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The effect of replacing soybean meal with Fava bean seeds in daily ration of Lebanese Baladi goat kids and Awassi sheep lambs: 2- Meat quality

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Abstract— *The objective of this study was the physical characterization of the qualitative traits of meat acquired from different small ruminant species. Local Baladi goat male kids and Awassi male lambs fed basal commercial ration supplemented with different proportions of fava bean seeds (FBS) and soybean meal (SBM). Upon reaching about 7 months of age the experimental animals were slaughtered and samples of muscle tissue were collected to be analyzed. Definitely, meat samples were exposed to evaluations of the physical parameters, including pH, color, water retention and meat texture. Physical quality of meat did not differ much among groups. pH indicator after 7 days of freezing was more acidic for both types of meat. Nevertheless, goat meat was more consistent in being more acidic than mutton calibrating from 6.22 as in GC0 group to 6.29 in G25 (P>0.05). Moreover, if to compare meat obtained from animals fed 25% FBS in daily ration we notice less acidity than other groups attaining the levels of 6.37 and 6.29 in groups S25 and G25, respectively (P>0.05). It shows that after cooling results of L* are higher than those obtained after freezing in all animal-groups of both sheep and goats. Lighter in color meat L* on 0-100 scale was scored in groups consuming the highest proportion of SBM: GC0, SC0, G25 and S25s, where it attained the levels of 54.90, 54.54, 54.41 and 55.64, respectively. The highest redness (a*) of goat meat was achieved in GC0- animal group whose kids were fed rations with 100 % SBM attaining the level of 21.09 (P>0.05) in comparison with all other groups. Although redness in G100 was the lowest (7.75) before freezing, we notice that after freezing this indicator was the highest in this group (13.08) when compared with all experimental animal groups (P>0.05): GC0 (11.20), G75 (8.89), G50 (7.46) and G25 (6.89) in the results obtained for after freezing in animal group. Better results for redness (a*) were achieved in animal groups GC0 (100 % SBM) before freezing at 24 h post-mortem and SCO (100 % FBS) after 7 days of freezing in meat of goat and sheep as well, attaining 21.09, 20.75, 13.08 and 13.91, respectively (P>0.05). In comparing the data obtained yellowness (b*) between goat and sheep meat before and after freezing shows that the highest level of b* was achieved in goat meat in group G75 before (19.08) and after (16.31) freezing (P>0.05) and GC0 (11) after freezing (P<0.05). Even though yellowness before freezing was high in both species it was observed that this indicator decreases after freezing on much higher rates in mutton than goat meat (P>0.05). It is worthy to mention that SC0 and GC0 attained statistically significant (P<0.05) higher level of drip loss in meat water after 24 h of cooling in comparison with all animal groups except S25 and G25 where this decrease was insignificant (P>0.05). Thawing loss (%) in sheep was higher than that obtained in goat meat when comparing each two different animal groups fed with the same ingredients as in S25 and G25, S50 and G50, S75 and G75 and S100 and G100, SC0 and GC0 (P>0.05). The highest values (P>0.05) were in groups SC0 (12.21 %) and GC0*

(10.93 %) and the lowest in S25 (7.22 %) and G25 (5.80 %). The least cooking losses in water was registered in S50, S25, S100, S75 and SC0 losing weight after cooking averaging to 26.18% Vs 11.09%, 27.54 Vs 11.96, 28.25 Vs 12.28, 32.47 Vs 14.27 and 33.15 Vs 13.09% in both conditions, 24 h Vs 7 days, respectively (P<0.05). The lowest level (6.90 mm) of tenderness of goat meat was noticed in group G50 (P>0.05) after cooking after 7 days of freezing whose animals were fed rations containing equal proportions of SBM: FBS (50: 50) next to G75 (7.14 mm), G100 (7.40 mm) and GC0 (7.45 mm). Whereas this trait after 24 h for sheep the lowest was obtained in group SC0 (2.06 mm) in comparison with all other groups, S100, S50, S25 and S75 attaining the levels of 2.08, 2.36, 2.47 and 2.87 mm, respectively (P>0.05). Note that all levels obtained in all goat groups after cooking after 7 of freezing days were significantly higher (P<0.05) meaning tender than those from sheep meat after freezing and 24 h of cooling in groups S25 (3.51 mm), S50 (2.50 mm), S75 (5.47 mm), S100 (4.27 mm) and SC0 (2.59).

Keywords— ***Soybean meal, fava bean seeds, Awassi lambs, goat kids, physical quality of meat.***

I. INTRODUCTION

The need for alternative protein sources to soybean meal (SBM) in domestic animal feeding has recently gained focus. The main reasons include the attempt to limit SBM import from extra-EU Countries, which represents a negative voice of the commercial balance. An effort to decrease costs of animal production and contemporarily reduce the loss of N-compounds in the environment and the search to prevent the presence of GMO (Genetically modified foods) in the food chain (Wilkins and Jones, 2000; Mordenti and De Castro, 2005; Formigoni *et al.*, 2007). Among the possible protein sources, lupins, peas and fava beans *(Vicia fava L.)* were successfully used in ruminants and nonruminants (Burel *et al.,* 2000; Bonomi, 2005; Moschini *et al.,* 2005; Masoero *et al.*, 2006; Vandoni *et al.,* 2007; Keller *et al.*, 2021). Demand for pulses for stock feed both locally and in export markets is likely to have a major influence on prices. Pulses are valuable stock feeds because of their high protein levels and palatability (Henchion *et al.*, 2017). They can be used as part of intensive livestock rations or as supplements for stall reared stock. In some countries lupines are generally the preferred pulse for sheep and cattle because of their higher protein, higher fiber and lower starch levels, but peas and fava beans (FBS) are also useful and are commonly used overseas (Zagorakis *et al.*, 2018a). Pulses are used in intensive rations to provide energy and essential amino acids for growth (Beigh *et al.,* 2017; Poutanen *et al.,* 2022).

Small ruminant's production contributes to the livelihoods of a large number of farmers and accounts for 28-58 % of agricultural output in the Middle East (Iniguez, 2005). In Lebanon small farmers in marginal lands, where milk constitute an important source of income (Hosri and El khoury, 2004; De Rancourt *et al*., 2006; Hosri *et al*., 2016), mainly conduct it. Awassi lamb-fattening and goat-fattening systems in Middle Eastern countries are popular because they can rapidly generate income. Nevertheless, feed costs constraining these systems and seasonal fluctuations in feed prices expose farmers to risk. Despite the important relative size of the small ruminant's flock in Lebanon (330000 head of sheep and 450000 head of goats (FAO, 2010), the sector is facing many difficulties.

