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Physicochemical, colorimetric properties and yield of bresaola from beef, Baladi-goat and Awassi-sheep in Lebanon

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Abstract—*Yield, physicochemical and colorimetric characteristics of bresaola from Lebanese Baladi-goat and Awassi-sheep compared to that from beef is studied. For this purpose, defatted lean meat cuts from Beef, Baladi-goat and Awassi-sheep were collected, weighed and processed following the EU-approved guidelines for Bresaola della Valtellina. The bresaola from beef (BFB) had the significantly lowest moisture and fat content compared to Bresaola from Baladi-goat (BFG), with the values of Bresaola from Awassi-sheep (BFS) being significantly the highest. Furthermore, the protein and ash content of BFB was significantly the highest, followed by the values of BFG with content of BFS being the lowest. The pH value of BFB was significantly the lowest, while there was no difference between those of BFG and BFS. There was no significant difference in the water activities of BFB, BFG and BFS (0.848±0.002). As for the colorimetric characteristics, the ΔE value of BFB with BFG is 14.74±4.10, while that of BFB with BFS is 17.88±4.10, and that of BFG with BFS is 16.00±4.10 noting that the values did not differ significantly. The BFB and BFG Hue values did not differ significantly both being significantly larger than that of BFS. The BFB and BFG Chroma values were not significantly different while both being significantly different from that of BFS. Bresaola from raw meat (kg-Bresaola/kg-raw meat) value for beef was found to be significantly higher than that of goat, with value for sheep being significantly the highest. Consequently, the opposite was true for weight loss (%).*

Keywords— ***Bresaola, Beef, Baladi Goat, Awassi Sheep, Conversion values, Physicochemical, Colorimetric properties.***

I. INTRODUCTION

Bresaola originate from Italy and is guaranteed by Protected Geographical Indication (PGI) community trademark "Bresaola della Valtellina," and gained popularity in the national and international market [1]. It is a dry meat product, similar to other products such as Turkish and Armenian pasturma [2] [3] and other dry-cured beef [4]. Bresaola has low fat and calories contents, and high amount of protein, iron, vitamins and minerals [5], fitting the current consumers' who favor meat that is authentic, tasty, rich in protein and low in lipid, cholesterol and carbohydrates [6] [7].

Traditionally, Bresaola is made by curing cuts from the hind quarter (mostly *Semimembranosus*, *Semitendinosus* and *Quadriceps femoris* muscles) of cattle, horses, or donkeys [7]. The meat is defatted, then marinated with dry salt and natural flavors for at least 7 days then dried and cured -with seasoning- under adequate environmental conditions (temperature, relative humidity and air velocity) for a duration of at least 3 weeks [8] [9]. The Bresaola

quality depends on the initial properties of the meat and its treatment [9, 10] influencing nutritional and sensorial characteristics of Bresaola [1]. In the last years several studies highlighted the favorable nutritional profile of meat and meat products from alternative animal species such as buffalo, goat [7, 11] and game animals [12-14].

In Lebanon, around 92-95 % of goat breeders raise the local population of goats called "Baladi" and 99% of sheep farmers raise the Awassi breed [15, 16]. They are mainly raised in extensive systems with different levels of concentrate supplementations [15]. Furthermore, more than 6000 families are living from the income of goat herd products such as milk, meat and fur [16]. The Awassi sheep is also a multipurpose breed with a dominance of meat production. The goat kids and the sheep lambs are slaughtered at the mature age of around one year for a weight varying between 40 and 55 kg [15]. The production of dry cured meat products that are available throughout the year could be a tool to increase the value of goat and sheep meat.

The aim of the work was to evaluate yield, chemical parameters like proximate composition, pH and aw in the raw material of Baladi goat and Awassi sheep compared to the traditional source of bresaola meat i.e. beef cattle, and the corresponding cured fermented and dried products prepared from the same meats, using the processing scheme of 'bresaola' production. Furthermore, the colorimetric properties of the produced beef, goat and sheep Bresaola was elucidated.

