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Effects of Partial Replacement of Alfalfa Hay with *Acacia saligna* Foliage on Carcass Characteristics and Meat Quality of Goats

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Abstract: The present study evaluated the inclusion of *Acacia saligna* foliage as a partial replacement for alfalfa (*Medicago sativa*) hay in a mixed diet. Sixty male Ardi goat kids were assigned to 4 treatment groups comprised of feed containing 0, 20, 30 and 40% *A. saligna*. The longissimus thoracis muscle was used to study the effects of *A. saligna* supplementation on carcass characteristics, chemical composition and quality properties of meat. The treatment groups were significantly different in slaughter weight as well as in weights of empty body, hot and cold carcasses. Moreover, omental and mesenteric fat depots increased significantly with increased Acacia foliage levels. Also expressed juice showed significant increase as *A. saligna* foliage inclusion levels increased. Generally, the meat quality results were insignificant and not fully consistent regarding their development in relation to the level of *A. saligna* inclusion. It is concluded that inclusion of up to 30% *A. saligna* foliage can effectively replace alfalfa hay as a potential feed resource in goat's diet without any adverse effects on meat quality.

Key words: Acacia, goat, saligna, salt-tolerant, drought-resistant, tanning

INTRODUCTION

Alfalfa (*Medicago sativa*) hay is a common green fodder used for ruminant feed in Saudi Arabia. However, given the passing of recent legislation aimed at ending local production of fodder material (Act No. 39 on Ban of Green Fodder Cultivation in Saudi Arabia) (MEWA., 2018), Saudi livestock producers are seeking suitable alternatives for green fodder in terms of both availability and quality. One such substitute is *Acacia saligna*, a drought and salt-tolerant shrub that produces high levels of green biomass and has high crude protein content (Salem *et al*., 2012). However, because *A. saligna* also contains an abundance of lignin and tannins it cannot be used as a sole source of feed for ruminants (Degen *et al*., 1995; El Nasr *et al*., 1997; Moujahed *et al*., 2005). These secondary compounds found in Acacia form complexes with its proteins making them unobtainable for rumen micro-organisms. Thus, *A. saligna* is typically fed to livestock either in combination with condensed tannin deactivators such as Polyethylene Glycol (PEG) or as a dietary supplement. Based on this view; Belay and Tesfay (2016) evaluated treated *A. saligna* leaves on growth performance and carcass characteristics of goat in the hot sub-moist lowland of the Tigray State in Northern Ethiopia. Four treatments; grass hay as a control, air-dried *Acacia saligna* leaves, water-soaked *Acacia saligna* leaves and wood ash soaked *Acacia saligna* leaves each included at 300 g/head/days were used as supplements. They concluded that feeding *A. saligna* leaves to goats at the time of scarcity would improve their body weight gain and carcass value. Eissa *et al.* (2015) used the combinations of cassava and ammoniated wheat straw along with *A. saligna* in a complete diet for feeding Barki lambs under semi-arid conditions. They noted that these combinations could be included up to 60% without negative impact on growth performance and blood metabolites. Varying from the suggested percentage of inclusion in the previous study, Meneses *et al.* (2012) advised not to include more than 25% of *A. saligna* foliage during pregnancy and lactation of goats.

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The objective of this study was to assess the effectiveness of *A. saligna* foliage as a replacement for alfalfa hay in the diets of Ardi goats and to evaluate its effects on carcass characteristics, chemical composition and quality properties of meat of this breed. The level of *A. saligna* inclusion in this study was set in the light of reviewing several previous studies.

MATERIALS AND METHODS

Experimental design: This study was carried out following the guidelines of work on living animals (Chapter 12, Article 38) set by The National Committee of Bioethics (NCBE), Saudi Arabia. A total of 60 male Ardi goat kids with average body weight of approximately 21±0.4 kg were used in this study that was performed in Riyadh city, Saudi Arabia (24.7136°N, 46.6753°E). The kids were stratified by weight and randomly assigned to 4 dietary treatment groups containing 15 kids per group with the animals in each group further subdivided into 5 replicates based on a completely randomized-block design. Each replicate comprised 3 kids that were housed in a concrete-floored pen in an open-sided building. The kids were supplied with enough feed and water facilities.