The outbreak of BSE in the 1990s caused proteins of animal product to be banned as feed, but now it will be permitted for non-ruminants (Minchin, 2021). A large integrated Project called "Grain Legumes" is combining the efforts of scientists from 18 countries in order to make legume crops more competitive for European agriculture, using the latest progress in genomics and ranging from plant improvement and crop management to feed processing. Existing protein sources are primarily hindered by their negative environmental impacts with some concerns around health. However, they offer social and economic benefits, and have a high level of consumer acceptance (Henchion *et al.*, 2017; Małecki *et al.*, 2021)

Duc (1997), Haciseferogullari *et al.* (2003), Hossain and Mortuza (2006), Crepon *et al.* (2010), Yah Konfor (2013) and Mayer Labba *et al.* (2021) published that the nutritional value of fava bean has always been traditionally attributed to its high protein content, which ranges from 27 to 34% depending on genotypes, Oil, 1.2 g; Crude Fiber, 5.1 g; Starch, 51 %; Sugars, 5 %; Iron, 4.2 mg; Thiamin, 0.45 mg; Riboflavin, 0.19 mg; Niacin, 2.4 mg; Energy, 328 kcal. Most of these proteins comprise of globulins (79%), albumins (7%) and glutelins (6%). In addition, Berrazaga *et al.* (2019) found that the nutritional value of fava bean was 87 and 31% for DM and CP, respectively. Legume seeds contain several comparatively minor proteins including trypsin inhibitors, lectins, lipoxygenase and urease, which are relevant to the nutritional quality of the seed (Bartsch and Valentine, 1986; Halmemies-Beauchet-Filleau *et al*., 2018).

Hanbury *et al.* (2000), Yin *et al.* (2011), Watson *et al.* (2017), Yaacoub and AlJammal (2018), Yaacoub *et al*. (2018), Halmemies-Beauchet-Filleau *et al.* (2018),

Lestingi *et al.* (2019), Ibáñez *et al.* (2020) and Parisi *et al.* (2020) reported that, to reduce reliance on imported soybean meal (SBM) in temperate environments, fava bean might be alternative protein sources for small ruminant diets. Surra *et al.* (1992), El Maadoudi (2004), Delmotte and Rampanelli (2006) noted that Fava bean is highly palatable for lambs, which prefer it to barley. In lambs, including fava beans up to 50% in the diet did not affect meat quality when compared to soybean meal (Antongiovanni *et al.*, 2002; Lanza *et al.*, 2007; Emiola and Gous, 2011). Mullan (2001), FAO (2002), Connell *et al.* (2004), Mukherjee *et al.* (2016), Sedláková *et al.* (2016), Addisu (2016), Shi *et al.* (2017), Naumann *et al.* (2017), Choi *et al.* (2019), Samtiya *et al.* (2020), Te Pas *et al.* (2021), Mazumder *et al.* (2021), Mayer Labba *et al.* (2021) and Landi *et al.* (2021) stated that bean, chickpeas and lupine cultivars grown in most countries of the World tend to have now low tannin, vicine and covicine in their seed coats. Cerioli *et al.* (1998) and Shi *et al.* (2017) concluded that the bean has a lower content of trypsin inhibitors than the soybean and no urease activity but contains more tannins. Aplocina and Veipa (2015) reported that fava beans could be used in dairy rations at inclusion levels of up to 35%.

To our knowledge, the present study is among the firsts to focus on the effect of feeding FBS (fava beans) on physical quality in Lebanese local *"Baladi"* goat and Awassi sheep breeds in fattening production. Therefore, data on the effect of FBS on meat quality of locally reared small ruminants are scarce.

The aim of our experiment was to evaluate the influence of replacing totally or partially soybean meal with fava beans in rations fed to weaned lambs and kids of local Awassi sheep and local goat breeds (*Baladi*) on some physical traits of meat.

II. METHODOLOGY

This experiment was implemented on two commercial farms situated in different districts of Lebanon (Bekaa for sheep and Akkar for goats). No big differences in ambient temperature and relative humidity between the two locations was registered.The nimals were controlled in agreement with the national legislation on animal welfare (Council Directive, 2008/119/EC) and slaughtered in amenability with the European Council Regulation No 1099/2009 (Council Regulation, EC, 2009).

In this experiment were randomely selected and used fifteen male Awassi lambs (S) and fifteen male Baladi goat kids (G) at about 100 days of age. Until the time of slaughter, every three animals were housed in seperated sheds equipped with collective drinking and feeding troughs. Concerning the experimental rations, every day each animal group fed a combination (1: 1) of alfalfa hay and wheat straw *ad libitum* with no more than 1 kg/head/day (depending on live body weight at the beginning of each week of the experiment) of a concentrate mix whose structure is reported in Table 1.

At the beginning of the trial and with the initiation of the preparatory period, (2 weeks) animals were dipped and treated for all kinds of helmentic worms. Besides, they were ear tagged and vaccinated against Anthrax and FMD; Albendazole was administered with drinking water as prevention for digestive tract parasites. Veterinary inspection was repeated every week where intramuscular injections of multivitamin dozes (A, D & E) were administered. The animals were in good health (veterinary examination).

Refused feeds (what was left behind in the feeding troughs) from each pen if existeded were collected, weighed and recorded each week in the morning before the start of group feeding. The trial proceeded for 8 weeks (collection of samples for analyses).

Table 1. Experimental concentrate-rations composition (percentage as fed basis) fed to lambs and kids

Animal groups	[1]S25/G25	[2]S50/G50	[3]S75/G75	[4]S100/G100	[5]SC0/GC0 (Control)
Ingredients	75% SBM+ 25% FBS	50% SBM+ 50% FBS	25% SBM+ 75% FBS	100% FBS+ 0% SBM	100% SBM+ 0% FBS
SBM	11.1	7.4	3.7	0.0	14.8
CSM	7.4	10.0	13.0	15.8	5.1
FBS	3.7	7.4	11.1	14.8	0.0
Wheat bran	16.0	15.0	12.7	12.3	14.7
corn	61.7	60.1	59.4	57.1	65.4

Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
CP	**17.9**	**18.0**	**17.9**	**17.9**	**18.0**
ME Mcal/kg	**2.85**	**2.52**	**2.94**	**2.28**	**2.96**

[1]Experimental groups - S25 (Sheep) & G25 (Goat) where FBS partially replaceing 25% of the SBM is added to the basal ration (25% FBS: 75% SBM). [2]Experimental groups - S50 (Sheep) & G50 (Goat) where FBS partially replacing 50% of the SBM is added to the basal ration (50% FBS: 50% SBM).[3]Experimental groups - S75 (Sheep) & G75 (Goat) where FBS partially replacing 75% of the SBM is added to the basal ration (75% FBS: 25% SBM). [4]Experimental groups - S100 (Sheep) & G100 (Goat) where FBS totally replacing 100% of the SBM is added to the basal ration (100% FBS: 0% SBM). [5]Experimental control groups - SC0 (Sheep) & GC0 (Goat) where this control ration was composed of 100 % SBM and no inclusion of FBS supplementing the basal ration (0% FBS: 100% SBM). In addition, this ration represents commercial feeding in fattening lambs and kids used at the Lebanese farms following the indoor keeping system.

All rations were isocaloric (2.9 Kcal/kg ME) and adjusted to the same level of crude protein (17%) as recommended by NRC (1989) and based on cotton seed meal (CSM), wheat bran and corn, fed continuously with different levels of Soybean meal (SBM) : Dry milled Fava bean seeds (FBS) for the whole experimental period.