II. MATERIALS AND METHODS

2.1 Meat and Bresaola

The beef, Baladi-goat and Awassi sheep top cut round meat were collected from certified local Lebanese-licensed abattoir who abide by the standard handling procedures. The top cut round meat was taken from the 3 bulls, 3 Baladi-goat and 3 Awassi-sheep hind areas. After trimming, defatting and taking samples of raw meat, the cuts were tumbled with a curing mixture (for 1kg of fresh meat: 25g of sodium chloride, 1.2g of Fructose corn syrup, 0.2g of sodium nitrite, 1g spices) turned and massaged every 3 days at a 70-80% RH for a total duration of 9 days at 2–3C. After 9 days after shaping step, rapping in a natural casing, tying with a food grade string and place it into a curing chamber, at 13C and 85%RH for 2 months, bresaola was produced.

2.2 Physicochemical properties

All raw and Bresaola samples were sent to the laboratories of the Industrial Research Institute, Lebanese University Campus Hadatt (Baabda) Lebanon, to study their physicochemical properties. The three samples of raw and bresaola meat were tested with three replications each. Each sample was assessed for theses parameters: Moisture content following drying Method (AOAC Official Method 950.46B)[17, 18]; Protein content following Kjeldahl method (AOAC Official Method 928.08)[19]; Fat content following Soxhlet extraction method (AOAC Official Method 960.39)[20]; Ash content following using the basic heating technique (550 C for 5 h) AOAC official method 920.15 [19]; pH was measured using a pH-meter Microcomputer based pH/conductivity/TDS/salinity and temperature pocket meter Model pH/EC80 (Jenco VisionP), with tip probe electrode at 25C; Water activity (aw), was measured using (TESTO650, Germany) with an accuracy of ±0.001 at 25C.

2.3 Colorimetric Properties

The color of Bresaola were determined using pantone color chart [21] which had the corresponding CIE L*a*b* values. Following the American Meat Science Association [22] these parameters were calculated:

i. Redness Ratio where Larger ratios of a*/b* indicate less discoloration [22]-[23]

Equation (1): Redness Ratio= a*/b*

ii. Chroma (C): larger values indicating more saturation of the principle hue of the sample [22]

Equation(2): C= (a*^2 + b*^2)^(0.5)

iii. Hue angle (HA): Larger values indicate less red. [22]

Equation(3): HA= {arctangent (b*/a*)}

iv. Delta E (ΔE): Total color change. It is used to assess the difference in color between bresaola from beef, Baladi-goat and Awassi-sheep [22]

Equation(4): ΔE= (ΔL*^2+ Δa*^2+ Δb*^2)^0.5

2.4 Yield attributes

The initial weight of meat cuts was recorded. Furthermore, the final weight of the bresaola produced was recorded. This has allowed the calculation of bresaola from meat cut (kg bresaola/ kg raw meat) (5). Furthermore, the percent weight lost during the process was calculated (6).

Equation(5): Bresaola produced= Bresaola weight / Initial weight

Equation(6): Weight loss= (Initial meat weight – Bresaola weight)*100 / Initial meat weight

2.5 Statistical analysis

All data were subjected to analysis of variance, using the GLM procedure of the SPSS statistical software (IBM SPSS statistics 21). The mathematical model included fixed effect due to animal species for bresaola. Significant differences were found if P is less than 0.05. Least Squares

means were evaluated to set the difference between the different parameters. Furthermore, the Pearson correlation was calculated between the CIE L*a*b*, colorimetric calculated attributes and the physicochemical properties of produced bresaola.

III. RESULTS

3.1 Physicochemical Properties

3.1.1. Physicochemical properties of raw meat

The moisture content of beef cuts did not differ significantly from that of Baladi-goats cuts, both being significantly higher from moisture content in Awassi-sheep cuts "Table 1". Concerning the fat content, beef cuts was found to have the significantly lowest value compared to that of Baladi-goat and Awassi-sheep cuts which did not differ significantly from each other "Table 1".