Feeds and feeding: Four experimental diets composed of different meal mixtures (on dry matter basis) of alfalfa hay (*Medicago sativa*), *A. saligna* foliage, barley grains, corn, wheat bran, soybean meal and vitamins and minerals were used in this experiment. In the 4 treatment diets, control, 20, 30 and 40% Acacia; the alfalfa hay was replaced (on dry matter basis) by 0, 20, 30 and 40% *A. saligna*, respectively. Around 30 g homogenized sample from each of the experimental diets was collected and used for moisture, ash, ether extract, crude fibre and crude protein determination according to the procedure outlined by the AOAC. (2000). The Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) were determined according to the method outlined by Van Soest *et al.* (1991). Table 1 showed the ingredients that were added on dry matter basis, chemical composition, fibre fractions and nutritive values of the experimental diets. The *Acacia saligna* foliage was analysed for total and condensed tannins as described by Makkar and Goodchild (1996). The wheat brand was added to estrange the negative impacts of corn as a pH-depressor ending up with balanced diets in terms of energy and protein. The feeding trial lasted for 84 days preceded by a 2-weeks adaptation period allowing the animals to acclimate to the experimental environment. Throughout the experiment, feed intake was recorded daily as the difference between the given feed and weigh-back while the animal's weights were performed weekly after fasting for 12 h and before offering the daily meal.

Slaughter data and carcass characteristics: At the end of the trial period, stratified sampling method was applied where 10 animals were selected randomly including 2 animals per each pen (simple random sampling using Microsoft Excel application) from each treatment to form 40 kids that were assigned to slaughter. Before slaughter, the animals were weighed to define slaughter weight and then slaughtered to evaluate carcass characteristics and meat-quality attributes. Weights of internal organs and fat depots were also recorded. The fat depots included omental, mesenteric, kidney knob and channel, pericardial, backfat and body wall fat. The proportions of internal organs and fat depots were also computed based on the empty body weight. The chill shrink was calculated after overnight chilling of the carcasses at 2°C. The carcasses were then split into two equal halves along the vertebrate column where only the Longissimus Thoracis (LT) muscles of the left side were used in determining meat chemical and quality characteristics. The physical separation of the body tissues was performed immediately on the same day by separating the rack cut (from the 5th-8th thoracic vertebrae) that was then dissected into 3 components; muscle, bone and fat. These components were estimated as percentages based on the cut weight. The dissected muscle component was kept frozen at -20°C for later analysis of chemical composition content that included moisture, ash, crude protein and ether extract. Moreover, the 9th-12th thoracic vertebrae of the LT muscles were excised, thereafter a portion (3-5 cm) thick was cut, vacuum packed and stored at -20°C for later determination of shear force values and texture profile components. The rest of the muscle was used for the other meat quality analysis. The fat depot's separation was performed including omental, mesentery, kidney knob and channel, pericardial, backfat and body wall fat. The last two fat depots were measured in millimetre (mm) using a digital vernier calliper. The backfat thickness was taken at a point 75% of the length of the longissimus thoracis muscle from the split chine bone while the body wall fat was measured from the outside of the rib to the outside fat at 4 inches below the rib-eye. The Rib-Eye-Area (REA) was measured on the longissimus thoracis muscle between the 12th-13th ribs. An acetate sheet was scrabbled over the rib-eye and then taken off. The sheet was wetted as a result of the rib-eye muscle leaving a certain area that was then traced using a pen. The sheet left to dry, then after, the area was coloured with black

and scanned (150 dpi Res.), then saved as a monochrome bitmap image which was later analysed for REA using an analysing digital image software program (AreaScan 2 MFC Application 2000) (Ferreira *et al*., 2012).

Meat chemical composition: The dissected lean from the rack cut mentioned above was used to estimate moisture, crude protein, ether extract and ash, in accordance with the method outlined by the AOAC. (2000).

pH, temperature and colour components: The initial meat pH and temperature (1 h post-mortem) were measured directly by inserting a portable meat pH-Meter (HI 99163, Hanna Instruments, Rhode Island, USA) into the hot carcass while on the rail through an opening between the 12th and 13th ribs after complete skinning and dressing of the animal. The mean value of the two readings was calculated and considered as the initial pH_i and temperature. The ultimate pH_u was measured after 24 h after overnight chilling at 2°C. The colour components (L^*, a^* and b^*) were measured using a tri-stimulus analysis (Minolta Chroma Meter CR-400, Konica, Japan) based on the CIELAB colour system Chriyaa *et al*. (1976), initially, after 1 h post-mortem directly on the cross-sectional surface of the hot carcass while on the rail through the same opening where the temperature and pH readings were taken and ultimately (after 24 h post-mortem at 2°C) after 30 min blooming time at the same site. Two reading were recorded to give the final mean value.

