animals. However, BG content in Treatment 1 seemed to be over the normal range, due to its meal concentrate intake of 59 % of total dry matter, affecting high BG content from readily available carbohydrate metabolisms in the rumen [30]. Conversely, mean BG content in Treatment 3 was at the lowest among the treatments, due to the highest NDF and ADF intake, which would depress the ruminal carbohydrate metabolism from high structural carbohydrates in the combination of forage sorghum and leucaena [36].

Table 5 Blood parameters of goats fed with different feeding regimes.

Blood parameters	Treatments		
	Treatment 1	Treatment 2	Treatment 3
Blood Glucose (mg/dl)			
0 h-pre feeding	66.40 ± 5.85	68.20 ± 7.59	60.60 ± 0.5
4 h-post feeding	78.40 ± 17.58	70.00 ± 4.79	62.40 ± 3.7
Blood urea nitrogen (mg/dl)			
0 h-pre feeding	18.80 ± 3.89	16.20 ± 1.92	15.00 ± 2.7
4 h-post feeding	20.00 ± 3.53	18.40 ±1.51	16.80 ± 3.70
Triiodothyronine (ng/dl) (4 h-post feeding)	203.00 ± 40.11	197.60 ± 55.15	157.00 ± 22.19

Blood urea nitrogen (BUN) concentrations before feeding (15.00 - 18.80 mg/dl) and 4 h after feeding (16.80 - 20.00 mg/dl) were not significantly different among treatments. BUN is indicated as a ruminal protein utilization, which has a normal range of 12.60 - 28.00 mg/dl [39]. BUN contents in this study were under the normal range. The animals in Treatments 1 and 3 appeared to have the highest and lowest BUN contents, due to different ratios of roughage to meal concentrate provided to the animals, affecting growth performance, shown in **Table 4** [29,30]. There were no significant differences in triiodothyronine (T_3) concentration among the treatments 4 hr after feeding (157.00 - 203.00 ng/dl). T_3 is a caloriegenic hormone with the function of body growth from the metabolism of carbohydrates, proteins and fats [40,41]. The T_3 contents after feeding in Treatment 1 were over the normal range of 90 - 190 ng/dl [42], due to the higher metabolic action on energy and proteins from meal concentrate. However, T_3 contents in Treatments 2 and 3 were in the normal range, which affected the stimulation of protein turnover for better growth performance [43].

Meat essential fatty acids

The essential fatty acid contents of C18:2 *n-6* and CLA in the *Longissimus dorsi* of goats (**Table 6**) were not significantly different among treatments, while omega 3 fatty acid contents in the form of C18:3 *n-3* were significantly different among treatments ($p < 0.05$). Higher meat essential fatty acid contents of C18:3 *n-3* ($p < 0.05$) appeared to increase in Treatment 3, according to the higher intake of 2 forages containing more precursors of those fatty acids (**Table 2**). Subsequently, goat meat in Treatment 3 tended to have a higher CLA content. The reason for this may be that they were fully offered forage sorghum and leucaena containing high C18:3 *n-3* content, which led to the higher accumulation in the meat than that in the goats fed with the other feed. Biohydrogenation of unsaturated fatty acids by rumen bacteria (*Butyrivibrio fibrisolvens*) are converted into the trans-11 of C18:1 (vaccenic acid), with absorption in the small intestine, and then occurs as CLA by Δ^9 desaturase [44, 45].

The CLA content was not significantly different among treatments, due to a high content of C18:2 *n-6* in meal concentrate, which is the precursor of CLA in goat meat [46, 47]. This study showed the CLA content was 0.34 - 0.51 g/100 g fatty acid methyl ester, in accordance to other research on ruminants [47]. In addition, all treatments provided no significant difference in the content of SFA, MUFA and PUFA, as shown in **Table 6**. The higher content of omega 3 acid in the *Longissimus dorsi* of Treatment 3 led to a decrease in the ratio of *n-6:n-3*. The ratio of *n-6:n-3* should be less than 4 to 1 to promote good health in the human diet [48,49].

Table 6 Essential fatty acids and CLA content in the *Longissimus dorsi* muscle of goats fed with different feeding treatments (g/100 g fatty acid).

Fatty acid	Treatments		
	Treatment 1	Treatment 2	Treatment 3
C14:0	1.81±0.67	1.71±0.52	2.49±0.78
C16:0	15.93±4.54	18.39±3.48	23.04±2.94
C16:1 *cis-9*	1.70±0.26	1.68±0.36	2.25±0.65
C18:0	12.22±3.31[b]	16.96±3.71[b]	24.18±1.20[a]
C18:1 *cis-9*	30.19±5.60	35.12±7.36	36.96±5.93
C18:2 *n-6*	2.51±0.97	3.72±1.38	2.85±0.72
C18:2 *cis-9, trans-11*(CLA)	0.34±0.17	0.40±0.17	0.51±0.06
C18:3 *n-3*	0.26±0.08[b]	0.46±0.10[b]	0.94±0.39[a]
C22:1	28.78±16.82	18.32±1.53	4.43±5.79
SFA[1]	36.19±10.09	40.28±6.28	52.03±2.10
MUFA[2]	60.68±11.09	55.12±7.59	43.66±1.90
PUFA[3]	3.12±1.19	4.59±1.32	4.30±1.05
n-6	2.51±0.97	3.72±1.38	2.85±0.72
n-3	0.26±0.08[b]	0.46±0.10[b]	0.94±0.39[a]
PUFA:SFA	0.08±0.02	0.11±0.01	0.08±0.02
n-6:n-3 ratio	9.66±2.22[a]	7.74±1.25[a]	3.17±0.81[b]

[a,b]Mean values within a row indicated with different superscripts are significantly different ($p < 0.05$).
[1]SFA-saturated fatty acids, [2]MUFA-monounsaturated fatty acids, [3]PUFA-polyunsaturated fatty acids.

Conclusions

The utilization of fresh forage sorghum as a roughage source and fresh leucana as a protein supplementation to replace meal concentrate feed could have the potential to replace at least 50 % of meal concentrate feeding. Although the meat quality obtained from leucaena supplementation in this study appeared to be lower than the normal standard for the animal, it could satisfactorily affect growth rate at 64.21 g/d, compared to the supplementation of meal concentrate at 94.91 g/d. Moreover, meat essential fatty acid content, in the form of omega 3 as linolenic acid (C18:3*n-3*), found in the goats that received forage sorghum supplemented with leucaena were higher than that found in those that received sorghum with meal concentrate feeding.

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