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Chemical and tissue composition of meat from carcass cuts of local goats affected by different feeding in Tunisian arid lands

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Abstract: An experiment was conducted to find out the nutritive value of different cuts of goat carcass. Meat samples were obtained from goat kids in Tunisia. Twenty-six indigenous kids were divided into three groups: oat hay (control), dried olive leaves + dried *Stipa tenacissima*, and grass hay. The cuts were the shoulder, chest, and leg of each goat carcass. Tissue compositions of different cuts and meat physicochemical parameters were determined. Percentage of muscle was higher in shoulders (61.57%) and legs (58.89%). The percentage of fat was higher in the chest (24.74%). Percentage of bone was higher in legs and shoulders. The percentage of muscle and bone was similar in the three diet treatments. The fat percentage tended to be higher in the grass hay group. The mean pH value of different cuts differed significantly; it was higher in shoulders, but pH values did not differ significantly according to different diets. The crude protein content of meat was similar in the three cuts and three diets. Fat contents and dry matter of different cuts differed significantly and shoulder portions contained higher crude protein and dry matter (3.95% and 22.61%) than other portions. The ash content was similar in different cuts and diets. The major mineral contents did not differ significantly

Key words: Carcass cuts, carcass quality, chemical composition, indigenous goat

1. Introduction

Goats play a crucial role in the rural economy of Tunisia. In South Tunisia, goat farming is predominant and goats use rangelands as main components of their diet. When resources from rangelands cannot meet the maintenance and growth requirements of goats, breeders develop several strategies to ensure the nutritional requirements of their livestock. They profit from the favorable season to establish reserves by harvesting range species as natural grass hay (GH). In summer and in drought periods, GH is a very important forage resource for small ruminants as well as equines and camels. GH is a mixture of annual and perennial species, which are always collected in the spring and stored in a closed room or in a heap in open air. The species most sought for the making of GH are *Launaea resedifolia*, *Chrysanthemum coronarium*, *Lolium multiflorum*, and *Erodium glaucophyllum* (1). Other dried resources are also commonly used, such as *Stipa tenacissima* and olive leaves. Goat meat is one of the most widely eaten red meats in the Tunisian arid lands, especially in southern Tunisia. Goat meat is one of the most important protein sources for people living in rural areas and is a high-quality protein source. It is leaner than other red meats and its fat is less saturated than that of other ruminants (2). There is a high demand for goat meat in the market due to its palatability, lower fat content, tenderness, and good flavor. In southern Tunisia, the local goat population is primarily bred for meat production, with meat of goat representing about 75% of the regional red meat consumption (3). The origin of the animals, carcass characteristics, and meat quality are important criteria for customers when it comes to making purchasing decisions (4). With the desire for leaner meat by consumers, goat meat is attractive compared to other types of red meat (5). Compared with sheep, goats deposit more internal and less subcutaneous intermuscular and intramuscular fat (6). Several studies have been carried out to characterize carcass traits of goat kids and their crossbreeds with milking breeds under intensive or semiintensive systems (3) and different diets. However, there is limited information related to carcass characteristics of indigenous goat kids with different diets and related to characteristics of different cuts in southern Tunisia. In centers for the sale of meat and abattoirs, there is not a classification system based on the joints of meat,

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the type of diet, and differences in age. In this context, this experiment was carried out to gain information about the attributes of various cuts of goat carcasses. Three cuts (leg, shoulder, and chest) were selected in this study. The objectives of this study were to determine the carcass composition and physicochemical composition of the different cuts (leg, shoulder, and chest) and to investigate the effects of local resources in arid lands on carcass characteristics of indigenous goat kids.

2. Materials and methods

The present study was conducted at the experimental station of the Arid Regions Institute (Medenine, Tunisia) situated at 33°30′N, 10°38′E and characterized by an arid bioclimatic stage with an annual average rainfall of 180 mm.