Cooking loss, shear force and Texture Profile Analysis (TPA): These measurements were determined following the method described by Al-Owaimer *et al*. (2014). Briefly, collected muscle samples were cooked to internal temperatures of 70°C with temperature adjustments made using a thermocouple thermometer probe (Ecoscan Temp JKT, Eutech Instruments, Ayer Rajah Crescent, Singapore) inserted into the centre of the muscle; cooking loss percentage was defined as the difference between the initial and final weights. Cooked samples were then used to evaluate shear force based on the procedures described by Wheeler *et al*. (2005) in which a Texture Analyser (TA-HD-Stable Micro Systems, Godalming, UK) equipped with a Warner-Bratzler attachment was used. The Texture Profile Analysis (TPA) was performed using the same apparatus equipped with a compression-platen attachment. The variables to be examined were hardness, cohesiveness, springiness and chewiness.

Expressed Juice (EJ): Expressed Juice (EJ) was determined following the method described by Hamm (1960) and Degen *et al*. (1997) where 2 replicates of a cube muscle sample weighing 0.5 g were placed between 2 pieces of filter paper and 2 plexiglass plates and then compressed with a 10 kg weight placed over the plates for 5 min. The difference between the weights of the muscle samples before and after compression represented water loss.

Myofibril Fragmentation Index (MFI): The Myofibril Fragmentation Index (MFI) was determined following the procedures described by Culler *et al*. (1978). The 4 g muscle samples were minced and then homogenized with a cold isolating MFI buffer. The absorbance of the solution was then determined at 540 nm to obtain the MFI value.

Data analysis: The overall objective was to compare the treatment means, μ_C, μ_{A20}, μ_{A30}, μ_{A40}. The attained results were statistically analysed using SPSS Software (IBM SPSS Ver. 22) and all data were expressed as means. Comparison of the means was performed by applying one-way ANOVA. The significant differences between the means were separated by the Least Significant Difference (LSD) multiple comparisons at a significance level of $p<0.05$. The statistical model was as follows:

$$y_{ijk} = \mu + k + \alpha_i + b_j + \varepsilon_{ijk}$$

Where:

y_{ijk} = Observation on experimental unit/lamb $_k$ in block $_j$ assigned to treatment $_i$
μ = Overall mean
K = Experimental unit $_k$ where, k = 1-3 lambs per each block
α_i = Effect of treatment $_i$ where, i = the 4 treatments C, 20, 30 and 40%
b_j = Effect of block $_j$ where, j = 1-5 are blocks per each treatment
ε_{ijk} = Random error

RESULTS AND DISCUSSION

Tannin content and growth performance: The total and condensed tannins of *Acacia saligna* foliage used in this study were quantified to be 39 and 35 g/kg, respectively (Table 1). Table 2 displayed the growth performance of the experimental animals fed the treatment diets. The treatment groups were significantly ($p<0.05$) different in Final Live Weight (FLW), Dry Matter Intake (DMI) and Daily Gain (DG) and Feed Conversion Ratio (FCR). The control group showed the highest daily dry matter intake that was significantly ($p<0.05$) different with the 40%

Table 1: Ingredients, chemical composition, fibre fractions and nutritive values of the experimental diets

Parameters	Experimental diets** (%)				
	Control	Acacia (20%)	Acacia (30%)	Acacia (40%)	SEM
Ingredients (%)					
Alfalfa hay	40	20	10	0	-
***Acacia saligna* foliage	0	20	30	40	-
Soy bean meal	7	7	7	7	-
Barley	21	21	21	21	-
Corn	30.40	20.20	15	10	-
Bran	0	10	15	20	-
Common salt	0.50	0.50	0.50	0.50	-
Minerals and vitamins	0.30	0.30	0.30	0.30	-
Limestone	0.80	1	1.20	1.20	-
Chemical composition (g/kg)					
Dry matter	918	920	918	918	0.50
Ash	67	90	102	111	9.63
Crude protein	150	148	149	146	0.85
Ether extract	25	26	24	26	0.48
Crude fiber	122	114	113	108	2.90
Nitrogen free extract	635	623	613	609	5.80
Fiber fractions (g/kg)					
Neutral detergent fiber	231	257	273	278	10.58
Acid detergent fiber	147	147	153	152	1.60
Nutritive values					
Digestible organic matter (g/kg)	705^{a}	625^{bc}	645^{b}	603^{c}	21.91
Digestible crude protein (g/kg)	100^{a}	84^{bc}	92^{ab}	81^{c}	4.27
Total digestible nutrients (g kg)	746^{a}	648^{b}	667^{b}	627^{b}	25.98
Digestible energy (Kcal kg/TDN)	32^{a}	27^{bc}	29^{b}	27^{c}	114.22
Metabolizable energy****(Kcal kg/TDN)	26^{a}	22^{bc}	24^{b}	22^{c}	92.42