Physical analysis of meat quality

At about 7 months of age, the experimental animals were managed in a commercial slaughterhouse. All internal organs were inspected by veterinary specialists to inspect (if any) any symptoms of illness or malnutrition. Each carcass was divided in half covered with a film during storage and conserved at a controlled temperature of 4°C. Samples of muscle tissue were taken immediately *postmortem* from the *longissimus dorsi* between the 12th and 13th ribs from the left side of the carcasses were collected after skinning and eviscerating and packed after immediate weighing by 100g in 2 polyethylene sheets. One of the two sheets was stored in refrigerators for 24 hours of cooling at 4°C - 5°C while the other polyethylene sheet was stored below -27ºC to freeze for 7 days.

Evaluation of pH, color and meat tenderness

At 24h (hours) *postmortem* and 7 days of freezing muscle slices of 2 g each were removed from each polyethylene envelop and immediately homogenized in 18 ml of 5 mM iodoacetate buffer (Jeacocke, 1977). The pH of the homogenate was measured using a portable pH meter (HI 8424 Microprocessor pH Meter, HANNA Instruments, Woonsocket, RI.) equipped with a combined electrode.

There are many options available for instrumental color analysis, however; according to Stevenson *et al.* (1991), the CIELab color space (Robertson, 1977), expressing color by the coordinates L*, a* and b*, are appropriate color measures. Lightness in meat color is represented by L* on a scale from 0 to 100, where 100 corresponds to pure white and 0 corresponds to pure black. A negative a* value indicates greenness and a positive a* value represents redness. A positive b* value indicates yellowness, while a negative b* value corresponds with blueness. At 24 hours, *postmortem* of cooling and 7 days of freezing, meat color was determined using a chromameter (ADCI - 60 - C). The instrument was set to measure using the CIE system (International Commission on Illumination; abbreviated CIE for its French name) values of luminance (L*), redness (a*), and yellowness (b*) using illuminate D and 65° standard observer (Robertson, 1977). All measurements (3 replicates on each 3-cm thick muscle slices) were carried out on the surface of the left muscle slice, in an area free of obvious color defects (over scalding, blood spots, and hemorrhages) using a Chromometer (ADCI-60-C; Beijing Chentaike Instrument Technology, CO, LTD) calibrated to a standard white tile.

Cooked meat tenderness was measured using a penetrometer (interface RS232C) with a needle of 2.5g on a weight of 47.5 g, thus attaining a total weight of 50 g. The penetration was carried out on meat slices (3 x 2 x 1 cm) prepared in a way the longest dimension was parallel to the fiber axis. The slices were placed on a horizontal support and a force of the needle was applied perpendicularly to the muscle fibers for 5 seconds (Becila, 2002). The penetrometer needle depth (PND), mm) was recorded (in mm) and calculated as the average of 3 replications of each sample. The procedure was conducted on cooked meat after 24 hours of cooling and after cooking after 7 days of freezing.

Drip loss (DL, %), Thawing loss (TL, %) and cooking loss (CL, %)

Drip loss was determined by the method of Offer and Knight (1988). Left raw muscle slices were weighed after cooling at 24 hours post-mortem, placed in a polystyrene

tray, wrapped in an oxygen permeable film and kept at 5-7°C for the 2nd day. Slices were reweighed at 48 hours *postmortem* and the drip loss was expressed as percentage of initial weight. After 12 hours thawing in a refrigerator at 5-7°C, Muscle slices were taken from bags, dried with filter paper, and reweighed before cooking. Thawing loss was expressed as a percentage of the frozen weight (Honikel, 1998). Cooking loss was determined immediately after cooling and thawing in meat samples vacuum packed in polyethylene bags and cooked in a water bath at 80°C for 15 minutes (corresponding to an internal temperature of 70°C (Honikel, 1998). Care was taken to ensure that all samples were of similar dimensions. Samples were chilled for 45 minutes under running tap water at room temperature. After that, they were taken from the bags, dried with filter paper and weighed. Cooking loss was expressed as the percentage loss relative to the weight immediately before cooking. Cooking loss was determined by weighing a 1.0- 1.5 cm thick sample and placing the raw meat in a plastic bag in a pre-heated water bath (80°C) for 1h (Cloete *et al*., 2005). The cooked meat sample was removed after 1h from the water bath and placed in a cooler for 24h at 4°C. Samples were blotted with tissue paper to remove the excess water before the final weight was recorded. The weight loss of each sample was expressed as a %-age of the initial weight of the raw sample.

Statistical analysis

Data were analyzed using the analysis of variance (ANOVA) procedure (Statistica, 2020). The experimental design was a randomized block design, with three replicates per treatment (3 x 5). Analysis of variance techniques were used to assess the statistical significance ($P<0.05$) of treatment effects. Feed intake (FI) and food conversion ratios (FCR) in each animal group were analyzed as apparent feed intake (aFI/head) and apparent feed conversion ratio (aFCR/head). Interaction and comparison among means was tested using the All-Pair wise Multiple Comparison Procedures (Bonferroni test method) at a level of 5% significance. Mean ± SD (Mean values of the traits ± Standard Deviation) is used in all obtained statistical studies.

III. RESULTS

Physical properties of goat and lamb meat

pH indicator

The comparison performed in pH indicator of meat between goat and lamb muscle tissue samples (Fig. 1) did not highlight significant differences ($P>0.05$) regarding pH level after 24h *postmortem* and 7 days of freezing in both types of meat. Nevertheless goat meat was more consistent in being more acidic than mutton calibrating from 6.22 as in GC0 group to 6.29 ($P>0.05$). Moreover if to compare meat obtained from animals fed 25% FBS in daily ration we notice less acidity than other groups attaining the levels of 6.37 and 6.29 in groups S25 and G25, respectively ($P>0.05$).

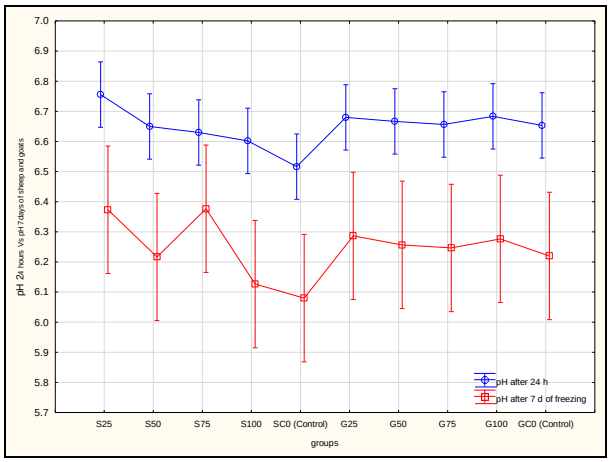

Fig.1. pH indicators after 24 hours postmortem Vs. 7 days of freezing among all groups of mutton and goat meat

Color

The characteristic color is a function of two factors: the meat pigments and the light-scattering properties (Miller, 1994; Gómez *et al*., 2019).