2.1. Animals and diets

Twenty-six kids of the local goat population in southern Tunisian were reared in individual pens. These animals were divided into three groups (average body weight: 15.85 kg; age: 4 months) and used over the course of 90 days. Each group was randomly assigned to one of three ad libitum alimentary treatments: the control group received oat hay (Group C), Group GH received mixed grass hay, and Group OL received *Stipa tenacissima* + dried olive leaves. In all groups, kids were supplemented with a commercial concentrate and received water twice a day. The *S. tenacissima* was hand-harvested on native rangelands from the neighboring Benikadeche Mountains (Southeast Tunisia) during the late growing period (April), air-dried, and stocked in a dry area. Grass hay was composed of 16 annual and perennial species; the specific contribution was 44% for *Launaea resedifolia,* 30% for *Lolium multiflorum*, 6.60% for *Chrysanthemum coronarium*, 4.12% for *Anacyclus cyrtolepidioides* , and other species. Dried olive leaves are supplied by neighboring private farmers.

2.2. Slaughter and sample collection

All kids were slaughtered in the morning between 0900 and 1000 hours. Before slaughter, body weights were recorded. The carcasses were stored at 4 °C for 24 h and then weighed. The tail was then removed and each carcass was split along the vertebral column midline into two halves. The left half-carcass was cut into six joints (leg, rib, anterior rib, chest, neck, and shoulder) according the procedures of Colomer-Rocher et al. (7), and every joint was weighed and dissected into fat, muscles, and bones.

After cutting, three cuts of each carcass were selected, namely those most requested by consumers. Seventy-two samples (3 cuts of each animal × 8 animals × 3 diets = 72; 24 shoulders, 24 chests, and 24 legs of kids) were dissected and 27 samples of meat (3 cuts × 3 animals of each group × 3 diets) were studied.

2.3. Physicochemical analysis of meat

The pH values were determined at room temperature (20 °C) using an inoLab pH Level 1 pH-meter (inoLab, Weilheim, Germany) after calibrating with two buffers (7.00 and 4.01); the samples (5 g each) were homogenized with 10 mL of distilled water. For chemical composition, samples of meat were chopped, homogenized, and analyzed in duplicate. According to the AOAC (8), samples of meat were dried at 105 °C in an oven for 24 h for dry matter determination. Ash was determined by incineration of 5 g of meat placed in a muffle furnace maintained at 550 °C for 6 h. The total nitrogen (N) content was determined by the micro-Kjeldahl method using a J.P. Selecta digestion unit and PRO-NITRO II distilling unit (Barcelona, Spain) according to the AOAC (8). Crude protein was calculated as N × 6.28.

Fat content was determined according to the method of Hara and Radin (9) using two solvents in a hexane/isopropanol mixture (3:2, v/v). Cooking loss was measured in the muscles of different cuts and meat samples were weighed, held in plastic bags, and then immersed in a water bath at 75 °C until the internal temperature, monitored with a thermocouple (30 min), reached 75 °C. After cooling, the sample weights were recorded again. Cooking loss was calculated using the following formula: Cooking loss % = [(weight before cooking (Wi) – weight after cooking (Wf))/weight before cooking (Wi)] × 100. Minerals were determined using an atomic absorption spectrophotometer (Shimadzu A 6800, USA).

2.4. Statistical analysis

Data were analyzed by ANOVA using SPSS 11.5 to determine the effects of diets and different cuts on the tissue composition of carcasses and the physicochemical parameters of meat. Significance of differences ($P < 0.05$) between means was determined with the Duncan test.

3. Results

3.1. Tissue composition

The tissue composition of different joints and diets is shown in Tables 1 and 2. The percentage of muscle was lower ($P < 0.001$) in the chest, while the highest percentage was observed in the shoulder. Percentage of fat was higher ($P < 0.01$) in the chest (24.74%) than in other cuts (14.41% and 13.00%, respectively, for shoulder and leg; Table 1). The percentages of muscle and bone were not affected by the diet (Table 2). The weight and the proportion of fat ($P < 0.05$) were higher in Group OL and Group GH compared to Group C (18.7% and 19.5% vs. 13.9%, respectively). The effect of diet on different cuts is shown in Table 3. The percentage of fat differed ($P < 0.05$) depending on the type of feed and the cut type. In the three cuts, the fat percentage was higher in Group GH compared to Group OL and Group C. In the leg and shoulder, percentages of

Table 1. Tissue composition of different cuts in goat carcass.