*Ingredients are on dry matter basis, **In this Table and in subsequent Table; Control: Acacia (0, 20, 30, 40%): Are treatment dietswhere Acacia replaced alfalfa hay (on dry matter basis) in control diet with the referred percentages, ***Total and condensed tannins of *A. saligna* foliage were 39 and 35 g/kg, respectively, ****Metabolizable Energy = Digestible Energy ×0.81, SEM = Standard Error of the Mean, $^{a-c}$Mean values within a row with different superscripts are significantly different at ($p<0.05$), TDN = Total Digestible Nutrients

Table 2: Growth performance of Ardi goats fed *Acacia saligna*-mixed diets

Parameter	*Acacia saligna* level				
	Control	Acacia (20%)	Acacia (30%)	Acacia (40%)	SEM
Trial period (day)	84	84	84	84	-
Initial live weight (kg)	20.70	20.30	20.40	20.60	0.26
Final live weight (kg)	34.70^{a}	31^{b}	30.70^{b}	27.30^{c}	0.75
Dry matter intake (g/d)	1076^{a}	1027^{a}	1040^{a}	902^{b}	21.49
Daily gain (g/d)	167^{a}	128^{b}	123^{b}	80^{c}	8.58
Feed conversion ratio	6.40^{b}	8^{b}	8.50^{b}	11.30^{a}	0.68

SEM = Standard Error of the Mean, $^{a-c}$Mean values within a row with different superscripts are significantly different at ($p<0.05$)

Acacia Group but not with the other treatment groups. Moreover, the control group also showed the best feed conversion ratio which along with the higher DMI resulted in the highest ($p<0.05$) daily gain that leading to the highest ($p<0.05$) final live weight. In contrast, the 40% Acacia Group exhibited the lowest ($p<0.05$) daily dry matter intake and worst ($p<0.05$) feed conversion ratio that leads to the least ($p<0.05$) daily gain and final live weight. The differences in final live weight and daily gain were ascribed to variations in dry matter intake which in turn arisen as the result of tannin content of the diets (D'Mello, 1992; Reed, 1995; El Nasr *et al*., 1997; Chriyaa *et al*., 1997). Moreover, this effect could be also attributed to the reduction of rumen protein degradability and to the increase of rumen transit velocity of protein as tannins are capable of binding with dietary proteins, rendering them less degradable within the rumen (Ben Salem *et al*., 1999; Min *et al*., 2003). On the other hand, growth performance responses to supplemental tannins have been generally, referred to enhancements in intestinal metabolizable protein supply. This was true for the 40% Acacia Group with the least ($p<0.05$) FLW, DMI, DG and FCE.

Slaughter and carcass components: Slaughter and carcass components data are shown in Table 3. Dietary treatment significantly ($p<0.05$) affected slaughter weights and all carcass values with the exception of chill shrinkage, rib-eye area, bone and fat contents. The highest slaughter, empty body, hot carcass, cold carcass,

Table 3: Slaughter and carcass components of Ardi goats fed *Acacia saligna*-mixed diets

