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**ORIGINAL RESEARCH PAPER**

# PHYSICOCHEMICAL PROPERTIES EVALUATION OF MARINATED LAMB MEAT FROM DIFFERENT PRODUCTION SYSTEMS

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**Abstract:** The objective of this study was to standardize two marination recipes and to determine any significant difference between intensively and extensively produced fresh and marinated lamb meat (Corriedale breed) through checking different quality parameters. One water-based and one oil-based marinade were standardized out of 14 marinades through sensory evaluation. Different physicochemical parameters including *p*H, color, volume loss, weight loss, tenderness, water holding capacity, moisture and fat content have been checked. Triangle test and ranking test were done to find out the best marinated samples. *p*H of marinated samples was significantly lower than fresh samples ($P < 0.05$). Marinated samples showed significantly higher lightness (L*) and yellowness (b*) but the lower value at redness (a*) comparing to fresh samples. All extensive samples and oil-based marinated sample exhibited significantly higher volume loss. Intensive samples were the tenderest while fresh and extensive samples appeared with higher water holding capacity. Intensive samples had the lowest and fresh samples had the highest moisture significantly ($P < 0.05$). Triangle test showed a significant difference in P value, 0.20 for water-based marinated sample and 0.05 for oil-based marinated samples. Extensive oil-based marinated samples had the highest ranking ($\alpha = 0.01$) among other samples.

**Keywords:** *lamb meat, marination, physicochemical properties, processing effect*

## INTRODUCTION

From the last decade, the global sheep industry was facing a progressive declination which was occurred for many possible reasons such as seasonal drought, unpredictable weather patterns, decreasing land resource and an unsteady economic condition with fluctuating meat prices. The consumption of lamb meat and meat products depends not only on the quality of the meat but also on meat prices and per capita income [1]. The market demand for lamb meat can be increased by developing its quality. On the other hand, value addition and marination may be a possible solution for this. Nowadays, in case of animal production, the global trend is to go systematically from small-scale extensive production to large-scale intensive production which increases the production rate and profitability. The main advantage of this intensive production system is that it is not affected by the environmental factors [2].

Though lamb meat consumption in Germany is very low (one kg per person per year), intensive and extensive lamb meats are moderately acceptable by the German consumers [3]. The way of presenting the lamb meat to the consumers in Germany while keeping high quality may increase its consumption. Some possible ways to keep the highest quality of meat, for instance, high-pressure freezing, antemortem supplementation with anti-freeze proteins and vitamin E [4]. Marination of lamb meat is another good idea. The consumption of marinated lamb meat is a very old method practicing all over the world. Marination is very famous because of less handling as marinated meat needs only heat treatment and does not need to add any further spices. The aim of marinating is to tenderize, add flavor and to enhance the shelf life of meat by suppressing the growth of the microorganism. Different type of harmful organism can be prevented using acidic marinades [5]. Marination recipes are basically two types: water-based and oil-based. Different juices can be used to fabricate marinade. Cranberry juice with other spices and herbs is a good example of water-based marinade [6]. In oil-based marination recipes, yogurt or buttermilk is used in maximum cases [7].

Given the fact that the enhancement of meat products with water- and oil-based marinades provides juicier, tenderer, and more flavorful, the objective of this study was to develop and standardize one water-based and one oil-based marinade. The additional objective was to assay their effect on intensively and extensively produced meat of Corriedale lamb breed and to determine any significant difference between intensive and extensive lamb meat in case of *p*H, color, volume loss, weight loss, tenderness analysis, water holding capacity, moisture and fat content.

## MATERIALS AND METHODS

### Preparation of marinades

For this study 7 water-based and 7 oil-based marinades sample were prepared at first. Sensory analysis based on consistency, smell and taste was done step by step by 5 expert panel members (trained personnel) from the Department of Nutrition and Food Engineering, Daffodil International University to find out final water-based and oil-based marinade. DLG (Deutsche Landwirtschafts-Gesellschaft – German Agricultural Society) - quality test method was used on some parameters like consistency, smell and taste to finalize water-based and oil-based marinades [8].