	Leg	Shoulder	Chest	SEM	P
Muscle	699.86 [a]	497.25 [b]	258.56 [c]	33.37	<0.0001
%	58.89 [a]	61.57 [a]	52.42 [b]	1.40	0.0180
Fat	153.63 [a]	115.11 [b]	123.16 [b]	5.97	0.0160
%	13.00 [b]	14.41 [b]	24.74 [a]	1.09	<0.0001
Bone	277.51 [a]	202.93 [b]	92.90 [c]	13.93	<0.0001
%	23.40 [a]	25.20 [a]	18.76 [b]	0.72	<0.0001

[a,b]Means within a row with different superscripts differ significantly; SEM, standard error of the mean; P, probability.

Table 2. Tissue composition of carcasses and proportions in three diets in southern Tunisia.

	C	OL	GH	SEM	P
Muscle	532.38	475.26	448.03	33.37	0.5876
%	61.74	56.48	54.67	1.40	0.0973
Fat	107.76 [b]	143.15 [a]	141.00 [a]	5.97	0.0203
%	13.97 [b]	18.68 [a]	19.50 [a]	1.09	0.0769
Bone	196.73	195.48	181.13	13.93	0.8849
%	22.48	22.94	21.95	0.72	0.8615

Group C, oat hay; group OL, *Stipa tenacissima* + dried olive leaves; group GH, grass hay; [a,b]means within a row with different superscripts differ significantly; SEM, standard error of the mean; P, probability.

Table 3. Effect of diet on tissue composition of different cuts of goat carcasses.

	C	OL	GH	SEM	P
Leg					
Muscle	59.24	58.00	59.45	1.63	0.9384
Fat	10.07 [b]	15.23 [a]	13.70 [ab]	0.94	0.0526
Bone	21.55	24.55	24.12	0.75	0.2186
Shoulder					
Muscle	63.06	58.87	58.34	1.15	0.1862
Fat	12.26 [b]	14.60 [ab]	15.31 [a]	0.56	0.0594
Bone	24.79	25.34	24.31	0.91	0.9085
Chest					
Muscle	56.37 [a]	51.78 [b]	50.36 [b]	1.19	0.0912
Fat	20.81 [b]	25.74 [ab]	27.20 [a]	0.79	0.0005
Bone	20.46 [a]	20.76 [a]	16.87 [b]	0.65	0.0215

Group C, oat hay; group OL, *Stipa tenacissima* + dried olive leaves; group GH, grass hay; [a,b]means within a row with different superscripts differ significantly; SEM, standard error of the mean; P, probability.

muscle and bone were not affected by the type of diet. On the other hand, the feeding affected the tissue composition in the chest, and the proportions of muscle and bone were higher in Group C in respect to the other groups.

3.2. Physicochemical properties

Physicochemical attributes such as pH, cooking loss, and nutritive value were observed and the results obtained are given in Tables 4 and 5. The mean pH values of leg, shoulder, and chest were 5.76, 5.92, and 5.91, respectively, and there were significant ($P < 0.05$) differences with different cuts (Table 4). The mean pH value of the meat was similar in the three diets (Table 5). The mean values of cooking loss in leg, shoulder, and chest were 31.99%, 30.22%, and 31.14%, respectively, which did not differ significantly between cuts. For diets, the cooking loss was also similar in the three groups, but tended to higher in Group C. Dry matter content of meat was higher in the chest (24.26%) than in other cuts (23.12% and 22.61%, respectively, for leg and shoulder), but it was comparable between diets (Table 5). Likewise, diet had no significant effect on crude protein content of meat in goats belonging to different groups and in different cuts. The fat content observed in meat was higher ($P < 0.05$) in shoulders than other cuts (Table 4) and was higher in meat from the C and OL groups (Table 5).

3.3. Mineral composition

The macrominerals analyzed were potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na). Unfortunately, iron (Fe), the most important element in goat meat, was not determined due to a technical problem. The results indicated that goat meat is rich in various major minerals. The Ca content was significantly affected by diet; it was higher in the meat of Group C (0.30% vs. 0.22% and 0.17%, respectively, for OL and GH groups). The value for potassium was the highest across all meat samples, followed by Na, Mg, and Ca (Table 4).