	Acacia saligna level				
Component	Control	Acacia (20%)	Acacia (30%)	Acacia (40%)	SEM
Slaughter wt. (kg)	33.80^{a}	32.56^{a}	30.70^{a}	27.48^{b}	0.66
Empty body wt. (kg)	30.56^{a}	29.23^{a}	27.34^{ab}	25.58^{b}	0.60
Hot carcass wt. (kg)	15.23^{a}	14.78^{a}	13.92^{a}	12.24^{b}	0.33
Cold carcass wt. (kg)	14.77^{a}	14.20^{a}	13.42a	11.79^{b}	0.32
Heart wt. (kg)	0.14^{a}	0.13^{a}	0.13^{a}	0.11^{b}	0.00
*Heart%	0.47	0.46	0.49	0.44	0.01
Liver wt. (kg)	0.58^{a}	0.56^{a}	0.52^{a}	0.44^{b}	0.01
*Liver%	1.91	1.93	1.94	1.73	0.04
Spleen wt. (kg)	0.06^{a}	0.06^{a}	0.06^{a}	0.04^{b}	0.00
*Spleen (%)	0.18^{ab}	0.19^{ab}	0.21^{a}	0.16^{b}	0.01
Kidneys wt. (kg)	0.11^{ab}	0.11^{ab}	0.12^{a}	0.10^{b}	0.00
*Kidneys (%)	0.37	0.38	0.44	0.40	0.01
Gutfill wt. (kg)	3.25^{a}	3.35^{a}	3.40^{a}	1.93^{b}	0.17
*Gutfill (%)	10.75^{ab}	11.43^{a}	12.60^{a}	7.45^{b}	0.64
Chill shrinkage (%)	3.05	3.99	3.57	3.57	0.17
Dressing (%)	49.74^{ab}	50.48^{ab}	51.38^{a}	47.64^{b}	0.60
Rib-eye area (cm^{2})	32.74	31.36	29.43	27.39	0.96
Muscle (%)	51.22^{ab}	57.68^{a}	52.68^{ab}	47.50^{b}	1.33
Bone (%)	31.98	28.47	32.20	33.93	1.00
Fat (%)	14.97	11.80	12.58	14.50	0.68

SEM = Standard Error of the Mean, ^{a,b}Mean values within a row with different superscripts are significantly different at ($p<0.05$); *The values were computed on empty body weight basis

heart and liver weights were obtained by the control treatment group. The significance differences ($p<0.05$) on a weight basis were only between the control group and the 40% Acacia Group for slaughter weight, hot carcass, cold carcass, heart, liver, spleen and gutfill. The significant difference ($p<0.05$) in empty body weight was exclusively between the control and 20% Acacia Groups in one side and the 40% Acacia Group in the other side. The significant differences ($p<0.05$) in kidney's weight and dressing percentage were only between 30 and 40% Acacia Groups. Contrary, the 40% Acacia treatment group had the lowest ($p<0.05$) slaughter, empty body, hot carcass, cold carcass, heart, spleen, liver, kidney and gutfill weight values as well as the lowest dressing and muscle content values. As the kids grew, the final slaughter weight increased. On the other side, the weights of empty body, hot carcass, cold carcass, heart, liver, spleen and rib-eye area increased while the total fat and bone content were decreased showing a negative association with the body weight. The treatments were not significantly ($p>0.05$) different in liver, heart and kidneys when these organs were calculated based on the empty body weight indicating no effect of Acacia. While the inclusion of Acacia in the treatment groups revealed an effect over the spleen and gutfill regardless of the final slaughter weight. The obtained results, here were in line with that reported by Al-Owaimer *et al.* (2013) who studied the allometric growth patterns of body and carcass components in Ardhi goats. The slaughter components were negatively affected by the inclusion of *A. saligna* and these impacts increased with increasing levels of Acacia inclusion. The differences between the control group and the 20 and 30% Acacia treatments were not significant ($p>0.05$) whereas they were, so for, the 40% Acacia treatment. Differently, Mousa (2011) reported an improvement in slaughter weight and carcass components when Acacia comprised up to 40% of the diet that unlike the results obtained in this study; however, the two studies were in accordance regarding the enhancement of dressing percentages with increasing proportions of *A. saligna*. Carcass muscle percentage also increased ($p<0.05$) obviously in the treatment group 20% Acacia as a result of increasing Acacia content comparing to the other treatments but decreased in the 30 and 40% Acacia Groups that may be ascribed to the increased tannin content which is known to impede dry matter intake. Gebru *et al.* (2016) concluded that inclusion of *A. saligna* in diets resulted in a higher average body weight of rams whereas Ahmed *et al.* (2015a, b) reported that replacing berseem (*Trifolium alexandrinum*) hay with an untreated mixture of *A. nummularia* and *A. saligna* (at 1:1 DM) had no effect on Bakri lambs; moreover and in line with the results obtained, here, the latter study reported a significant ($p<0.05$) improvement in the carcass dressing percentage of lambs fed a halophyte mixture. The negative results regarding slaughter weight and carcass components observed in this study may be attributed to the higher tannin content of *A. saligna* which interfered with the dry matter intake and absorption of the nutrient by the kids in the treatment groups compared to those fed the control diet. Boufennara *et al.* (2013) concluded that although, foliage from Acacia tree species is high in