## Preparation of lamb meat and marinade

For sample preparation exact 40 kg of lamb meat (Breed: Corriedale; Portion: hind-shank) from Landcorp Farming Ltd. and 40 kg of lamb meats (Breed: Corriedale; Portion: hind-shank) from Wilson Hellaby Ltd. were brought for this experiment. These samples were further named in this research intensive and extensive lamb meat, respectively. All lambs were slaughtered at 20 weeks of their age. After deboning both intensive and extensive lamb meat were divided into 3 portions as the fresh sample, oil-based marinade and water-based marinade sample. Each portion weighed 7 kg. Before and after the deboning process lamb meats were stored in the cooling chamber at 3.5 °C. Thick polyethylene (30 microns) was used for the packaging. Both water-based and oil-based marination recipes were prepared as 1600 g based on measurement. To settle down properly, marinades were kept in the chilling chamber at 3.5 °C for two days. Each 1600 g recipe was divided into half for intensive and extensive meat. Then 4 marinated samples were prepared: water-based intensive, water-based extensive, oil-based intensive and oil-based extensive samples. Samples were packed in polyethylene wrap with vacuum condition and kept in chilling temperature (3.5 °C) for 14 days. Including fresh intensive and fresh extensive meat total, six categories of meat samples were taken for further experiments and sensory evaluation.

## Physicochemical properties evaluation

### *pH and CIELab color measurement*

Determination of *p*H value in case of meat processing has special importance as it directly influences shelf-life, color, and quality of meat [9]. To measure the *p*H, 5 samples from every six categories of chilled meat were selected randomly and a WTW™ ProfiLine™ *p*H 3210 portable meter was used (Fisher Scientific, Sweden). The temperature was maintained at 3 °C to avoid the error for this instrument while room temperature was 23 °C. Randomly selected 10 samples from each six categories of meat were taken for color measurement. Fresh samples were measured immediately after collecting the meat whereas marinated samples were measured after 14 days of marination. Color measurement was done with the help of a spectral colorimeter (Lange spectro color d/8°, Labstuff Limited, Ireland) (Measuring aperture: 10 mm illuminated / 8 mm measured, Illuminants: CIE D65, C, A, F 11, (TL 84)). *L*, *a*, and *b* values were determined for each sample at 3 °C temperature [10]. Delta E value was evaluated to differentiate the colors of fresh and marinated samples. The total differences of two CIELab value are denoted by one numerical value known as ΔE with the following formula as observed at eqn. (1). If the ΔE values go more than 1, there will be a significant difference, as the value 1 denotes Just Noticeable Difference (JND).

$$\Delta E = \sqrt{[(\Delta L^2) + (\Delta a^2) + (\Delta b^2)]} \quad (1)$$

### *Weight loss and volume shrinkage measurement*

To measure the weight loss and volume shrinkage for fresh intensive and extensive meat each time 10 samples were picked up randomly. The dimension of each sample was prepared exactly as 3 cm × 2 cm × 2 cm. The weight of the sample was measured before and after cooking in a microwave oven of 1500 Watt for 40 seconds to figure out the exact weight loss. To calculate volume shrinkage length, width and height of each

sample were measured using a digital slide caliper ruler after cooking. The whole process was repeated after 14 days for oil-based and water-based intensive marinated and oil-based and water-based extensive marinated meat samples.

***Texture analysis***

Warner-Bratzler Texture Analyzer (Model: TA.XT*ExpressC*, Stable Micro System, United Kingdom) was used to measure the texture for randomly selected 10 samples from each four categories after 14 days of marination and both intensive and extensive fresh samples were measured immediately after collecting the meat. All the samples were measured at 40 °C and length, height and width of each sample were 3 cm × 2 cm × 2 cm. Fresh meat and marinated meat were roasted for 8 minutes and checked properly whether the inner portion of the meat was cooked or not. Roasted samples were measured at tolerable hotness. The test speed of the texture analyzer was 20 $mm \cdot s^{-1}$. Warner-Bratzler shear blade with "V" shape probe (cutting distance was 42 mm) was used for raw meats and Warner–Bratzler shear blade with guillotine probe (cutting distance was 25 mm) was used for fried meat. Sample area, force, and work were measured for each sample.

***Moisture content, water holding capacity and fat content measurement***

Random samples from each six categories of meat were taken to determine moisture content using oven-dry (Benchtop Drying Oven LX250BDOB, UK) method at 105 °C for overnight [11]. To measure the water holding capacity, filter paper press method has experimented with randomly selected samples from each category [12]. A small amount of meat sample (nearly 0.5 g) which was placed between two glass plates within a filter paper was pressed by 1 kg weight for 10 minutes in this method. The Soxhlet extraction method was used for fat determination [13]. A moisture determination is a good idea as the accurate weight of the sample can be found out easily. Total eight thimbles were used; four for fresh intensive lamb meat and four for fresh extensive lamb meat. And after 14 days again eight thimbles were used for water-based intensive & extensive and oil-based intensive & extensive samples.