4. Discussion

4.1. Tissue composition

The tissue composition was significantly different between cuts. The muscle percentage was higher in shoulders. However, the percentage of fat was higher in the chest than in other cuts (Table 1). Shoulder tissue composition is a reasonable predictor of carcass tissue composition in kids (10). In some cases, slaughter weight is the main factor influencing carcass composition (11). Generally, goats have less fat content than sheep, although the extent of the difference can vary depending on the type of the fat deposit considered (12). The percentages of muscle and bone were not affected by the diet (Table 2). Since the kids were slaughtered at similar live weights, there were no significant differences in the weight and percentage of the tissue composition that were closely related to body weight (11). The weight and the proportion of fat were higher in the group that received the pastoral diet. These results are contrary to those found by Priolo et al. (13), who showed that animals that grazed on grass had more muscle than those that received concentrate and oat hay. Murray and Slezacek (14) showed that in lambs, at the same dissected side weight, the amount of muscle, bone, and total fat was similar for three different feeding levels. Burton and Reid (15) found that sheep body composition was not related to

Table 4. Chemical composition of meat in different cuts.

	Leg	Shoulder	Chest	SEM	P
pH	5.76 ^{b}	5.92 ^{a}	5.91 ^{a}	0.02	<0.0001
Cooking loss	31.99 ^{b}	30.22 ^{b}	33.14 ^{a}	0.56	0.042
Dry matter	23.12 ^{ab}	22.61 ^{b}	24.26 ^{a}	0.26	0.012
Ash	4.79	4.70	4.98	0.20	0.818
Crude protein	20.19	21.36	20.20	0.80	0.258
Fat	2.18 ^{b}	3.95 ^{a}	2.29 ^{b}	0.14	0.042
K	9.37	8.95	7.60	1.25	0.659
Ca	0.24	0.18	0.28	0.17	0.358
Mg	0.87	0.73	0.65	0.31	0.528
Na	3.17	2.96	3.26	0.12	0.425

Ca, Calcium; K, potassium; Mg, magnesium, Na, sodium; ^{a,b}means within a row with different superscripts differ significantly; SEM: standard error of the mean; P, probability.

Table 5 . Chemical composition of meat in different diets.

	C	OL	GH	SEM	P
pH	5.86	5.9	5.91	0.42	0.376
Cooking loss	33.36	31.37	30.38	0.92	0.835
Dry matter	22.78	23.92	23.44	0.76	0.191
Ash	4.78	5.07	4.59	0.24	0.623
Crude protein	20.19	21.37	20.20	0.47	0.312
Fat	2.28 [a]	2.52 [a]	1.70 [b]	0.15	0.034
K	7.42 [b]	9.05 [a]	9.09 [a]	0.89	0.012
Ca	0.30 [a]	0.22 [ab]	0.17 [b]	0.10	0.042
Mg	0.60	0.81	0.76	0.22	0.332
Na	2.69	3.55	3.07	0.19	0.257

Group C, oat hay; group OL, *Stipa tenacissima* + dried olive leaves; group GH, grass hay; Ca, calcium; K, potassium; Mg, magnesium, Na, sodium; [a,b]means within a row with different superscripts differ significantly; SEM: standard error of the mean; P, probability.

prior energy intake but was chiefly associated with body weight. Similarly, carcass composition is said to be weight-dependent and largely uninfluenced by age or nutritional regime (16).

In the leg and shoulder, percentages of muscle and bone were not affected by the type of diet (Table 3). The shoulder and leg are known to have the highest proportion of muscle. As observed in the present study, in Group GH, the values were higher in the leg compared to the shoulder (three to four points more); however, in Group C, the proportions of muscle were slightly higher in the shoulder. The percentage of muscle in the shoulder and leg was similar in Group OL compared to the other groups. The higher muscle percentage recorded for the leg and the shoulder could be due to their lower fat content (10%–15%); inversely, for the chest, the percentage of muscle was lower. Similar conclusions were reported by Abdullah et al. (17). The description of the meat potential can be done via the muscle/bone ratio. In many countries, muscle and not fat is the most important carcass tissue to the consumer, while fat is related to health problems mainly in developed societies. In Tunisia, as in other tropical regions, the bone part is considered as a negative aspect, and lack of muscularity seems to characterize the local breeds, which are poorly rated due to their small frame. However, the muscle/bone ratio is a trait particularly relevant for the local male goats, which attained the upper range of goat values of the literature (17).