Table 4: Carcass fat depots of Ardi goats fed *Acacia saligna*-mixed diets

	Acacia saligna level				
Depots	Control	Acacia (20%)	Acacia (30%)	Acacia (40%)	SEM
Omental fat (g)	690^{c}	660^{c}	1070^{b}	1330^{a}	0.06
*Omental fat (%)	2.23^{c}	2.26^{c}	4.02^{b}	5.25^{a}	0.25
Mesenteric fat (g)	240^{b}	200^{b}	580^{b}	1400^{a}	0.10
*Mesenteric fat (%)	0.78^{b}	0.69^{b}	2.15^{b}	5.57^{a}	0.41
KKCF (g)	420	400	460	320	0.02
*KKCF (%)	1.37	1.35	1.72	1.24	0.09
Pericardial fat (g)	70	70	70	60	0.00
*Pericardial fat (%)	0.24	0.25	0.26	0.22	0.01
Backfat (mm)	1.57	1.73	1.28	1.39	0.15
Body wall fat (mm)	1.90	1.87	1.58	1.99	0.14

SEM = Standard Error of the Mean; $^{a-c}$Mean values within a row with different superscripts are significantly different at ($p<0.05$); KKCF = Kidney Knob and Channel Fat; * The value was computed on empty body weight basis

protein, the high lignin and tannin contents act as limiting factors that interfere with absorption and utilization processes in ruminant digestive systems.

Carcass fat depots: The carcass fat depots values are displayed in Table 4. Only omental and mesenteric fats were differed significantly ($p<0.05$) among the treatments. No significant differences were detected among the treatments regarding Kidney Knob and Channel (KKC), pericardial, back and body wall fats. The 40% Acacia treatment group achieved the highest ($p<0.05$) omental and mesenteric fat contents. Oppositely, the lowest omental and mesenteric fat contents were obtained by the 20% Acacia experimental group. The proportions of the fat depots showed the same trend when they were given based on the empty body weight. This indicating an effect of Acacia inclusion on omental and mesenteric fat content. The fat deposition generally increased with increasing proportions of Acacia in the diets this outcome similar to that reported by Ahmed *et al.* (2015a, b) who found that total fat weight and ether extract increased in lambs fed halophytes as a partial or whole replacement of berseem hay. Moreover, Mousa (2011) reported a higher internal fat weight in Awassi lambs fed *A. saligna* foliage. Furthermore, tannins are known to have an effect on ruminal fatty acids biohydrogenation (Morales and Ungerfeld, 2015). In this concept, tannins were shown to inhibit linolenic acid (LNA = n-3 fatty acid) disappearance *in vitro* which is considered an early step of biohydrogenation (Kronberg *et al*., 2007). The increase in omental and mesenteric fat compared to intramuscular fat may be assigned to the fact that visceral fats developed earlier than intramuscular; moreover, deposition of fat in goats takes place quite late and reaches cognizable levels when the animals are at their mature body weight (Owen *et al*., 1983) and most of the fat is deposited in the innards rather than carcass depots (Webb *et al*., 2005). It is observed that fat depots of omentum and mesentery were visibly increased with the development of kids and as the level of Acacia hikes but not with the slaughter weight. This result also agreed with that obtained by Bonvillani *et al.* (2010) who stated that most of the internal fat depots increased in weight at a faster rate than body weight. Contrary to these results, Marques *et al.* (2014) found an increase in non-carcass fat with the increase of slaughter weight with the exception of mesenteric fat yield which was not influenced. The variation in quantity and distribution of fat tissues observed in this study is reconciled with the notice stated by Da Rosa *et al.* (2005). Generally, internal fat is quite variable based on different factors as a breed (Rodrigues *et al*., 2013); slaughter weight (Al-Owaimer *et al*., 2013) and nutrition (Bezerra *et al*., 2013). In addition, the higher visceral fat deposition showed in this study could also be attributed to the process of vascularization. Kozloski *et al.* (2001) explained that goats in warm climates have more irrigated visceral areas encouraging fat deposition and utilization.