Luminosity (L)

Figure 2 shows the results obtained after testing Luminosity (L) using the Chromometer of goat meat before and after 7 days of freezing. It was noticed that there is no significant differences before ($P>0.05$) or after ($P>0.05$) freezing in goat meat among all samples in all animal groups. Nevertheless, it is worthy to mention that raw meat samples taken from the loin eye of animals of G100 animal group were lighter in color (51.03) on 0 – 100 scale measurement followed by G75 (50.67). Data in figure 2 shows that after cooling results of L* are higher than those obtained after freezing in all animal-groups of both sheep and goats. Lighter in color meat L* on 0-100 scale was scored in groups consuming the highest proportion of SBM: GC0, SC0, G25 and S25s, where it attained the levels of 54.90, 54.54, 54.41 and 55.64, respectively. Even though meat quality was darker at 24 h *postmortem* in all animal groups of both species if compared to that data achieved after freezing, we notice that the lowest levels (darkest color of meat) were attained in sheep in group S25 (40.34) whereas the lightest (lighter color of meat) scores was obtained ($P<0.05$) in G100 (51.02) and G75 (50.67).

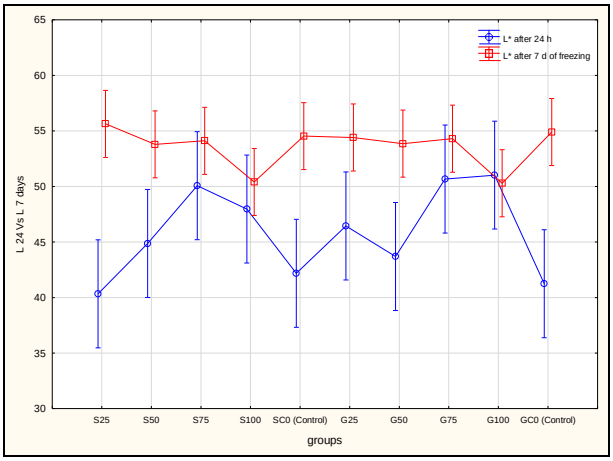

Fig.2. Comparison of luminosity L between Goat and sheep Meat.*

Data obtained from figure 2 on raw goat meat before freezing at 24 h post-mortem shows that as the %age of SBM increases in rations as in G50- 50 % SBM, G75- 75% SBM and GC0- 100% SBM) meat color (L) becomes relatively darker (P>0.05). In contrast to what was observed in before freezing, the after freezing Chromometer tests show that as the %age of SBM increases in rations, lighter (L) in color meat was obtained. The highest score was observed in group GC0 attaining the level (P>0.05) of 54.9 (100 % SBM) Vs G100 with 50.29 (100 % FBS). Moreover Figure 2 shows that raw meat before freezing taken from animal-groups fed SC0 ration containing 100 % SBM followed by S25 with 75 % SBM : 25 % FBS were insignificantly (P>0.05) darker than S50 (44.88), S75 (50.07, P<0.05) and S100 (47.97). Even though this tendency was seen in after freezing results it was statistically insignificant (P>0.05). The highest scores were attained in groups S25 (55.64) and SC0 (54.54) and GC0 (55.1).

Redness (a)

Statistically non-significant results are shown in Figure 3 in measuring the redness of goat meat before freezing. The highest redness (a*) of goat meat was achieved in GC0-animal group whose kids were fed rations with 100 % SBM attaining the level of 21.09 (P>0.05) in comparison with all other groups. Although redness in G100 was the lowest (7.75) before freezing, we notice that after freezing this indicator was the highest in this group (13.08) when compared with all experimental animal groups (P>0.05): GC0 (11.20), G75 (8.89), G50 (7.46) and G25 (6.89) in the results obtained for after freezing in animal group.

Note that there is a tendency of reducing the red color of goat meat after freezing as the concentration (%) of SBM increases in the ration to attain the highest level in group G100 with 0 % SBM.

Figure 3 shows the results obtained after testing for sheep meat redness (a*). The same tendency in this trait was shown also in sheep meat (mutton) after freezing revealing the fact that as %age (%) of FBS portion increases in rations fed to Awassi lambs redness goes up attaining the highest score (13.91) in group S100 whose animals were fed 100 % FBS in concentrate mixture followed by S75, S50 and S25 reaching 7.96, 7.21 and 6.74, respectively (P<0.05). The results obtained before freezing shows a highest level in SC0 whose animals were fed 100 % SBM in daily concentrate mix in comparison with all other groups (P>0.05).

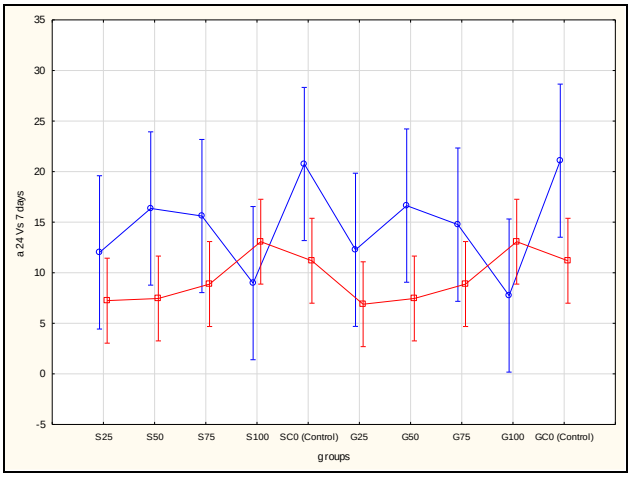

Fig.3. Comparison of redness (a) between Goat and sheep meat before and after freezing*

Meat quality as seen in figure 3 shows that better results for redness (a*) were achieved in animal groups GC0 (100 % SBM) before freezing at 24 h *postmortem* and SCO (100 % FBS) after 7 days of freezing in meat of goat and sheep as well, attaining 21.09, 20.75, 13.08 and 13.91, respectively (P>0.05).

It seems as proposed by Kerry *et al.* (2000) and Lawrie (1998) that the oxygenation of myoglobin, when meat is exposed to air, is responsible for the bright red color of lamb meat. The concentration of hemo-proteins such as hemoglobin, myoglobin and cytochrome C, their chemical states, the type of myoglobin present and the light scattering properties of meat are all factors influencing meat color.

Yellowness (b)

Figure 4 shows the results of Chromometer on yellowness of goat meat achieved before and after freezing. The color indicator b* was higher before freezing in G75 (19.07) animal group fed 25 % SBM: 75 % FBS in daily concentrate mix than all other groups G100 (17.77), G50 (15.15), GC0 (13.16) and G25 (12.44) whose animals were fed with daily rations 100 % FBS, 50% SBM: 50 % FBS,

100 % SBM and 75 % SBM: 25 % FBS, respectively (P>0.05).