4.2. Physicochemical properties

The mean pH value of the meat was similar in the three diets. This result was similar to the pH value of incised muscles being 5.65 at 6 h after slaughtering at ambient temperature, with a gradual decline in pH observed up to 48 h after slaughtering (18). The pH of the leg is closest to the ultimate pH of 5.5 and must not exceed 6. The leg rate has more importance than the shoulder and chest rate of glycogenolysis. These results are in agreement with those reported by Ben Lassoued (19), who found that the thigh had the lowest pH values in sheep meat from the race Barbarine, while sheep of the coastal region had the highest values. Values in our study are slightly higher than those (5.69 and 5.65) found by Islam et al. (20) for the shoulders and legs of goats in Korea. The change in pH levels is not homogeneous in the carcass: they differ from one muscle to another or even from one location to another in the same muscle. These variations between species and muscles are related to the metabolic type of muscle fibers (21). The ultimate pH value reached 5.80 ± 0.2 after maturation in the shoulder, while it was 5.71 for the leg and 5.59 for rib meat.

The cooking loss in the leg, shoulder, and chest was not affected by the type of cut. Cooking loss, which is one of the meat quality parameters, refers to the reduction in weight of meat during the cooking process (22). The percentage of cooking loss generally varies in the range of 18% to 34% as reported by Dhanda et al. (23). Values found in the present study were in range (33%–41%) reported by Kadim et al. (24) and higher than that (14%–17%) reported by Tadora et al. (25). Various factors affecting cooking loss include water-holding capacity, fat content, time and temperature of cooking meat, the final pH of the muscle used, and the type of animal (24).

Dry matter content of the meat was comparable between diet systems (Table 5), and this was in agreement with the results found by Dhanda et al. (23). The fat content observed in meat of goats was not above 3% in different cuts and with different diets. The very low fat content, which is widely recognized in goat meat, leads to higher quality than that of sheep or cattle meat (26). These results are comparable to that found for lambs, whose fat content varied from 2% to 5% for the leg and 6% to 9% for the chop and shoulder (21). Kids are more often selected for health-conscious consumers due to their low fat content compared to other traditional red meats such as lamb and beef.

4.2. Mineral composition

The results indicate that goat meat is rich in various major minerals. Potassium had the highest values across all the meat samples. The results of mineral content analysis in Tables 4 and 5 also reveal that goat meat can be regarded as a good source of calcium, important for preventing iron-deficiency anemia, as well as for bone development, secretory functions, buffers, and certain coenzymes (27). The analysis also indicated that goat meat is a good source of magnesium (average: 0.82%), which is necessary for many essential biochemical reactions. These values were comparable to the results obtained by Sheridan et al. (28) for different goat breeds.

The contents of major minerals were similar in different cuts. Similar to other livestock species reared for meat production, the major mineral in goat muscle is potassium. These results are in accordance with the findings obtained by Casey (29). The mean potassium content was 7.69%, 8.95%, and 9.37%, respectively, for the chest, shoulder, and leg. Calcium content was 0.18%, 0.24%, and 0.28%, respectively, for the shoulder, leg, and chest. These values are higher than those mentioned (0.04% and 0.03%) by Islam et al. (20) for the shoulders and the legs of Korean kids. The magnesium content was 0.65%, 0.73%, and 0.87%, respectively, for the chest, shoulder, and leg. In addition, it is worth mentioning that, comparing the nutritive value of cooked goat meat to that of beef, it was reported that goat meat has lower fat and sodium contents, similar protein and iron, and higher calcium, magnesium, and potassium (30); this further lends support to the view that goat meat offers an attractive alternative to other types of red meat.

In the present study, it is concluded that the leg and shoulder have higher percentages of muscle and are low in fat, but diet did not affect the tissue composition. The dry matter content was significantly higher in the chest, and the fat content was higher in the shoulder. It can be concluded that there was little difference in the nutrient content of different cuts of carcasses and diets, particularly in fat content.

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