**Sensory evaluation**

In the beginning, the sensory analysis was done to find out 2 water-based and 2 oil-based marinades out of 7 water-based and 7 oil-based marinades. Different parameters such as consistency, smell and taste were measured using the DLG quality test methods by 5 expert panel members. Marinades were again examined by those 5 expert panel members using DLG quality test method for different parameters such as appearance, look, color, composition, consistency smell and taste to finalize the final water-based and oil-based marinades [8]. In the second session of sensory analysis, intensive and extensive lamb meat samples were also examined before and after frying. DLG quality test method was used to compare some parameters such as appearance, smell and color before frying and look, color, composition of prepared meat, the consistency, smell and taste after frying [8]. Six (6) minutes frying process was done for each sample and while frying the inside of meat sample was examined randomly to check if it was properly cooked or not. Finally, two triangle tests were done to find out water-based and oil-based marinated meat. The ranking test was done to find out the best sample among fried fresh, fried oil-based and fried water-based marinated samples.

Total 18 (8 trained (excluding previous 5 expert panel members) and 10 untrained) panel members participated in these evaluations.

### Data analysis

The average values with a standard error of all the samples were calculated. Multiple comparisons (Tukey's HSD) was done to check the significant differences ($P < 0.05$) among fresh intensive, fresh extensive, intensive water-based marinated, extensive water-based marinated, intensive oil-based marinated and extensive oil-based marinated meat samples with the help of IBM SPSS (version 21) Statistics software [14]. The triangle test describes an assessment for determining whether a perceptible sensory difference or similarity exists between samples of two products. This assessment is a forced-choice method. It is applicable to find out whether a difference exists in a single sensory attribute or in several attributes. From the table of a minimum number of correct responses for the detection of a difference in the triangle test at various levels of significance, it would be detectable whether the level of difference is 5 % or 1 % or 0.1 %. The ranking test can be used to determine if a panel of assessors collectively agrees with the rank order of some property that a set of samples is known to have. F value was determined by detecting the average value and sum of the square of those data. From the calculated F value and the tabulated F value, it is detectable that whether the level of significant difference is 5 % or 1 % [15].

## RESULTS AND DISCUSSIONS

### Standardized marination recipes

Seven water-based marinades and seven oil-based marinades were developed and tested for consistency, smell and taste by the expert sensory panel to finalize 2 water-based marinades and 2 oil-based marinades at first (Table 1).

***Table 1.*** *Sensory evaluation for the selection of two water-based and two oil-based recipes*

| Type of marinade | No. of marinade | Sensory parameters | | | Approved / Eliminated |
|---|---|---|---|---|---|
| | | Consistency | Smell | Taste | |
| Water-based marinades | 1st marinade | Less fluid | Optimum | Optimum | **Approved** |
| | 2nd marinade | Optimum | Thyme smell | Sour, not homogenous | Eliminated |
| | 3rd marinade | Optimum | Not intensive | Bitter taste | Eliminated |
| | 4th marinade | Optimum | Optimum | Bitter taste | Eliminated |
| | 5th marinade | Tough texture | Chemical smell | Not homogenous | Eliminated |
| | 6th marinade | Tough texture | Not good | Not balanced, bitter taste | Eliminated |
| | 7th marinade | Optimum | Fruity aroma | Optimum | **Approved** |
| Oil-based marinades | 1st marinade | Optimum | Sour | Sour, not homogenous | Eliminated |
| | 2nd marinade | Oil separated | Optimum | Optimum | **Approved** |
| | 3rd marinade | Optimum | Not good | Not balanced | Eliminated |
| | 4th marinade | Not okay | Optimum | Garlic taste | Eliminated |
| | 5th marinade | No emulsion | Pleasant | Optimum | **Approved** |
| | 6th marinade | Not homogenous | Vinegar type | Not balanced | Eliminated |
| | 7th marinade | Not homogenous | Balsamic vinegar type | Not balanced | Eliminated |

The first marinade was selected for proper smell and taste and the 7th marinade was selected for proper consistency and taste from all the water-based marinades. 2nd and 5th oil-based marinades were selected for adequate smell and taste (Table 2).

***Table 2.*** *Sensory analysis based on 5-point Hedonic Scale to finalize the water-based and oil-based recipes*

| Sensory parameters | | Water based 1st recipe | Water based 7th recipe | Oil based 2nd recipe | Oil based 5th recipe |
|---|---|---|---|---|---|
| **Consistency** | Pleasant | 3 | 5 | 4 | 5 |
| | Tender | --- | 2 | 4 | 5 |
| | Less tender | 5 | --- | --- | 1 |
| | Juicy | --- | 5 | --- | 5 |
| | Less juicy | 5 | --- | 5 | --- |
| | Too soft | --- | 3 | --- | --- |
| **Smell** | Pleasant | 4 | 5 | 5 | 5 |
| | Mild | 5 | 5 | 5 | 5 |
| | Special meat smell | --- | --- | 5 | 5 |
| **Taste** | Pleasant | --- | 3 | 5 | 5 |
| | Tasty | --- | --- | 5 | 3 |
| | Intensive lamb smell | 4 | --- | --- | --- |
| | Spices balanced | --- | --- | 5 | --- |
| | Mild | 5 | 5 | --- | 2 |
| | Sweet | --- | 1 | --- | --- |
| | Seasoning unbalanced | 5 | --- | --- | 2 |
| | Too less meaty flavor | --- | 4 | --- | --- |
| | Too less salty | --- | --- | --- | 1 |