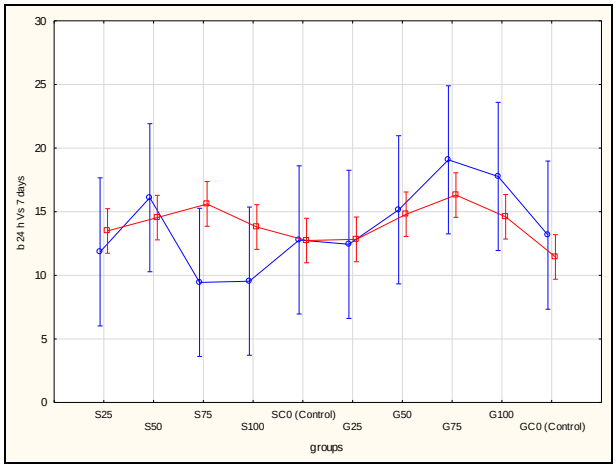

Fig.4. Comparison of yellowness (b) between goat and sheep meat before and after cooking*

Results of group G75 before and after freezing and S75 after 7 days of freezing reveal the fact that meat originating from animals fed 25 % SBM: 75 % FBS contains more fat than other groups fed different proportions of SBM: FBS. The highest level (P>0.05) of yellowness after 7 days of freezing was obtained in mutton of group S75 (15.61) whereas the lowest level was in group SC0 (12.73). This illustrates the fact that feeding 100 % SBM with rations as in group SC0 results in less fat in meat than other groups like in S75. Despite the fact that the level of yellowness (b*) indicating stored tissue fat was decreased as shown in S75 (P>0.05) after freezing, we notice that this indicator was pertained in group SC0 in after freezing (12.78) as it was at 24 h of cooling. It is worthy to mention that the lowest level (P>0.05) of yellowness before freezing in sheep meat was obtained in group S75 (9.44) and S100 (9.54) where animals were fed rations containing 75 % and 100 % FBS respectively.

In comparing the data obtained yellowness (b*) between goat and sheep meat before and after freezing shows that the highest level of b* was achieved in goat meat in group G75 before (19.08) and after (16.31) freezing (P>0.05) and GC0 (11) after freezing (P<0.05).

Even though yellowness before freezing was high in both species it was observed that this indicator decreases after freezing on much higher rates in mutton than goat meat (P>0.05).

Meat Tenderness

Juiciness is related to the water-holding capacity (WHC) and fat content of the meat. Dry meat is undesirable and excessive drip and exudation is a specific quality defect. Because, meat is sold by weight, drip loss must be minimized for economic reason. Meat from females is juicier than that of males, and meat from lambs slaughtered at medium weights is juicier than that of lambs slaughtered at lighter weights (Miller, 1994; Varnam and Sutherland, 1995; Vergara *et al.*, 1999).

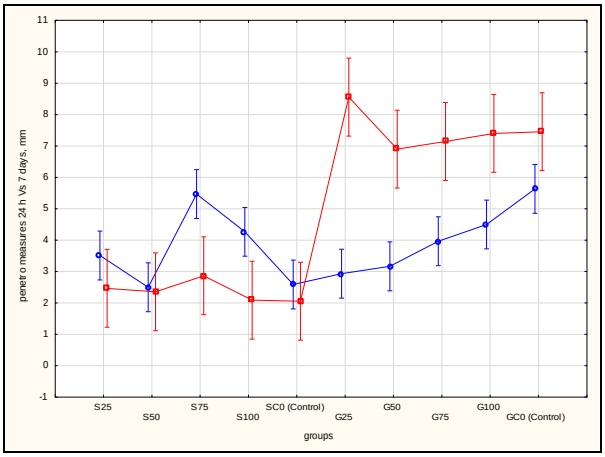

Fig.5. Comparison in penetration force between goat and sheep meat (mm)

Figure 5 shows that at 24 h *postmortem* meat after cooking attained lower level of tenderness (Penetrometer) than those obtained after 7 days of freezing. It was observed that in group G25 the penetration level of the needle after cooking attained the lowest level among the five goat groups (2.93 mm) and attaining the highest (8.56 mm) after thawing and cooking after 7 days of freezing (P<0.05). The lowest level (6.90 mm) of tenderness of goat meat was noticed in group G50 (P>0.05) after cooking after 7 days of freezing whose animals were fed rations containing equal proportions of SBM: FBS (50: 50) next to G75 (7.14 mm), G100 (7.40 mm) and GC0 (7.45 mm). Whereas this trait after 24 h for sheep the lowest was obtained in group SC0 (2.06 mm) in comparison with all other groups, S100, S50, S25 and S75 attaining the levels of 2.08, 2.36, 2.47 and 2.87 mm, respectively (P>0.05). It was noticed that as the amount of milled SBM increases in ration fed to sheep groups as in SC0 penetration level decreases attaining the lowest score after cooking in both refrigerating conditions, 24 h Vs 7 days (P>0.05).

Comparing the obtained results between goat and sheep meat as shown in Figure 5 we conclude that penetration force of cooked goat meat Vs cooked sheep meat before and after freezing was higher in all animal groups revealing more tenderness of goat meat.

Drip loss

Figure 6 shows the variations in the drip loss (DP, %) after 24 hours of refrigerating at 7° C between all animal groups of both sheep and goat meat. As it is observed from fig. 6

that the largest water loss was realized in both groups SC0 and GC0 fed daily rations containing no FBS, averaging to 22.69 and 24.27 %, respectively (P>0.05). The lowest losses was achieved in all groups containing different proportions of FBS: SBM as in S25, S50, S75, S100, G25, G50, G75 and G100 averaging to 9.15%, 12.80, 12.97, 13.05, 17.11, 13.57, 13.69 and 13.68, respectively (P>0.05).

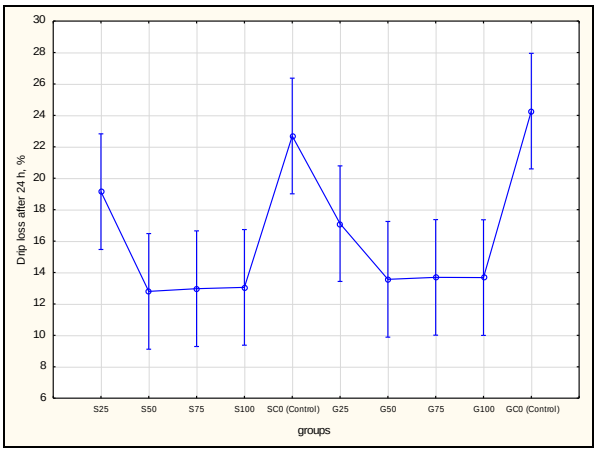

Fig.6. Variations in the drip loss (DL, %) after 24 hours of cooling between sheep and goat meat.

It is worthy to mention that SC0 and GC0 attained statistically significant (P<0.05) higher level of drip loss in meat water after 24 h of cooling in comparison with all animal groups except S25 and G25 where this decrease was insignificant (P>0.05).

Thawing Loss

Lawrie (1998) reported that water is generally held between the thin filaments of actin/tropomyosin and the thick myosin filament within muscles. He added that water can be either 'bound' or 'free' in muscles and a total of 75% of muscles are composed of water.

Figure 7 shows that as FBS proportion in rations fed to goat kids increases thawing loss increases, attaining the highest level 10.93 % in the 100 % SBM: 0 % FBS diet such as in group GC0. Despite the fact that neither G25 nor GC0 were significantly different with the results obtained in G25, G50, G75 and G100 (P>0.05) we observed that the difference between G25 (5.8 %) and SC0 (12.21%) was statistically significant (P<0.05).