Table 1: Physicochemical properties of raw meat cuts

	beef	Baladi-goat	Awassi-sheep
	mean±S.E	mean±S.E.	mean±S.E.
M.[1] (%)	74.6[a]±0.3	73.8[a]±0.3	69.6[b]±0.3
Fat (%)	1.37[a]±0.09	3.80[b]±0.09	4.03[b]±0.09
Prt.[2] (%)	22.4[a]±0.3	20.7[b]±0.3	25.0[c]±0.3
Ash (%)	1.23[a]±0.06	1.17[a]±0.06	1.17[a]±0.06
pH	5.60 [a]±0.03	5.47 [b]±0.03	5.97 [c]±0.03
aw[3]	0.967[a]±0.004	0.940[a]±0.004	0.947[a]±0.004

Within rows, means with different letters are significantly different. 1: Moisture; 2: Protein; 3: Water activity;

The protein content and pH values, the values recorded of Awassi-sheep cuts were significantly the highest followed by that of beef cuts, with that of Baladi-goat cuts being the significantly lowest. Last but not the least, the pH and aw values of the beef, Baladi-goats and Awassi-sheep cuts showed no significant difference "Table 1".

3.1.2. Physicochemical properties of Bresaola

The moisture and fat content of bresaola from beef (BFB) were significantly the lowest, those recorded for bresaola from Awassi-sheep (BFS) were significantly the highest with those recorded for bresaola from Baladi-goats (BFG) in between "Table 2". The opposite was true for the protein and ash content, where the values for BFB were found to be significantly the highest, followed by the values of BFG with those values of BFS being significantly the lowest "Table 2". The pH values of BFG and BFG did not differ from each other with that of BFB being significantly lower "Table 2". Concerning the water activity (aw) value there was no significant difference recorded in this study for BFB, BFG and BFS "Table 2".

Table 2: Physicochemical properties of Bresaola

	BFB	BFG	BFS
	mean±S.E.	mean±S.E.	mean±S.E.
M.[1] (%)	33.73[a]±0.07	34.97[b]±0.07	37.17[c]±0.07
Fat (%)	2.73[a]±0.05	5.23[b]±0.05	7.73[c]±0.05
Prt.[2] (%)	55.2[a]±0.1	53.2[b]±0.1	48.6[c]±0.1
Ash (%)	7.77[a]±0.03	6.27[b]±0.03	6.07[c]±0.03
pH	5.53 [a]±0.04	6.00 [b]±0.04	5.93[b]±0.04
aw[3]	0.850[a]±0.002	0.847[a]±0.002	0.852[a]±0.002

Within rows, means with different letters are significantly different. 1: Moisture; 2: Protein; 3: Water activity; BFB: Bresaola from beef; BFG: Bresaola from Baladi-goat; BFS: Bresaola from Awassi-sheep

3.1.3. Colorimetric properties

All the L, a* and b* values were positive. The L value of BFB was significantly higher than those values of BFG and BFS, both being non-significantly different "Table 3". As for the a* value, it was significantly the highest for BFB compared to those of BFG and BFS which did not differ significantly from each other "Table 3". Furthermore, the b* values of the BFB, BFG and BFS did not differ significantly from each other "Table 3".

*Table 3: CIE-L*a*b* values of Bresaola*

	BFB	BFG	BFS
	mean±S.E.	mean±S.E.	mean±S.E.
L	47.25[a]±1.75	37.80[b]±1.75	41.17[b]±1.75
a*	49.91[a]±3.49	50.61[b]±3.49	65.44[b]±3.49
b*	35.17[a]±2.35	30.51[a]±2.35	33.40[a]±2.35

Within rows, means with different letters are significantly different. BFB: Bresaola from beef; BFG: Bresaola from Baladi-goat; BFS: Bresaola from Awassi-sheep

As for the colorimetric calculated values, it was found that the Redness Ratio (1) and Chroma values of BFB and BFG did not differ significantly from each other while BFS values were significantly the highest "Table 4".

Table 4: Redness Ratio (1), Chroma (C) and Hue Angle (HA) values for bresaola

	BFB	BFG	BFS
	mean±S.E.	mean±S.E.	mean±S.E.
Redness Ratio	1.44^{a}±0.13	1.68^{a}±0.13	1.96^{b}±0.13
C	61.3^{a}±3.4	59.1^{a}±3.4	73.30^{b}±3.4
HA	35.5^{a}±2.5	30.9^{ab}±2.5	23.4^{b}±2.5

Within rows, means with different letters are significantly different. BFB: Bresaola from beef; BFG: Bresaola from Baladi-goat; BFS: Bresaola from Awassi-sheep

Concerning the Hue angle value, there was no significant differences between the BFB and BFG while that of BFS was significantly the lowest "Table 4". As for the Delta E, the color difference between BFB and BFG is 14.7±4.1, while that between BFB and BFS is 17.9±4.1 and last but not least the color difference between BFG and BFS is 16.0±4.1.