Meat pH, temperature and colour components: The results of meat pH, temperature and colour components are presented in Table 5. The recorded meat pH in this study was relatively high but within the normal range of goat meat. However, only the control and 40% Acacia Groups were significantly ($p<0.05$) different in pH and Lightness (L^*) colour value at 1 h PM. While at 24 h PM, the pH was significantly ($p<0.05$) different between 30 and 40% treatment groups where the 40% Acacia Group attained the lowest value. On the other hand, there were no significant differences between the treatments for L^* and a^* at 24 h PM and yellowness (b^*) at both 1 and 24 h PM. Moreover, the meat temperature at 1 h postmortem was also not significantly different between the treatment groups. The highest initial pH occurred in the control group whereas the highest final pH was detected in 30% Acacia treatment group; the lowest levels for both initial

Table 5: Meat pH, temperature and color components of Ardi goats fed *Acacia saligna*-mixed diets

	Acacia saligna level				
Parameters	Control	Acacia (20%)	Acacia (30%)	Acacia (40%)	SEM
pH_i (1 h PM)	6.40^{a}	6.30^{ab}	6.30^{ab}	6.20^{b}	0.03
pH_u (24 h PM)	6.10^{ab}	6.10^{ab}	6.20^{a}	6^{b}	0.03
Temperature°C (1 h PM)	24.90	24.60	24.30	25	0.1
Color components (1 h PM)					
L^*	36.74^{b}	38.77^{ab}	38.00^{ab}	41.61^{a}	0.75
a^*	17.19^{a}	15.05^{b}	16.30^{ab}	16.03^{ab}	0.33
b^*	4.54	3.75	4	3.85	0.23
Color components (24 h PM)					
L^*	40.49	42.92	41.45	42.62	0.93
a^*	19.78	19.66	18	17.54	0.63
b^*	8.45	9.96	7.14	8.99	0.48

SEM = Standard Error of the Mean, $^{a, b}$Mean values within a row with different superscripts are significantly different at ($p<0.05$), PM = Post Mortem

Table 6: Physical meat characteristics of Ardi goats fed *Acacia saligna*-mixed diets

	Acacia saligna level				
Parameters	Control	Acacia (20%)	Acacia (30%)	Acacia (40%)	SEM
Cooking loss %	30.92	29.80	28.07	29.32	0.47
Expressed juice	0.31^{a}	0.32^{a}	0.26^{b}	0.29^{ab}	0.01
Shear force (kg)	3.30^{ab}	4^{a}	3.10^{b}	2.90^{b}	0.14
MFI	77.38	93.22	82.31	92.20	3.04
Texture Profile Analysis (TPA)					
Hardness (kg)	0.91	0.91	0.99	1.16	0.07
Springiness	0.61^{b}	0.57^{b}	0.67^{a}	0.69^{a}	0.01
Cohesiveness	0.52^{a}	0.50^{a}	0.45^{b}	0.49^{a}	0.01
Chewiness	0.29	0.28	0.34	0.40	0.03

SEM = Standard Error of the Mean, $^{a, b}$Mean values within a row with different superscripts are significantly different at ($p<0.05$), MFI = Myofibril Fragmentation Index

and final pH occurred in 40% Acacia experimental group. This group also exhibited the highest lightness colour at 1 h PM compared to the other treatment groups whereas the lowest lightness colour occurred in the control treatment group. The control treatment group also had the highest levels of redness at 1 h PM. The results showed that meat from goats fed diets supplemented with *A. saligna* had a lighter colour and lower ultimate pH values compared to that from goats in the control group, trends that increased with increasing levels of Acacia inclusion. Ngambu *et al.* (2013) also reported an insignificant increase in lightness and several studies have reported that feeding small ruminants with tannin-containing feedstuff produces meat of a lighter colour than meat from animals fed on diet lacking tannins (Priolo *et al*., 2005; Yayneshet *et al*., 2008; Marume *et al*., 2012). The quantified amount of tannin and condensed tannin reported in this study was relatively higher compared to other studies (Krebs *et al*., 2003; El-Waziry, 2007; Krebs *et al*., 2007). These variations could be attributed to the genotype (Baldwin *et al*., 1987), growing season (Hagerman, 1988) and age of plant and leaves (Degen *et al*., 1997). The average daily intake of Acacia tannin by the treatments based on the tannin content of the respective diets and their daily feed intake is found to be 0, 8.01, 12.17 and 14.07 g/day for the control, 20, 30 and 40% Acacia Groups, respectively. The higher intake of tannin by the 40% Acacia Group resulted in lighter meat showed by this group which was significantly different at 24 h PM and not, so at, 1 h PM (Priolo and Vasta, 2007).