The appearance of the samples was observed before frying and different parameters under consistency, smell and taste were observed after frying the samples. Between 1st and 7th water-based marinades, the 7th recipe was finalized and between 2nd and 5th oil-based marinades, the 2nd recipe was finalized by panel members. DLG quality test methods were used to finalize the marinade where panelists marked on a 5-point scale [8].

***Table 3.*** *Final marination recipes*

| No. of ingredients | Water-based marination | | | Oil-based marination | | |
|---|---|---|---|---|---|---|
| | Ingredients | Total [g] | in 100 g | Ingredients | Total [g] | in 100 g |
| 1 | Cranberry syrup | 300 | 17.89 | Plain yogurt | 150 | 73.53 |
| 2 | Water | 900 | 53.67 | Dried red chili strings | 10 | 4.90 |
| 3 | Coarse salt | 57 | 3.40 | Coarse fresh garlic | 6 | 2.94 |
| 4 | Ground black pepper | 15 | 0.89 | Olive oil | 15 | 7.35 |
| 5 | Sliced onion | 150 | 8.94 | Dried thyme | 5 | 2.45 |
| 6 | Dried marjoram | 100 | 5.96 | Coarse salt | 6 | 2.94 |
| 7 | Dried red chilli strings | 55 | 3.28 | Soya oil | 12 | 5.88 |
| 8 | Dried rosemary | 100 | 5.96 | | | |

**Effect of marination on *p*H**

Fresh intensive meat showed significant difference with all the four marinated samples ($P < 0.05$). The water-based and oil-based marinade sample contained cranberry juice and plain yogurt, respectively, which had a lower *p*H value. Intensive meat with water-based marinade showed lower *p*H compared to oil-based marinade. Sugar from the cranberry juice in water-based marinade samples helped the substrates for the acid formation and thus decreased *p*H [16]. Both extensive water-based and oil-based marinated samples showed the lowest *p*H 5.21 (Table 4).

**Effect of marination on color**

Water-based marinade and oil-based marinade samples contained some ingredients like sliced onion, red chili string, soya oil and olive oil which were responsible for the higher light reflection than the fresh one. Fresh meat showed the highest a* value than the water-based marinade and oil-based marinade samples (Table 4). The denaturation of globin moiety occurred in the myoglobin molecule causes autoxidation while marinating meat for 14 days. Fresh samples showed less b* value than marinated meat. Water-based marinade samples showed the highest b* value as those contains rosemary and marjoram. Delta E ($\Delta E$) has been determined to find out the difference between 3 different types of intensive and extensive samples (fresh, water-based and oil-based). The values of $\Delta E$ were 6.08, 4.64 and 2.69 respectively. All the values were more than 1 i.e. JND (Just-Noticeable Difference - the smallest level of stimulation that an examiner can detect 50 % of the time) value, which proved that there was a significant difference in every case of fresh and marinated meat samples ($P < 0.05$). Early study has been also found that the extensive lamb meat always shows darker color with a lower L* value while comparing to intensive lamb meat because of higher myoglobin content and lower intramuscular fat [17, 18]. Thus, sensitivity to the stress of extensively raised lamb with a low energy diet gives them high muscle *p*H which will cause a low L* value [19].

**Effect of marination on volume loss**

Meat protein starts to denature when the temperature reached to 75 ºC. Longitudinal and transversal shrinkage of muscle fiber and shrinkage of connective tissue took place in the experiment. Intensive meat having skeletal muscle with high intramuscular fat content showed a low percentage of volume loss and the extensive meat having skeletal muscle with low-fat content and high amount of moisture and insoluble collagen showed a high level of volume loss. Oil-based marinated samples showed the highest level of volume loss compared to others. Length loss, width loss, height loss and volume loss are shown in the graph. There was no significant difference in the data (Table 4).

**Effect of marination on weight change**

Although intramuscular fat prevents weight loss in skeletal muscle but the moisture and insoluble collagen support to weight loss [20]. The fresh extensive sample showed lower weight loss than a fresh intensive sample. Water-based intensive and extensive

samples had lower weight loss than all other meat samples as they contain dried rosemary and marjoram which soaked most of the water from the marinade and from the meat for their hygroscopic nature. Oil-based marinated samples had the highest weight loss. There was no significant difference among the samples (Table 4).

