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Studies on chemical, physical and microbiological quality characteristics of Barki sheep burger fed on medicinal plants with yeast

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***Abstract*— *The current study aimed to evaluate the effect of dietary supplementation of medicinal plants with yeast on the fatty acid profile, chemical, physical and microbiological quality of Barki sheep burger during frozen storage at -20 °C for 90 days. Fifteen Barki lambs (13.46 ± 3.47 kg body weight, 4.5 months of age) were randomly divided into three groups (5 lamb/group). T1: control group fed on berseem hay and concentrate feed mixture. T2: fed on control diet + air dried powder of medicinal plants mixture which consisted of (garlic, cumin, ginger and turmeric). T3: fed as group two with (Saccharomyces cerevisiae). Results indicated that addition of yeast to medicinal plants significantly decreased ($p<0.05$) palmitic acid, myristic acid and increased the content of oleic acid and decatrienoic acid with non-significant effect on linoleic acid and α linolenic acid. Burger of medicinal plants with yeast group had the lowest index of atherogenicity (IA) which is healthier for human consumption. Feeding type had a slight significant effect on pH values of fresh sheep burger. No significant differences were found in shear force values of sheep burger. Cooking loss of sheep burger processed from sheep fed on medicinal plants recorded the lowest cooking loss, followed by sheep burger of medicinal plants with yeast. Burger of medicinal plants group showed the lowest TBA value. Feeding types and storage conditions significantly ($p<0.05$) affected on color parameters (L*, a* and b*). No significant changes in microbiological quality of sheep burger during frozen storage. In conclusion, sheep burger processed from lambs fed on diet supplemented with medicinal plants and yeast improved the composition of fatty acids, delayed the lipid oxidation and decreased the cooking loss without any negative effects on color parameters, shear force and microbial analysis which is subsequently affected on sheep burger quality and human health.*

***Keywords*— sheep burger; medicinal plants; yeast; quality characteristics**

I. INTRODUCTION

Sheep is Known as excellent source of protein, fatty acids, amino acids, vitamins and minerals, beside its unique flavor. Barki sheep breed is also commonly known for its tolerance to arid and semi-arid environmental conditions. For such advantages, sheep production is becoming increasingly important in Egypt because of sheep meat can be contributed in solving the problem of animal protein deficiency for human consumption [1]. Sheep meat quality is affected by many factors including, age, breed, sex, slaughter weight and feeding type [2].

Diet is the most important factor that influence on the fatty acids profile of animals' meat. In this regard, it is possible to enrich lamb meat and provide high quality products for consumers by modification sheep diet [3]. Recently, one of the feeding strategies to improve animal production is phytogenic additives, using of natural substances has a beneficial impact on animal health, animal products (milk and meat) quality and subsequently human health [4].

Medicinal plants can be used as natural feed additives to improve feed efficiency and growth rate [5]. Probiotics could enhance growth performance by improving rumen fermentation and increasing the uptake of nutrients which is resulting in increased yield of livestock products.

Yeast (*Saccharomyces cerevisiae*) is a commonly used probiotic in ruminant production to improve feed efficiency by increasing nutrients availability and utilization resulting in increased animal products' yield such as wool, milk and meat [6].

Despite these advantages, there is a lack of information available regarding the efficacy of feeding animals on medicinal plants alone or combined with yeast on the quality of meat products processing. Thus, this filed of research needs more investigations on how to modify and enrich meat to achieve meat products that meet consumer's desire.

Therefore, the objectives of the current study were to evaluate the effect of addition medicinal plants and yeast to sheep diets on fatty acid profile, chemical, physical and microbiological quality of sheep burger during frozen storage.

II. MATERIALS AND METHODS

The experimental procedures were approved by Animal and Poultry Nutrition Department and Animal Breeding Department, Poultry Production Division, Desert Research Center.

2.1 Location

The current study was conducted at Maryout Research Station belonging Desert Research Center, located 35km south west of Alexandria (Latitude 31.02 °N and Longitude 29.80 °E), Egypt.