3.1.4. Correlation between Colorimetric properties and physicochemical properties

The moisture, fat and protein content were not correlated with the brightness (L) value of the meat, while it was highly and positively correlated with the ash content and highly and negatively correlated with the pH value.

*Table 5: Pearson correlation between CIE-L*a*b* value and physicochemical properties of bresaola*

	Brightness L	Redness a*	Yellowness b*
Moisture	n.s.	0.772	n.s.
Fat	n.s.	0.731	n.s.
Protein	n.s.	-0.786	n.s.
Ash	0.743	n.s.	n.s.
pH	-0.761	n.s.	n.s.
aw	n.s.	n.s.	n.s.

n.s.: Not significant

The redness value (a*), on the other hand was positively and highly correlated with the moisture and fat content and highly and negatively correlated with the protein content.

3.1.5. Yield parameters of Bresaola

As for the bresaola produced from kg of raw meat, it was found that Awassi-sheep meat produced the significantly highest bresaola weight, followed by that of beef meat with that of Baladi-goat meat being significantly the lowest "Fig. 1".

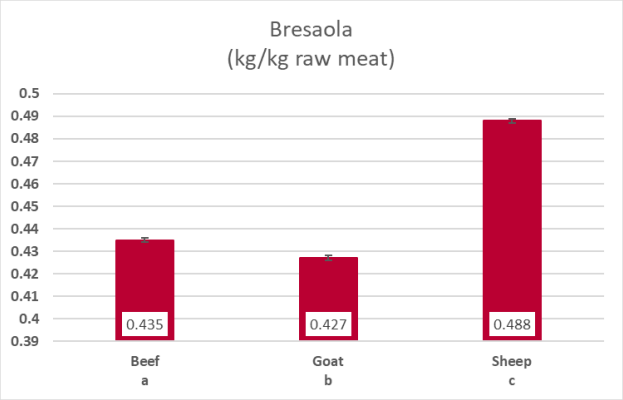

Fig.1 kg Bresaola from 1 kg raw meat
Different alphabetic letter indicate significant difference

Following the opposite tendency of bresaola weight produced, the weight loss during bresaola production was the lowest in BFS production, followed by that in BFB production with that in BFG production being the highest "Fig. 2".

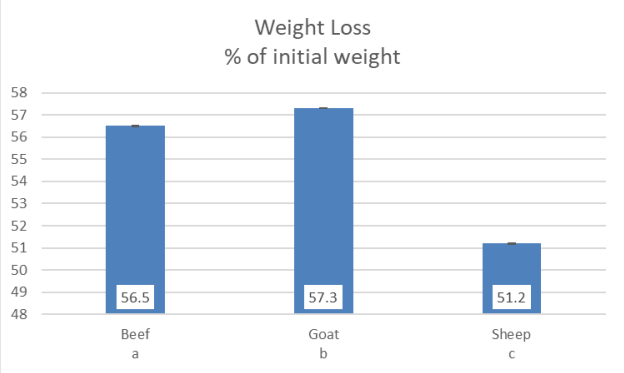

Figure 2 Percent weight loss during bresaola production
Different alphabetic letter indicate significant difference