***Table 4.*** *Comparison of different physicochemical properties (P < 0.05)*

| Number of sample | Type of meat | *p*H | CIELab color value | | | Volume loss [%] | Weight loss [%] |
|---|---|---|---|---|---|---|---|
| | | | L value | a value | b value | | |
| 1 | Fresh intensive | 5.88 ± 0.101$^{abcd}$ | 35.24 ± 4.84$^{a}$ | 23.41 ± 3.53$^{abcde}$ | 13.52 ± 4.64$^{abc}$ | 35.63 ± 4.96$^{a}$ | 39.09 ± 1.52 |
| 2 | Fresh extensive | 5.64 ± 0.112$^{fg}$ | 33.84 ± 2.58$^{bc}$ | 17.50 ± 4.44$^{afgh}$ | 13.40 ± 3.83$^{defg}$ | 44.60 ± 5.37 | 38.46 ± 1.31 |
| 3 | Intensive water marinated | 5.44 ± 0.197$^{a}$ | 36.42 ± 3.07 | 10.18 ± 1.62$^{bf}$ | 23.98 ± 2.59$^{adh}$ | 35.56 ± 7.34$^{b}$ | 37.16 ± 3.19$^{a}$ |
| 4 | Extensive water marinated | 5.21 ± 0.103$^{bfh}$ | 37.76 ± 3.56 | 13.75 ± 2.06$^{cij}$ | 26.63 ± 5.04$^{beij}$ | 36.56 ± 11.01 | 37.94 ± 3.47 |
| 5 | Intensive oil marinated | 5.52 ± 0.086$^{chi}$ | 39.02 ± 3.57$^{b}$ | 7.54 ± 3.47$^{dgi}$ | 18.23 ± 1.92$^{fhi}$ | 46.73 ± 8.87$^{ab}$ | 40.63 ± 2.87$^{a}$ |
| 6 | Extensive oil marinated | 5.21 ± 0.129$^{dgi}$ | 40.80 ± 3.65$^{ac}$ | 8.98 ± 3.68$^{ehj}$ | 20.92 ± 2.33$^{cgj}$ | 41.51 ± 7.62 | 38.96 ± 2.61 |

Values are means of three replicates. Superscript 'a' to 'j' in a row indicates higher to lower values respectively and the same superscripts were not significantly different (P > 0.05) *(Mean value ± Standard deviation)*

## Effect of marination on textural properties

Texture analysis was performed two times: before frying with Warner-Bratzler shear blade with "V" shape probe and after frying with guillotine probe. Both water-based and oil-based marinade samples needed higher force and work compared to the fresh samples (Table 5).

***Table 5.*** *Comparison of different physicochemical properties (P < 0.05)*

| Sl. No. | Type of meat | Texture analysis before frying | | Texture analysis after frying | | Moisture [%] | Water holding capacity [%] | Fat [%] |
|---|---|---|---|---|---|---|---|---|
| | | Force [N·cm$^{-2}$] | Work [Nm·cm$^{-2}$] | Force [N·cm$^{-2}$] | Work [Nm·cm$^{-2}$] | | | |
| 1 | Fresh intensive | 13.10 ± 5.22$^{ab}$ | 22.01 ± 7.82$^{ab}$ | 11.66 ± 2.85 | 12.44 ± 2.65 | 74.27 ± 1.48$^{ab}$ | 55.81 ± 2.65$^{abc}$ | 11.61 ± 0.72 |
| 2 | Fresh extensive | 14.65 ± 5.60$^{cd}$ | 24.23 ± 9.48$^{cd}$ | 12.55 ± 1.68 | 13.22 ± 1.53 | 74.12 ± 0.89$^{cd}$ | 56.77 ± 3.25$^{defg}$ | 7.06 ± 1.41$^{a}$ |
| 3 | Intensive water marinated | 23.15 ± 7.41$^{ace}$ | 35.26 ± 9.02$^{ace}$ | 11.96 ± 1.75 | 14.82 ± 2.09 | 68.85 ± 1.10$^{ac}$ | 36.10 ± 2.68$^{adh}$ | 14.53 ± 2.24$^{a}$ |
| 4 | Extensive water marinated | 16.67 ± 4.99 | 28.12 ± 6.93 | 12.26 ± 3.68 | 13.94 ± 2.39 | 70.43 ± 0.36$^{bd}$ | 38.08 ± 3.27$^{bei}$ | 11.16 ± 3.01 |
| 5 | Intensive oil marinated | 23.98 ± 6.45$^{bdf}$ | 38.30 ± 8.63$^{bdf}$ | 11.87 ± 2.24 | 13.83 ± 2.71 | 71.64 ± 0.07 | 47.80 ± 5.61$^{fhi}$ | 12.74 ± 0.07 |
| 6 | Extensive oil marinated | 14.37 ± 3.56$^{ef}$ | 24.20 ± 4.77$^{ef}$ | 12.13 ± 2.52 | 13.94 ± 1.69 | 72.02 ± 0.33 | 43.39 ± 3.12$^{chg}$ | 11.14 ± 1.65 |