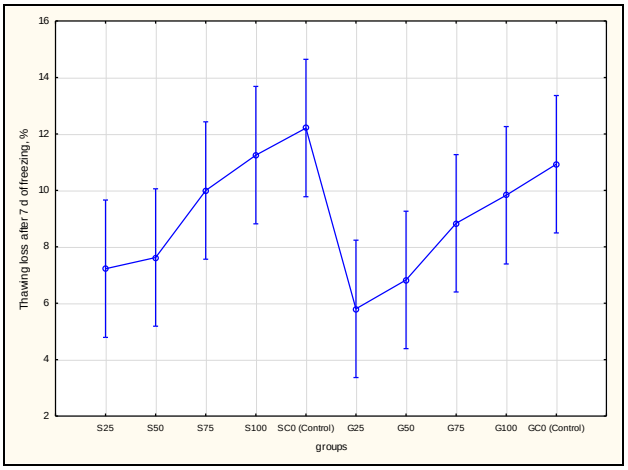

Fig.7. Variations in the thawing loss (TL, %) of meat after 7 days of freezing among sheep and goat meat.

The same tendency as in Goat meat was observed in thawing loss concerning mutton as shown in Figure 21, where the highest level of TL was attained in sheep group SC0 (12.21 %) fed with 100 % SBM and the lowest in group S25 (7.22 %) fed with 75 % SBM: 25 % FBS in rations (P>0.05). Thawing loss (%) in sheep was higher than that obtained in goat meat as shown in Figure 21 when comparing each two different animal groups fed with the same ingredients as in S25 and G25, S50 and G50, S75 and G75 and S100 and G100, SC0 and GC0 (P>0.05). The highest values (P>0.05) were in groups SC0 (12.21 %) and GC0 (10.93 %) and the lowest in S25 (7.22 %) and G25 (5.80 %).

Cooking Loss

Sales (1996**)** and Lawrie (1998) stated that the ability of meat to retain this water during the presence of external factors such as mincing, cutting and storage is known as the water holding capacity (WHC) of meat.

Figure 8 shows the different trends in cooking loss after 24h of cooling Vs after 7 days of freezing. It was noticed that water loss after cooking of those samples obtained after 24 h of cooling was highly significant (P<0.05) with those cooked after 7 days of freezing. On the graph we notice the same tendency in variations of high and low spots in both conditions. The least losses in water after cooking was registered in S50, S25, S100, S75 and SC0 losing weight after cooking averaging to 26.18% Vs 11.09%, 27.54 Vs 11.96, 28.25 Vs 12.28, 32.47 Vs 14.27 and 33.15 Vs 13.09% in both conditions, 24 h Vs 7 days, respectively (P<0.05). Although we observe a statistical significance (P<0.05) in some groups (G25, and G50) of cooking goat meat in both conservative conditions we notice a contradictory increase in groups G100 and GC0 where the loss increases P>0.05). As long as rations

fed to goats contain solely FBS% or SBM% as in groups G100 and GC0 we achieve higher losses in weight of goat meat after cooking after 24 h Vs 7 days, 18.88% Vs 21.38% and 29.47% Vs 27.13%, respectively (P>0.05).

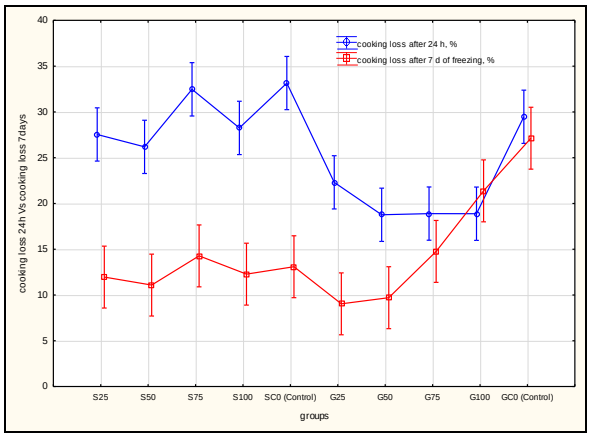

Fig.8. Variations in the sheep and goat meat cooking loss after 24 h of cooling and 7 days of freezing, %

There is a positive significant (P<0.05) correlation (r = 0.424) between color of meat before cooking and water holding capacity after cooking.

IV. DISCUSSION

However, during *postmortem* period, some meat quality parameters may be modified, e.g. pH, Water Holding Capacity (WHC), color and lipid oxidation (Tarsitano *et al*., 2013). The Meat freshness determines the choice of the product by the consumer (Xiong *et al*., 2015). Obtained results on meat pH24 (24 h *postmortem*) show average values between 6.6 for lamb meat and 6.7 for kid meat that can be evaluated as an acceptable quality level and therefore these values might be considered within the range of acceptable values (Hoffman *et al*., 2020). In a related context, Calnan *et al*. (2014) found in their obtained results that increasing pH24 across a range of 5.4 to 6 reduced meat redness (a*) in lamb meat. In contrast to what was achieved by the previous researchers, our findings showed a negative correlation (r=-0.4, P<0.05) between pH7 and a* (Appendix, Table 10) after 7days of freezing and not after 24 hours of cooling. In general, the freezing duration for 7 days in both lamb and kids meats as well showed significant increase (P<0.05) in meat pH where more acidic levels were illustrated after the period of 24 hours of cooling where pH results were basic. Note that, pH24 of goat meat was more basic than sheep and then decreased to become more acidic after 7 days of freezing than sheep with only exception in groups of sheep fed 25% and 75% FBS attaining more basic levels. Regardless of this fact, we notice more acidic levels in both control groups of sheep (SC0) and goat (GC0) longissimus muscle as well whose animals were fed 100% SBM. This is attributed to the presence of Soybean inclusion as the only protein legume source in ration. Time after maturation period of 7 days, pH values decreased. This result can explain about growth of lactic acid bacteria, which optimally grow at pH < 6.

In previous studies, the effect of FBS on meat pH was in conflict. Although some authors (Beriain *et al*., 2000; Ekiz *et al*., 2019) observed significant influence of FBS on meat pH24, some other studies found no significant variation among lambs slaughtered at different weight groups (Juárez *et al*., 2009). In the earlier studies, significant meat pH24 differences among different groups were generally attributed to differences in response to pre-slaughter processes (Ekiz *et al*., 2012a) or differences in glycolytic potential (Hopkins and Fogarty, 1998). In contrast, Oliveira *et al*. (1998), who tested the maturation of bovine biceps femoris muscle at 24 hours, 14 days, 21 days, and 28 days post-mortem, observed an increase in pH. The authors attributed this increase to the greater susceptibility of this muscle to enzymatic attack during maturation due to the increased osmotic pressure of the medium because of the breakdown of proteins into smaller molecules and the intramolecular reorganization of these proteins, which undergo changes in their electric charges.