2.2 Experimental design

Fifteen Barki lambs (4.5 months age, 13.46 ±3.47 kg body weight) were used. Lambs were randomly divided into three feeding groups (5 lamb/group). T1: the control group fed on berseem hay (*Trifolium alexandrinum*) and concentrate feed mixture (CFM) without additives. T2: fed on control diet + 1% air dried powder of medicinal plants mixture which consisted of garlic (*Allium sativum*), cumin (*Cuminum cyminum*), ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) with equal ratio (1:1:1:1). T3: fed as group T2 + yeast (*Saccharomyces cerevisiae*) 5 gm /head/ day. All animals were fed on 1.5 % of LBW hay + 2.5% of LBW concentrate according to NRC [7] requirements. At the end of the experiment period (224 days), all lambs were fasting for 12h and slaughtered at average final body weight 36.72 ± 5.70 kg. The hot carcass weighted and kept at 4 °C overnight, then weighed again.

2.3 Preparation of sheep burger

Carcasses of each feeding treatment were deboned with a sharp knife. Lean meat and fat were separately minced and weighted. Three batches of each feeding treatment were used in burger processing. Each batch was mixed with salt (1%, w/w) and black pepper (0.1%, w/w) and handily mixed and formed by using manual burger press machine (Metaltex No.25.17.25). Sheep burgers (1cm thickness, 10cm diameter and 65±2g weight) were placed in plastic foam trays packed in polyethylene bags and frozen at -20 ºC±1until further analysis.

2.4 Chemical analysis

2.4.1 Fatty acid profile

Fatty acid profile of raw sheep burger was determined as described by Folsch et al [8]. The fatty acids are methylated with boron trifluoride in methanol, extracted with heptane and determined by using a gas chromatograph (GC/MS/MS Agilent 7000, Germany) with FID detector (PE Auto System XL) with an auto-sampler and Eẓchrom integration system. Carrier gas (He); ca. 25Psi- air 450ml/min- Hydrogen 45ml- split100 ml/min.

2.4.2 TBA value

Assessment of lipid oxidation in raw sheep burger samples was determined as described in Oil Chemists' Society AOCS [9] by measuring 2- thiobarbituric acid reactive substances (TBARS). Results were expressed as (µmol TBARS/g).

2.5 Physical analysis

2.5.1 pH value

Estimation of pH values in raw sheep burger were assessed according to Khalil [10] by using a digital pH-meter (Jenway 3320 conductivity and pH meter, England).

2.5.2 Cooking measurements

Sheep burger were cooked in a preheated oven for 15 min each side. Cooking loss was determined by using the following equation according to Naveena et al. [11] as follows:

$$\text{Cooking loss (\%)} = \frac{(\text{Uncooked sample weight}) - (\text{Cooked sample weight})}{(\text{Uncooked sample weight})} \times 100$$

2.5.3 Shear force value

Cooked sheep burger shear force was determined by using Instron Universal Testing Machine (Model 2519-105, USA) for three times at different positions. Results were expressed as (Kg/f).

2.5.4 Color measurements

Color measurements (L^*, a^* and b^*) of raw sheep burger were evaluated according to CIE [12] by using Chroma meter (Konica Minolta, model CR 410, Japan). Lightness (L^* value), redness (a^* value) and yellowness (b^* value). Color measurement data for the samples was under standard illuminant D65 and 10º observer. The average was obtained of three spectral readings at different locations for burgers of each treatment.

2.6 Microbial analysis

The microbiological quality of raw sheep burger was evaluated at 0, 30, 60 and 90 days of storage at -20 °C. Total bacterial and psychrophilic bacteria counts were estimated as described by Ercolini et al. [13]. Molds and yeasts were estimated according to NMKL [14]. Results were expressed as log of Colony Forming Unit (log CFU/g).

2.7 Statistical analysis

All data were analyzed using statistical analysis system SAS [15]. Two- way ANOVA was applied for physical analysis (pH, shear force, cooking loss and color measurements), TBA and microbiological analysis. One – way ANOVA was applied for fatty acid.