Values are means of three replicates. Superscript 'a' to 'j' in a row indicates higher to lower values respectively and the same superscripts were not significantly different (P > 0.05) *(Mean value ± Standard deviation)*

Both intensive samples from water-based (23.15 $N \cdot cm^{-2}$, 35.26 $N \cdot cm^{-2}$) and oil-based (23.98 $N \cdot cm^{-2}$, 38.30 $N \cdot cm^{-2}$) marinades showed a higher value for force and work. Significant differences were found among the six categories of meat samples ($P < 0.05$). Fried samples needed less force and work comparing to non-fried samples. All three categories of fried intensive samples always took less force than extensive samples. Excess works were done for marinated meat sample compared to the fresh sample. There were no significant differences among the fried samples.

**Effect of marination on moisture content**

The fresh intensive meat showed 74.27 % (± 1.48) moisture content and indicates a higher standard error than the fresh extensive meat (74.12 ± 0.89). Fresh samples showed the highest and water-based marinade samples showed the lowest moisture content than the other four categories (Table 5). The moisture content of intensive and extensive water marinated meat was 68.85 % and 70.43 % which lower than both fresh and oil based marination. The water-based marinade recipe contained 4.6 g extra salt per kg than the oil-based marinade recipe which worked as a dehydrator [16]. Dried marjoram and rosemary in the water-based marinade sample were hygroscopic and soaked water from the meat samples and for the oil-based marinade, soybean oil and olive oil helped to retain the moisture.

**Effect of marination on water holding capacity (WHC)**

The fresh intensive and extensive meat had the highest WHC i.e. 55.81 % and 56.77 % while the water-based marinade (36.10 % and 38.08 %) and oil-based marinade (47.80 % and 43.39 %) samples had the lowest. The result agreed with previous study and the possible reason of decreasing WHC is not only the disruption of muscle fiber structure but also the denaturation of proteins [21]. While chilling for 14 days, WHC of marinated meat reduced. WHC of oil-based samples had not reduced like water-based marinade samples. The water-based marinade sample showed the lowest WHC as it contained a higher amount of salt. Salt helped water to come out from the meat. On the other hand, soybean oil and olive oil helped to retain water in the case of oil-based marinade meat samples (Table 5).

**Effect of marination on fat content**

Extensive meat samples contained less fat than intensive samples in case of fresh and marinated samples (Table 5). The meat yield of a carcass is inversely correlated with the subcutaneous fat layer. The fat contents were also higher for marinated samples while compared to fresh samples. The fat contents of oil-based marinade samples (intensive 12.74 % and extensive 11.14 %) were naturally higher as those contained a good amount of soya oil and olive oil.

**Sensory analysis**

All six categories of meat samples were checked for sensory evaluation by 5 expert members before and after frying. Before frying, different attributes for appearance were

checked. The result of Sensory analysis of six categories of meat before cooking is shown in Figure 1.

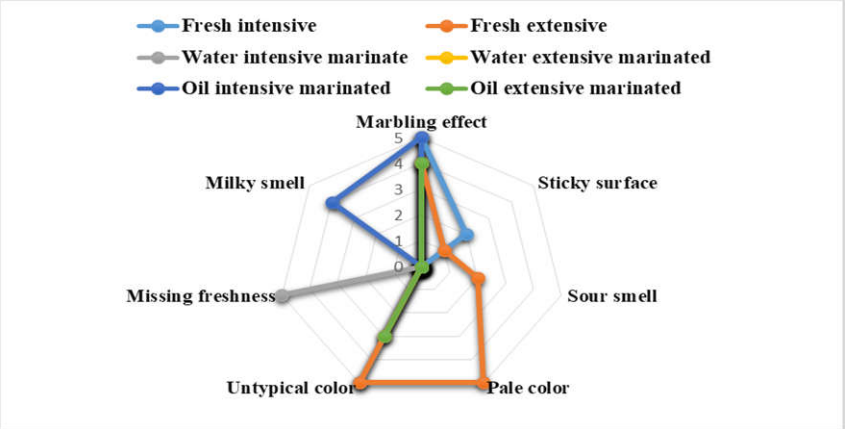


***Figure 1.*** *Sensory analysis of six categories of meat before cooking*

In case of the marbling effect, the entire panel member gave a full score to the intensive meat (Table 6).