Luminosity (L*), the red intensity (a*), and the yellow intensity (b*) displayed an increasing linear effect with maturation time of 7 days. With the increase in the maturation period, the meat becomes clearer with increase in a* and b* scores. With the increase in the maturation period, the meat became clearer, and there was also an increase in a* and b*. Live body weight of the animals in all stages of the trials was not seen as a correlated trait based on the findings of Tejeda *et al*. (2008) who found no effect of live weight on meat color. Besides that, Martínez-Cerezo *et al*. (2005) noted that a greater effect in meat color is brought about by a change in diet, than either carcass weight or age. It is worthy to mention that there is a significantly (P<0.05) negative correlation (r=-0.4) before freezing between a* and b* indicators after freezing. In other research the increase in L* may be related to the decrease in the final pH of these meats, as L* displayed an inverse correlation with the pH, indicating that the lower the pH, the greater the luminosity, i.e., the muscle appears clearer (Maganhini *et al*., 2007). Vasta *et al*. (2008) reviewed the quality of meat from sheep and goats offered alternative feeds legume seeds and pods as a replacement for concentrates. They found that many of these alternative feed resources (AFR) contain secondary compounds, such as tannins. Tannin-containing feeds result in meat of a lighter color and tend to increase protein

content, probably because they protect dietary proteins from ruminal degradation.

The red intensity (a*) is directly linked to the state and amount of myoglobin present in the meat. Low-pH conditions, such as those seen in meats with greater maturation times, cause a denaturation of globin, leaving the heme function unprotected, which leads to rapid oxidation of the metmyoglobin. According to Arima *et al.* (1997), the matured meat still displayed a different gradient when compared to the non-matured meat, even after equalizing the color, as the iron present in the myoglobin combined with the low oxygen tension turns into the oxidized form (Fe+++), leading to metmyoglobin, which displays a dark color.

The yellow intensity (b*) increased with the increase in the maturation period. According to Sañudo (2004), the increase in the maturation time of the meat tends to make it darker and browner; in other words, b* tends to increase over time.

Upon analyzing the refrigerated storage time of vacuum-packed pork, Apple *et al.* (2001) also obtained similar results for L*, a* and b*, reporting that the color of the loin becomes more vivid and that there is a greater red intensity when the refrigerated storage time is increased. Similar results were also found by Frederick *et al.* (2006), who tested vacuum-packed and refrigerated pork for 0, 4, and 8 days. As the maturation period increased, there was a linear increase in the mesophilic and psychrotrophic bacterial counts have led to the oxidation of the myoglobin into metmyoglobin, thus increasing a* (Taylor, 1985).

Low-pH conditions, such as those seen in meat with greater maturation times, because a denaturation of globin, leaving the heme function unprotected, which leads to rapid oxidation of the metmyoglobin. According to Arima *et al.* (1997), the matured meat still displayed a different gradient when compared to the non-matured meat, even after equalizing the color, as the iron present in the myoglobin combined with the low oxygen tension turns into the oxidized form (Fe+++), leading to metmyoglobin, which displays a dark color. No evidences of dietary effects on meat physical characteristics as a* and b* were found. Ultimate pH values were higher than those reported by Lanza *et al.* (2003a, 2003b) in lambs fed peas based- or chickpeas based diets (5.78 vs 5.5-5.6). The final pH values reflected that animals were not exposed to severe stress during pre-slaughter handling which is of major concern (Geesink *et al.*, 2001). Nevertheless SBM lambs in comparison with FBS showed average pH-value >5.8 which is considered undesirable (Devine *et al.*, 1993). The lack of significant differences in ultimate pH probably explained the absence of differences among groups in meat color. Lightness values were lower than those found in similar trials in meat from lambs fed different proportions either of peas or of fava beans (Lanza *et al.*, 1999, 2003b). Probably these differences could be attributed to the lower slaughter ages (around 100 days) compared to the age (139 days) in the trial of Lanza *et al.* (1999 and 2003b). Increasing the slaughter age is a well-recognized cause of lowering meat lightness (Santos-Silva *et al.*, 2002). The mesophilic microorganisms are important, as they are primarily acidifying microorganisms.

Meat color is an important criterion to judge the quality and freshness of meat at purchase by consumers (Ekiz *et al.* 2012a). Redness is closely associated with the state and amount of myoglobin in the meat. The luminosity (L*), the red intensity (a*), and the yellow intensity (b*) displayed an increasing linear effect with maturation time. Drehmer (2005) observed that the increase in the refrigerated storage of meat (0, 7, and 14 days) without using organic acids caused an increase in the mesophilic bacteria counts (2.72, 7.35, and 9.48 CFU/g with increasing refrigeration time). The bacterial load found in this study is within the standard established for meat fit for consumption. Mesophilic microorganism counts are used to indicate the sanitary quality of foods, yet mesophilic bacteria do not represent a potential risk to human health (Capta *et al.*, 1999).

The prolongation of ageing time up to one week of freezing, significantly affected some of the meat quality traits. Lightness, redness, and yellowness increased with prolonged ageing within SBM while in FBS, only redness was affected. This partially disagrees with Li *et al.* (2014), who only found an ageing time effect on lightness, but not on red- or yellowness in vacuum aged beef. On the other hand, color changes due to ageing have been previously reported for vacuum aged beef by Boakye and Mittal (1996). However, the meat color remained unaffected by ageing in SBM, which may be attributed to the high content of antioxidant carotenoids possibly transferred to the muscle tissue (Li and Liu, 2012; Soni *et al.*, 2017).

The drip loss percentage was obvious in animal groups (SC0 and GC) fed 100% SBM in the basic rations. More over thawing loss was higher after 7 days of freezing in sheep meat rather than in goats. Note that the highest losses were achieved in both control groups (SC0 and GC0) where animals were fed 100% SBM in the basic ration. It is worthy to mention that after strict observation it was found that as percentage of FBS in rations increase thawing loss increases linearly. Water loss represents a decreasing linear effect with maturation time; that is, the water retention capacity of the meat increased with the increase in the maturation time. During maturation, could not in fact be a slight increase in water retention capacity

due to the proteolytic action of cathepsins, which break down the enzymes of the myofibrillar structure, causing changes in the electrical charges of these proteins. Furthermore, Lawrie (2005) found that this breakdown in the ion-protein relationship increases the absorption of potassium ions (K+) and the release of calcium (Ca++) and sodium (Na+) ions. Roça (2000) added that this exchange of ions during maturation causes better water absorption. These results are in agreement with those found by Apple *et al*. (2001), who tested the effect of refrigerated storage on the quality of vacuum-packaged pork loins and identified a reduction in the water loss of the loin with increasing storage time (0, 4, and 8 weeks). The fluid lost in freezing present a decreasing linear relationship with maturation time. Due to the slight increase in the water retention capacity of the ageing meat, the fluid lost in freezing was also reduced. Although maturation may improve the water retention capacity of proteins, the post-mortem denaturation of the proteins and the decline in pH considerably contribute to a loss of muscle exudates (Lawrie, 2005). According to Miller *et al*. (1996) there is a greater loss of exudate during the refrigerated storage process, thus increasing the fluid lost during cooking. The fluid lost in cooking presented an increasing linear regression with maturation time. With increasing storage period, the water retention capacity of the muscle increases, and therefore, during cooking, there was a greater percentage of fluid to be released. This result was similar to that found by Apple *et al*. (2001), who reported that the percentage of liquid lost due to cooking increased linearly with increasing maturation.