III. RESULTS AND DISCUSSIONS

3.1 Fatty acid profile

Fatty acids profile of sheep burger processed from sheep fed on different types of medicinal plants and yeast is presented in Table 1. It was observed that feeding type had no significant effect on capric acid (C10:0), lauric acid (C12:0), pentadecanoic acid (C15:0), heptadecanoic acid (C17:0), stearic acid (C18:0). However, supplemented diets with yeast significantly decreased ($p<0.05$) palmitic acid (C16:0) and myristic acid (C14:0). Contrariwise, addition of yeast to diet increased the content of oleic acid (C18:1ω9) and decatrienoic acid (C16:3ω4). On the other hand, feeding types had no significant effect on linoleic acid (C18:2ω6) and α linolenic acid (C18:3ω3). However, burger of sheep fed on diet containing yeast had the higher ∑UFA, MUFA/ SFA and UFA/SFA than the other feeding groups. On the other hand, burger of yeast group had the lowest index of atherogenicity (IA) which is healthier for human consumption. These results are constant with Moreno-camarena et al. [16] result, where they found that dietary supplement with different levels of chromium-yeast decreased the palmitic (C16:0) and stearic (C18:0), while palmitoleic (C16:1n-7), vaccenic (C18:1n-7), linoleic (C18:2n-6) and arachidic (C20:4) fatty acids increased in lamb meat. Addition of yeast in sheep diets significantly decreased ($p<0.05$) the content of saturated, increased the content of monounsaturated and total of unsaturated fatty acids. Milewski et al. [17] found that meat of sheep fed on *Saccharomyces cerevisiae* (Inter Yeast® S brewer's yeast) had the lower palmitic acid (C16:0) and higher linoleic acid (C18:2ω6). Similar results were found by Milewski and Zaleska [18]. On the other hand, Rodríguez-Gaxiola et al. [19] found that supplemented diet with enriched-chromium yeast increased palmitic acid and decrease vaccenic acid in Rambouillet lamb meat. In addition, enriched-chromium yeast had no significant effect on the total content of saturated, unsaturated and unsaturated/saturated fatty acid ratio. Regards to feeding on medicinal plants, the results of the current study contradict the findings of Redoy et al. [20] they found that sheep meat of herbal-supplemented feeding groups had lower saturated fatty acids and higher unsaturated fatty acids content compared with the control diet group. Data of atherogenic index of sheep burger came in accordance with the results of [16] they found that significant decrease was found in the index of atherogenicity in sheep *Longissimus dorsi* as the level of yeast in the diet increased. Similar results were found by [17].

Table 1 Fatty acids profile of sheep burger

Fatty acids		T1	T2	T3	SEM
Capric acid	C10:0	0.71	0.71	0.11	0.20
Lauric acid	C12:0	0.94	0.89	0.12	0.27
Myristic acid	C14:0	4.41	4.79	2.41	0.66
Pentadecanoic acid	C15:0	1.13	1.14	1.22	0.13
Palmitic acid	C16:0	25.60^{ab}	29.37^{a}	22.96^{b}	1.13
Heptadecanoic acid	C17:0	2.83	2.38	2.22	0.27
Stearic acid	C18:0	21.81	20.92	23.26	0.92
Arachidic acid	C20:0	0.14	0.14	-	0.02
∑SFA		57.60^{ab}	60.37^{a}	52.33^{b}	1.47

Palmitoleic acid	C16:1ω7	1.77	1.75	2.42	0.17
	C16:1ω5	0.20	0.25	0.25	0.01
Oleic acid	C18:1ω9	32.38	30.94	37.17	1.36
Vaccinic acid	C18:1ω7	2.94	1.95	2.65	0.26
6 Octadecosanic acid	C18:1ω5	0.89	0.74	0.84	0.07
∑MUFA		38.79^{ab}	36.15^{b}	44.07^{a}	1.45
Linoleic acid	C18:2ω6	2.28	2.26	2.63	0.18
	C18:2ω5	0.28	0.29	0.24	0.01
Decatrienoic acid	C16:3ω4	0.59^{ab}	0.50^{b}	0.73^{a}	0.04
γ Linolenic acid	C18:3ω6	0.14	0.13	0.14	0.01
α Linolenic acid	C18:3ω3	0.21	0.20	0.19	0.01
α Octadectetraenoic	C18:4ω3	0.28	0.24	0.35	0.03
∑PUFA		3.22	3.14	3.57	0.20
∑UFA		42.01^{ab}	39.29^{b}	47.64^{a}	1.56
UFA/SFA		0.73^{ab}	0.65^{b}	0.91^{a}	0.04
MUFA/ SFA		0.68^{ab}	0.60^{b}	0.84^{a}	0.04
PUFA/ SFA		0.05	0.05	0.07	0.04
∑ω6		2.43	2.39	2.78	0.18
∑ω3		0.50	0.45	0.54	0.04
n-6: n-3		4.84	5.75	5.23	0.44
Index of atherogenicity (IA)		1.08	1.27	0.68	0.13

$^{a-b}$ means within the same row with different superscripts letters are different ($p<0.05$). T1: control, T2: contains medicinal plants, T3: contains medicinal pants with yeast. SEM: standard error of means. Index of atherogenicity (IA) = [C12:0 + (4 × C14:0) + C16:0]/ ∑UFA.