***Table 6.*** *Sensory analysis based on 5-point Hedonic Scale on meat samples before and after frying*

| Sensory analysis | Sensory parameters | Fresh intensive | Fresh extensive | Water intensive marinate | Water extensive marinate | Oil intensive marinate | Oil extensive marinate |
|---|---|---|---|---|---|---|---|
| Sensory analysis on appearance of meat samples before cooking | Marbling effect | 5 | 4 | 5 | 4 | 5 | 4 |
| | Sticky surface | 2 | 1 | 0 | 0 | 0 | 0 |
| | Sour smell | 0 | 2 | 0 | 0 | 0 | 0 |
| | Pale color | 0 | 5 | 0 | 0 | 0 | 0 |
| | Untypical color | 5 | 5 | 0 | 3 | 0 | 3 |
| | Missing freshness | 0 | 0 | 5 | 0 | 0 | 0 |
| | Milky smell | 0 | 0 | 0 | 0 | 4 | 0 |
| Sensory analysis on color and consistency of meat samples after frying | Typical color | 5 | 0 | 5 | 5 | 5 | 5 |
| | Pale color | 0 | 5 | 0 | 0 | 0 | 0 |
| | Pleasant | 5 | 3 | 5 | 5 | 5 | 5 |
| | Not pleasant | 0 | 2 | 0 | 0 | 0 | 0 |
| | Tender | 5 | 4 | 5 | 5 | 5 | 5 |
| | Less tender | 0 | 1 | 0 | 0 | 0 | 0 |
| | Juicy | 5 | 0 | 5 | 5 | 0 | 2 |
| | Less juicy | 0 | 5 | 0 | 0 | 5 | 3 |
| Sensory analysis on smell and taste of meat samples after frying | Pleasant | 5 | 5 | 5 | 5 | 5 | 5 |
| | Tasty | 5 | 0 | 0 | 0 | 0 | 0 |
| | Smelling milky | 0 | 5 | 0 | 0 | 0 | 0 |
| | Tasting milky | 0 | 4 | 0 | 0 | 0 | 0 |
| | Untypical taste | 1 | 0 | 0 | 0 | 0 | 0 |
| | Seasoning unbalanced | 0 | 0 | 5 | 5 | 0 | 0 |
| | Too less seasoning | 0 | 0 | 0 | 0 | 3 | 5 |
| | Smelling spicy | 0 | 0 | 5 | 5 | 5 | 5 |

Fresh samples showed stickiness properties. All the members found a pale color in case of fresh extensive meat.
The color was found untypical for all extensive type meat samples with or without marinades as shown in Figure 2.

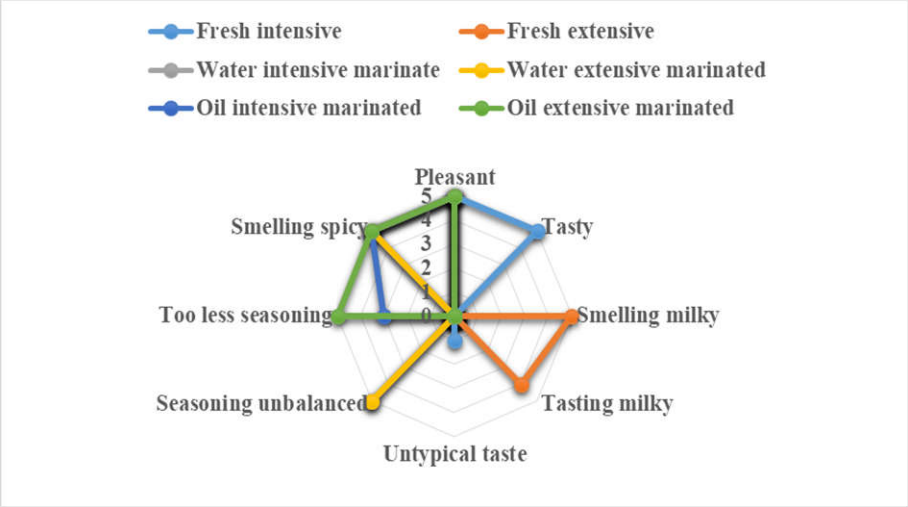


***Figure 2.*** *Sensory analysis on color and consistency of six categories meat after frying*

After frying, the fresh extensive sample did not show typical color rather too the pale color. Tenderness is the main sensory attribute on what consumer depends on. Fresh extensive and oil-based marinated extensive samples showed the most tenderness among all. The consistency was marked as pleasant for all the samples by 5-panel members except the fresh extensive sample, as shown in Figure 3.