IV. DISCUSSION

Animal species did affect significantly the physicochemical properties of Fresh meat and bresaola produced which is similar to the results found by Marino et, al. 20015[1], Zhang et al. 2015 [5] and Paleari *et. al.* 2003 [7]. The moisture content of fresh meat was highest in beef but turned to be lowest in the BFB produced. The opposite was true for Awassi-sheep raw meat, where it started to be the lowest and the moisture content was the highest in the BFS produced. This might be due to the higher fat content in Awassi-sheep meat compared to that of beef meat. This was different from the study in New-Zealand where bresaola done from lamb and mutton had the lowest fat content [5]. This difference might be attributed to the different species of sheep predominant in New-Zealand [24] which does not include the Awassi-sheep. The trend of fat content was the same in raw meat

and that of bresaola, where Beef and BFB had the lowest fat content followed by Baladi-goat and BFG with Awassi-sheep and BFS having the highest fat content. Concerning the protein content, it started by raw Awassi-sheep meat having the highest protein content but ended up by having the lowest one in the BFS. This might be explained by the fact mentioned by Zhang *et. al.* 2015 [5] who found that bresaola from mutton meat, when compared to bresaola from beef, veal, wagyu and lamb, had undergone the highest proteolysis rate leading to highest free amino acids content. As for the ash content, while there was no difference at the raw meat level, BFB had the highest ash content followed by BFG and then BFS. The increase of ash content is due to the salting stage, however the highest increase in beef ash content might be due to the lowest fat content which might have hindered salt penetration where the leaner the outer surface area the higher the penetration of salt [25]. As expected, the reductions in moisture content and increase in ash content resulted in a significant decrease in the aw of bresaola produced, around 0.851±0.002, compared to that of the fresh meat product, around 0.951±0.004. This reduction renders the bresaola produced relatively shelf stable even against *listeria monocytogenesis* [26, 27]. Concerning the pH there was no significant difference between the bresaola Bresaola produced, the values being within the acceptable range [9], keeping the product under the low acid food category [28].

Concerning the colorimetric properties of the BSB, BSG and BSF, there was significant difference among the different species which is in compliance with the literature [5, 29]. Starting with the brightness (L*) they were higher than those reported by Zhang *et. al.* 2015[5], ranging from 20 to 30, similar to those reported for young bulls[8] and commercial bresaola, around 40 [30]. This is although the moisture content of the produced Bresaola is similar to that recorded by Zhang *et. al.* 2015 [5] it has similar values to those recorded by the commercial bresaola. The BSB had the highest light reflectance, followed by that of BFS and BSG having the lowest value. The L value was correlated positively with the ash and negatively with the pH values. The redness value (a*) of BFB and BFG were similar to each other both being less red than the BFS. This might be due to the significantly highest moisture content which was reflected by high correlation between moisture content and a* value. This was not in accordance with Zhang *et. al.* 2015 [5] but this might be explained by the much lower moisture content recorded. The yellowness values of the BFB, BFG and BFS did not differ from each other which might explain the non-significant correlation was recorded between b* and the physicochemical properties. The calculated colorimetric values did differ significantly between BFB, BFG and BFS. The BFS had the highest Redness Ratio and HA values indicating least discoloration and more redness. This is in parallel to the a* values of BFN, BFG and BSB recorded and to the high change in color vales (ΔE) between BFN, BFG and BSB.

One of the most important attributes in any processing are the yield attributes. BFS had the highest yield and the least weight loss, despite starting with the highest moisture content. Weight loss of around 56 - 57% is a bit higher than the 34.1% to 40.5% recorded by Alabiso *et. al.* 2020 [10] who produced bresaola made from Cinisara cattle. The meat from Cinisara cattle had a starting moisture content from 74.5% to 76%, while we had the highest at 74.6% for beef, 73% for goat and 69.6% for sheep. Furthermore, the last stage of bresaola production, it which was kept at 13C and 85%RH for 2 months, compared to 12C and 72-75% RH for 1 month by Zhang *et. al.* 2015 [5], and to 10°C and 90% of RH for 1 month by Alabiso *et. al.* 2020 [10] might be the reason behind this variation.

V. CONCLUSION

Meat from Awassi-sheep and Baladi-goat can be used for bresaola production with their yield being higher than that observed in meat from beef. In addition to that, more studies should be done to monitor the effect of each stage and parameter on the end product. There was difference in the physicochemical properties and colorimetric properties between the beef, Baladi-goats and Awassi-sheep. More studies should be conducted to confirm some of the differences realized between the local breeds and those recorded by the literature. A sensory analysis should be conducted to assess the acceptability of BFG and BFS compared to BFB and the imported brands.

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