3.2 Physical properties

3.2.1 pH values

Data of the physical properties of sheep burgers processed from sheep fed on different types of medicinal plants and yeast during frozen storage are illustrated in Table 2. It can be noticed that feeding type had a slight significant effect on pH values of fresh sheep burger. Regards to storage time, significant decrease ($p<0.05$) was found in all burger samples after 60 days of storage and surprisingly significant increase was found at the end of storage time 90 days. These results are consistency with data of Tekce et al. [21] they indicated that slight significant differences were found in pH values of lambs fed on rations supplemented with different doses of probiotics and yeast. Similarly, Gloria-Trujillo et al. [22] postulated that lambs fed diets supplemented with different levels of *Saccharomyces cerevisiae* had no significant effect on pH values of meat. On the other hand, Smeti et al. [23] they stated that feeding lambs on aromatic plants not affected on pH values of lamb meat. Similarly, Lozano-Sánchez et al. [24] they reported that lambs fed on diet supplemented with different levels of polyherbal had no significant effect on pH values of lamb meat. However, the decrease or the increase in pH values during frozen storage is due to the microbial activity. The decrease in pH values is probably due to the increase in psychrophilic bacteria activity leading to producing lactic acid which is responsible for the decrease in the pH values. On the other hand, the increase in decomposition bacteria and enzymes activity resulting in producing alkali compounds which is responsible for increase the pH values [25].

Table 2 Physical properties of sheep burger during frozen storage at -20 °C for 90 days

	Storage periods (days)				
Treatments	0	30	60	90	SEM
		pH value			
T1	6.39^{aAB}	6.03^{abB}	5.81^{bA}	6.04^{abA}	0.06
T2	6.23^{aB}	6.33^{aA}	5.86^{bA}	6.17^{aA}	0.06
T3	6.56^{aA}	5.96^{bB}	5.99^{bA}	6.20^{abA}	0.06
		Tenderness (Shear force value kg/f)			
T1	1.50^{aA}	1.87^{aA}	1.31^{aA}	1.61^{aA}	0.20
T2	1.75^{aA}	1.40^{aA}	1.23^{aA}	1.81^{aA}	0.20
T3	1.28^{aA}	1.59^{aA}	1.04^{aA}	1.51^{aA}	0.20
		Cooking loss (%)			
T1	45.96^{bA}	51.51^{aA}	48.34^{aA}	42.07^{bA}	1.38
T2	39.31^{bB}	49.44^{aA}	48.19^{aA}	45.07^{aA}	1.38
T3	40.91^{bAB}	48.49^{aA}	45.90^{aA}	38.41^{bB}	1.38

$^{a-b}$ means within the same row with different superscripts letters are different ($p<0.05$).

$^{A-B}$ means within the same column with different superscripts letters are different ($p<0.05$).

T1: control, T2: contains medicinal plants, T3: contains medicinal pants with yeast.

SEM: standard error of means.

3.2.2 Shear force

No significant differences were found in shear force values among sheep burger of feeding groups as shown in Table 2. Regards to storage condition, although slight increase was found in shear force values during frozen storage, but the differences were not significant. These findings came in accordance with the results of Orzuna-Orzuna et al. [26] they documented that feeding lambs with diet supplemented with polyherbal mixture had a slight difference on shear force of meat. Similar results were found by [24] they reported that shear force values not affected by feeding lambs on polyherbal diets. On the same line, Marcon et al. [27] indicated that diet supplemented with curcumin had no significant effect on shear force of lamb meat. On the other hand, Guimarães et al. [28] found that diets containing yeast (*Saccharomyces cerevisiae*) not significantly affected on shear force value of lamb meat.

3.2.3 Cooking loss

Cooking loss of sheep burger processed from sheep fed on different types of medicinal plants recorded the lowest cooking loss, followed by sheep burger of medicinal plants with yeast (Table 2). During frozen storage, significant increase ($p<0.05$) in cooking loss was found in all burger samples after 30 days, followed by significant decrease till the end of frozen period 90 days. However, at any time of frozen storage burger processed from medicinal plant with yeast recorded the lowest cooking loss. The results of the current study contradict the findings of [26] they stated that cooking loss significantly increased in lamb meat fed on polyherbal mixture and cooking loss increased as the doses of polyherbal mixture increased. Similarly, [20] they found that cooking loss of sheep meat feeding on diets supplemented with herbals was higher than control feeding group. Regards to storage conditions, the changes in cooking loss are consistency with results of Sadallah and Khalil [29] they found that cooking loss of all the lamb samples significantly increased after 30 days of frozen storage after that the reduction in cooking loss was small and not significant till the end of storage period.