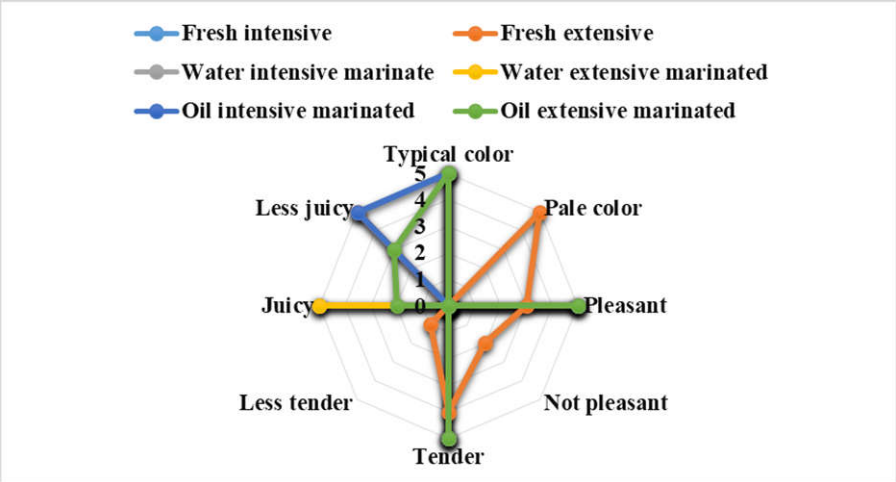


***Figure 3.*** *Sensory analysis on smell and taste on six categories of meat after frying*

For tenderness evaluation, marinated and fresh all samples were found tender. The fresh intensive sample was regarded as the juicy and fresh extensive sample was regarded as less juicy. In case of evaluation of smell and taste, all the six samples were regarded as

pleasant and fresh intensive ranked as the most pleasant one. The seasoning was balanced for the entire four samples except for water-based marinated samples (Table 6).

***Triangle test***

Triangle test was carried out to find out the odd sample (water-based extensive) from water-based marinade samples and to find out the odd sample (oil-based extensive) from oil-based marinade samples. For the first triangle test, 6 out of 8 experts and 3 out of 10 non-expert members found out the odd sample correctly. According to expert members, water-based extensive sample (odd sample) was dry, less aromatic, very spicy, soft, and different in texture than the other two. According to non-expert members, the sample had spicy flavor than the other two and was tender. As 9 persons found it correctly, there was a strong significant difference and level of significance was 0.20. For the second triangle test 6 out of 8 and 5 out of 10 found out correctly. For expert members, the oil-based extensive sample (odd sample) was tender, had strong smell, better taste than the other the two, juicy and less connective tissues than other two. For non-expert member, oil-based extensive sample had minor flavor comparing the other two and was juicy, tender, and salty. Significantly difference between oil-based extensive samples was found where the level of significance was 0.05.

***Ranking test***

Samples were fresh, extensive water-based marinated and extensive oil-based marinated. All 8 experts and 5 out of 10 non-experts selected the extensive oil-based marinated sample as the best sample. The reasons for selection were based on good taste, spicy, tender, juicy, reduced lamb flavor. 10 out of 18 put the extensive water-based marinated sample in their second ranking. That sample was pleasant and tender but had the spicy flavor. 13 out of 18 ranked the fresh as last number. It was not tasty and had strong lamb flavor inside. The score of extensive water-based marinate, extensive oil-based marinate and Fresh samples were 2.11, 1.28 and 2.61, respectively. The calculated F-test value 16.33 was greater than normal F value. Samples were significantly different, and the level of significance was 0.01 here.

## CONCLUSION

These findings indicated that the intensive oil-based marinated meat was the best sample in this study comparing all the parameters including consumers' preference. The fresh intensive sample showed better color appearance comparing with extensive meat. Both marinated samples should give a good impression to consumers as all samples showed good values in CIELab system. Oil marination may not be advised if processors concern about volume. In case of volume loss, oil based marinated sample showed significantly higher than any others. Effect of spices was discussed in details and the result reveled that marination supported much volume loss of all kind of meat samples. From the values of force and work, it was observed that before frying, the marination process did not help to tender the meat as the value of force was higher for marinated meat samples and lower for fresh samples. Significant differences were found in all cases. But after frying, it was observed that more or less force was needed for fresh and

marinated samples as there was no significant difference. Fresh meat samples showed significantly the highest values for water binding capacity and intensive marinated samples showed the lowest. Intensively produced lamb has significantly more amount of fat than extensively produced meat and it can cause a negative impression to the consumer as they always prefer lean meat with less visible fat. Marinated meat samples also showed higher fat content than fresh meat samples. Therefore, these results can be used as an important way to accelerate curing and tenderizing lamb meat or other tough meat. Additional studies should be performed to compare lamb meat from different countries in order to obtain more significant variations, and the microbial test is needed to detect the shelf life.

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