Physical meat characteristics: The physical meat characteristics of the Ardi goats are shown in Table 6. The treatment groups differed significantly ($p<0.05$) in EJ, tenderness, springiness and cohesiveness while there were no significant differences among these groups with respect to cooking loss, MFI, hardness or chewiness. The EJ was significantly ($p<0.05$) improved with the inclusion of Acacia foliage up to 30% of the diet. The highest Cooking Loss (CL) was observed in the control group; however, the lowest was in the 30% Acacia treatment group which also exhibited the lowest EJ value. The higher CL obtained by the two groups was reconciled with their higher EJ which in turn assumed to be affected by the increased pH values (Kerth, 2013). The results regarding cooking loss were in line with those of Ngambu *et al.* (2013), who reported that meat from goats fed diets supplemented with *A. karroo* had lower ($p<0.05$) ultimate pH and cooking loss values than did meat from non-supplemented goats. This was also true for tenderness which was improved as the inclusion

Table 7: Meat chemical compositions of Ardi goats fed *Acacia saligna*-mixed diets

	Acacia saligna level				
Compositions (%)	Control	Acacia (20%)	Acacia (30%)	Acacia (40%)	SEM
Moisture	63.92	65.84	65.86	65.69	0.44
Ash	1.07	1.09	1.09	1.16	0.02
Crude protein	20.66	21.33	21.52	21.30	0.19
Ether extract	1.44[a]	1.17[b]	1.16[b]	1.19[b]	0.46

SEM = Standard Error of the Mean, [a,b]Mean values within a row with different superscripts are significantly different at ($p<0.05$)

of *A. saligna* foliage increased. The most tender meat (as represented by the lowest shearing force value) was attained by the 40% Acacia experimental group followed by 30% Acacia, control and finally, 20% Acacia treatment groups at the respective rates of 2.9, 3.1, 3.3 and 4.0 kg. On the other side, there was an increase in pH accompanied by the treatments with low percentages of Acacia that thought to be linked with toughness (Young *et al*., 1993, 1994). The obtained results in this study were in agreement with that reported by Priolo *et al*. (2000). Generally, the Texture Profile Analysis (TPA) components were increased with the inclusion of Acacia foliage in the treatment diets that showed relatively higher values than the control group. This trend was observed in all components but not in the case of cohesiveness where the ratios were decreased with Acacia addition. Although, the 40% Acacia Group the inclusion of Acacia foliage in the treatment diets that showed relatively higher values than the control group. This trend was observed in all components but not in the case of cohesiveness where the ratios were decreased with Acacia addition. Although, the 40% Acacia Group showed a higher value than the other two treatment groups, still attained lower value than the control group. The highest level of springiness was observed in 40% Acacia treatment group with the lowest value measured in 20% Acacia Group. The increased value of springiness in the 40% Acacia may be referred to the higher inclusion of the Acacia. The highest cohesiveness was recorded in the control group, followed by 20% Acacia >40% Acacia >30% Acacia treatment groups.

Meat chemical composition: The meat chemical composition of the Ardi goats fed *Acacia saligna*-mixed diets is presented in Table 7. Moisture, ash and crude protein did not differ significantly between the treatments while they were, so for, ether extract. The kids in the control treatment group (0% Acacia) had the highest ($p<0.05$) intramuscular fat content compared to the kids in the other treatments whereas the lowest (11.57%) intramuscular fat content exhibited by the kids fed 30% Acacia diet. In this study, the inclusion of *A. saligna* in diets generally resulted in significant ($p<0.05$) declines in meat fat content; in contrast (Ahmed *et al*., 2015a, b; Krebs *et al*., 2003) reported an insignificant increase in fat content in Bakri lambs fed diets containing a mixture of *A. nummularia* and *A. saligna*.

CONCLUSION

As a result of adding Acacia as a partial replacer for alfalfa, the dietary energy concentration is reduced leading to a significant reduction in the daily gain. Moreover, slaughtering at a fixed time of 84 days as in this study, the addition of Acacia reduced the final live and carcass weights as long as the proportion of Acacia increased. On the other hand, slower growing goats had heavier internal fat deposits which are associated with the inclusion of Acacia foliage up to 40%; moreover, dry matter intake was significantly reduced. As would be expected, the treatment groups with smaller carcasses had less fat within the meat. The obtained meat quality results were rather insignificant and not perfectly coherent regarding their development in relation to the level of *A. saligna* inclusion.

RECOMMENDATIONS

It is recommended to replace alfalfa hay with *A. saligna* foliage as a potential feed resource in proportions of up to 30% in goat diets without having any adverse effects regarding dressing percentage, slaughter and carcass components. However, the inclusion of Acacia in diets for goats at the recommended level will guarantee a reasonable source of forage with large biomass throughout the year in regions with dry conditions or those facing water shortages.

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