3.2.4 Color measurements

Data of color measurements of sheep burger from sheep fed on different types of medicinal plants and yeast are showed in Table 3. Feeding types and storage conditions slightly affected in $L*$ values of sheep burger. Contrarily, feeding types and storage conditions significantly affected in $a*$ values. Burger of control group had the highest $a*$ value followed by burger of medicinal plants, while the lowest $a*$ value found in burger of medicinal plants with yeast. Regards to storage time, $a*$ values significantly decreased after 30 days of storage in all burger samples, followed by slight increase after 60 days and the decreasing continued till the end of storage time 90 days. Conversely, *b** values not affected by types of feeding. Regarding to storage time, significantly increased after 30 days of storage and slight decreased after 60 days and the increased continued to the end of storage 90 day. The changes in color measurements of sheep burger are close to results that obtained by [26] they found that supplemented lamb's diet with polyherbal mixture had no significant changes on meat color parameters (*L**, *a**, *b**). In the same line, [24] indicated that addition of polyherbal as supplementation not significantly affected on meat color measurements. On the other hand, [28] found that addition of yeast (*Saccharomyces cerevisiae*) to lambs' diet not affected on meat color. The changes in color parameters during frozen storage are concordant with the results of Fernandes et al. [30] they found that (*L** values) of lamb meat did not significantly change during frozen storage time. On the other hand, the changes in *a** values were not significant. Contrarily, *b** values showed significant variation during storage, which can be explained by a quadratic model of decreased followed by increase till the end of storage period.

Table 3 Color measurements of sheep burger during frozen storage at -20 °C for 90 days

	Storage periods (days)				
Treatments	0	30	60	90	SEM
			*L**		
T1	55.35^{bA}	58.44^{aA}	57.72^{bA}	57.18^{bA}	0.67
T2	56.26^{aA}	58.58^{aA}	57.10^{aA}	57.83^{aA}	0.67
T3	56.37^{aA}	56.47^{aA}	56.73^{aA}	58.52^{bA}	0.67
			*a**		
T1	8.94^{aA}	3.78^{bA}	4.51^{bA}	3.67^{bA}	0.28
T2	7.53^{aB}	3.88^{bA}	4.47^{bA}	4.04^{bA}	0.28
T3	5.71^{aC}	4.33^{bA}	4.24^{bA}	2.89^{cB}	0.28
			*b**		
T1	9.40^{cA}	11.72^{abA}	11.06^{bB}	12.45^{aA}	0.27
T2	9.69^{bA}	12.05^{aA}	12.04^{aA}	12.89^{aA}	0.27
T3	9.86^{bA}	12.58^{aA}	12.21^{aA}	12.38^{aA}	0.27

$^{a-c}$ means within the same row with different superscripts letters are different (p<0.05).
$^{A-C}$ means within the same column with different superscripts letters are different (p<0.05).
T1: control, T2: contains medicinal plants, T3: contains medicinal pants with yeast.
SEM: standard error of means.

3.3 TBA value

Table 4. showed the effect of feeding and storage time on TBA values of raw sheep burger. It can be noticed that at zero time, no significant differences were found in sheep burger samples. During frozen storage, significant decreased (p<0.05) were found in all burger samples after 30 days of storage and the decreasing continued till 60 days of storage which recorded the lowest TBA values in all burger treatments. Significant increase was found at the end of frozen period 90 days. Regards to feeding type, burger processed from sheep fed on medicinal plants showed the lowest TBA value during storage time followed by burger processed from sheep fed on medicinal plants with yeast while, burger of control group showed the highest TBA values at the end of storage time. These results are close to that obtained by Leal et al. [31] they found that TBA values of lamb meat significantly increased as the time of storage increased. Also, they found that meat from lambs supplemented with vitamin E and rosemary extracts exhibited the lower TBA than meat of control feeding group. In the same line, Afele et al. [32] they found that Malondialdehyde (MDA) significantly decreased in meat of sheep fed on diet supplemented with garlic and ginger powder than meat of control group. Generally, the decrease in TBA values in meat of medicinal plants feeding groups may be due to the bioactive compounds such as Gingerol in ginger and allicin in garlic which are responsible for the high antioxidant activity. TBA value of lamb meat fed on yeast was higher while, the lower TBA value found in meat fed on yeast with minerals [28].