The water holding capacity (WHC) of the meat can increase with time after finishing due to the proteolytic action of cathepsins, which break down enzymes of the myofibrillar structure and influence physioelectrical charges. These changes increase the absorption of ions such as potassium, calcium and sodium (Sung *et al*., 2017), while maturation time affects meat tenderness. Note that in our experiment maturation time of 7 days was tested where our objectives did not take into consideration more periods of maturation.

It is significant to mention that in our study penetration force in mm was used to test meat tenderness, which is a new way that could not be found in literature searches; instead, the traditional and most common method was in applying the shear force as Warner-Bratzler shear (WBS). Comparing the obtained results between goat and sheep meat we conclude that penetration force of cooked goat meat Vs cooked sheep meat before and after freezing was higher in all animal groups revealing more tenderness of goat meat. Tarsitano *et al*. (2013) reported that during the period after full maturation, shear force may decrease due to proteolysis of the myofibrillar structural components. When WHC decreases, shear force was observed to increase.

However, drip loss value of SC0 and GC0 (100% SBM) animal groups was significantly higher than all other groups in Awassi lambs and Baladi goat kids. In contrast with the current results, Vergara *et al.* (1999) found an increase in expressed juice value with increase in lambs fed FBS. In some previous studies (Ekiz *et al*., 2012b; Yaranoğlu and Özbeyaz, 2019), it has been reported that levels of expressed juice, drip loss and cooking loss are closely related with meat pH24. Ekiz *et al*. (2012b) found significant and negative correlation of pH24 with expressed juice and cooking loss. At higher muscle pH, proteins are able to bind with water more strongly and therefore less water is released (De la Fuente *et al*., 2010; Ekiz *et al*., 2019). However, in the current study, the correlation of pH24 with expressed juice, drip loss and cooking loss were not significant. On the other hand, Rajkumar *et al*. (2014) noted that increased meat water holding capacity in heavier lambs might be related to their higher fatness. One of the reasons of tougher meat in heavy lambs at slaghter might be the decrease in the amount of soluble collagen with increasing age and the increase in the number of heat-resistant linkages between the collagen fibres (Beriain *et al*., 2000). Supporting the current results, Ekiz *et al*. (2019) found no signicant differences among the meat of Kivircik lambs slaughtered at 25 kg, 30 kg and 35 kg weights regarding juiciness, odour and flavour intensity

Results of the study indicate that slaughter weight (SW) of young growing animals (at the termination of the experiment) has an evident influence on carcass and meat quality characteristics in both Awassi lambs (about 30 kg SW) and Baladi goat kids (about 20 kg SW).

Cooking loss values were lower than those reported by Lanza *et al*. (2003b) in meat from lambs fed different percentages of peas (19 and 39% on as fed basis) probably due to higher pH values.

Destefanis *et al*. (2008) attributed tough judgement to meat that showed penetrating force values less than 62.8N. Certainly, the different cooking method (waterbath) could have negatively influenced penetrating force values obtained in our experiment (from 2.5 to 5.5 mm).

The physical meat quality was not affected by the diets, including FBS or SBM partially or sololey. In contrast, Cutrignelli, *et al*. (2008a; 2008b) found a reduced water holding capacity in meat of faba-bean fed Marchigiana bulls. Calabrò *et al*. (2014) observed a slight

reduction in intramuscular fat content in meat of buffalo bulls fed fava beans instead of SBM. The authers added that he partial substitution of SBM by Fava bean seed fed to fattening lambs and goat kids did not affect meat color, which supports the present results obtained with a complete replacement of SBM by FBS. It also seems that including legume protein supplementation basic diets is without consequence for meat composition, water holding capacity, meat color, and meat tenderness of beef cattle (Geletu *et al*., 2021) which is comparable to the present study.

Prolonging ageing successfully promoted tenderization, as exhibited from the higher penetration levels and reported repeatedly by others (Lestingi *et al*., 2019). Note that all levels obtained in all goat groups after cooking after 7 of freezing days were significantly higher ($P<0.05$) meaning tender than those from sheep meat after 24 h of cooling in groups S25 (3.51 mm), S50 (2.50 mm), S75 (5.47 mm), S100 (4.27 mm) and SC0 (2.59). The penetration force presented decreasing linear behavior with maturation time; that is, it decreased as a function of the maturation time, making the meat tenderer. The shear force may have decreased due to proteolysis of the myofibril structural components, which occurs during refrigeration (Koohmaraie and Geesink, 2006). The values found indicate that maturation led to meats with a high degree of tenderness, and according to Boleman *et al*. (1997), shear force values for muscle less than 3.6 kgf/cm2 indicate extremely tender meat. Evaluating the effect of maturation (0, 8, 12, 24, 48, and 72 hours) on the texture of the meat from broiler chickens, Kriese *et al*. (2005) found that the sheer force increased with the maturation time.

Despite this fact, a stable minimal difference was observed in sheep meat after cooking, Koohmaraie *et al*. (1990) and Safari *et al*. (2001) concluded that the meat tenderness is the most important attribute affecting meat quality. Forrest *et al*. (1975), Tornberg *et al*. (1985) and Tshabalala *et al*. (2003) found that the ease of penetration, the ease with which meat breaks into fragments and the amount of residue that remains in the mouth after mastication, all contribute to the impression of meat tenderness. Lawrie (1998) reported that muscle fibers primarily affect tenderness where older animals have coarser muscle fibers and are thus tougher while younger animals have finer fibers. He also added that the connective tissue in young animals also has more soluble collagen linked to lower amounts of cross-bond connective tissue where, as animal age increases, the solubility of the collagen decreases, inducing a decrease in enzyme attack susceptibility. Meat becomes tendered *postmortem* through either a decrease in calpastatin and/or an increase in calpain activity that regulates protein breakdown (Therkildsen *et al*., 2002). However, Sazili *et al*. (2004) found that a feed restriction early in life, accompanied by an increase in growth rate before slaughter resulted in more tender meat than animals with a fast growth rate throughout their lives. Sazili *et al*. (2004) concluded that this effect is brought about by the interaction between protein synthesis and protein degradation on calpain and calpastatin activity.

V. CONCLUSION

The current study's research objectives broadly sought to evaluate the potential of Fava been seeds as alternative protein sources in feeds. The evaluation was designed around the *in vivo* evaluation the dietary effects of completely and partially substituting SBM with FBS on growth performance and meat quality. it was concluded that FBS qualified as potential legume protein sources in feeds and could be used /evaluated as feed ingredients with no risk of deleterious effects on growth (body mass, linear growth and physical meat quality) in growing male kids and lambs. Based on the present findings, SBM can be replaced by FBS legume protein sources on an isonitrogenous basis in diets comprising 50% SBM with 50% FBS concentrate without impairing performance, carcass and meat quality, thus confirming hypothesis. In summary, the 50: 50 and 75: 25 proportion of FBS: SBM improved the meat quality profile compared to values reported for conventional fattening diets, while maintaining reasonable animal performance and carcass and meat quality, without additional metabolizable protein-concentrate supplementation.

CONFLICT OF INTEREST

The auther certifies that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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