Table 4 TBA value of sheep burger during frozen storage at -20 °C for 90 days

	Storage periods (days)			
Treatments	0	30	60	90
	TBA value (μmol TBARS/g)			
T1	26.51^{aA}	10.50^{bA}	6.58^{bA}	25.42^{aA}
T2	30.38^{aA}	13.34^{bA}	9.21^{bA}	14.35^{bB}
T3	33.12^{aA}	14.66^{bcA}	10.55^{cA}	18.08^{bB}
SEM	1.71	1.71	1.71	1.71

$^{a-c}$ means within the same row with different superscripts letters are different (p<0.05).

$^{A-B}$ means within the same column with different superscripts letters are different (p<0.05).

T1: control, T2: contains medicinal plants, T3: contains medicinal pants with yeast.

SEM: standard error of means.

3.4 Microbiological quality

Table 5. showed the microbiological quality of sheep burger during frozen storage. It can be noticed that feeding types had slight effect on total bacterial count of sheep burger samples. During frozen storage, burger of medicinal plants group exhibited lower total bacterial count than burger of yeast group. On the other hand, feeding types and storage condition had no significant effects on psychrophilic bacteria, mold and yeast counts. These results are close to that obtained by [30] they found that microbiological analysis showed good stability during storage period. On the other hand, Al-Rubeii and Hussen [33] found that feeding lambs on diet supplemented with medicinal plants resulting in significant decreased in total plate count and psychrophilic count in lamb meat during cold storage periods.

Table 5 Microbiological quality of sheep burger during frozen storage at -20 °C for 90 days

Treatments	**Storage periods (days)**				
	0	**30**	**60**	**90**	**SEM**
	Total bacterial count (log CFU/g)				
T1	4.24^{aB}	4.56^{aA}	4.08^{aAB}	4.08^{aA}	0.33
T2	4.60^{aB}	4.51^{aA}	3.47^{bB}	4.46^{aA}	0.33
T3	5.85^{aA}	4.45^{bA}	4.43^{bA}	4.78^{abA}	0.33
	Psychrophilic (log CFU/g)				
T1	3.84^{aA}	3.28^{aA}	3.70^{aA}	3.57^{aA}	0.37
T2	3.82^{aA}	3.86^{aA}	3.50^{aA}	3.74^{aA}	0.37
T3	4.64^{aA}	3.46^{aA}	3.88^{aA}	4.23^{aA}	0.37
	Mold and yeast (log CFU/g)				
T1	4.23^{aA}	5.54^{aA}	3.27^{aA}	2.95^{aA}	0.57
T2	3.56^{aA}	4.00^{aA}	3.79^{aA}	2.41^{aA}	0.57
T3	5.11^{aA}	4.39^{aA}	4.14^{aA}	3.44^{aA}	0.57

$^{a-b}$ means within the same row with different superscripts letters are different (p<0.05).

$^{A-B}$ means within the same column with different superscripts letters are different (p<0.05).

T1: control, T2: contains medicinal plants, T3: contains medicinal pants with yeast.

SEM: standard error of means.

IV. CONCLUSION

The purpose of the current study was to evaluate the quality characteristics of sheep burger processed from sheep fed on diets supplemented with medicinal plants as feed additives and yeast as probiotic during frozen storage. The addition of medicinal plants combined with yeast improved the fatty acid profile, delayed the lipid oxidation and decreased the cooking loss without negative effects on color parameters, shear force and microbial analysis during frozen storage which subsequently affected on sheep burger quality and human health.

AUTHORS CONTRIBUTION

E.F.Z. and M.M.G. Formal analysis: E.F.Z. and M.M.G. Investigation: E.F.Z. and M.M.G. Methodology: E.F.Z. and M.M.G. Writing—original draft preparation: E.F.Z. Writing—review, and editing: E.F.Z. Validation and supervision: E.F.Z. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Animal care and experimental protocol were reviewed and approved by the Local Experimental Animals Care and Welfare Committee in Desert Research Center.

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DATA AVAILABILITY

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

CODE AVAILABILITY

Not applicable.

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