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MICROBIOLOGICAL, PHYSICOCHEMICAL AND TECHNO-FUNCTIONAL CHARACTERIZATION OF DRIED SALTED *KADDID* PRODUCED IN SOUTHWESTERN ALGERIA

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Abstract

Description of the subject: *Kaddid* is a traditional dry-salted meat produced in Maghreb countries.
Objective: *Kaddid samples* from Southwestern Algeria were analyzed for their characteristics.
Methods: After 12-14 days of homemade production, microbiological, physicochemical and techno-functional analyses have been performed.
Results: The microbiological survey, showed the salt tolerant coagulase negative *Staphylococcus* as the dominant population. Lactic acid bacteria (LAB), total coliforms and yeast/molds were present in all *Kaddid* samples with lower count. Physicochemical characterization showed pH and total titratable acidity with average values of 5.55±0.03 and 1.81±0.4% lactic acid, respectively. Moisture (8.7±3.5%) was in correlation with low a_w (0.68±0.03). Protein and fat content were variable among samples exhibiting average values of 12.1±2.5% and 10.9±2.1%, respectively, salt content was high (average 12.2±4%). Functional properties showed low hygroscopicity, moderate water absorption while higher oil absorption; moderate foaming and emulsifying capacities/stability were also determined.
Conclusion : Characterization of traditional meat products like *Kaddid* would allow to preserve their particularities while assure safety and sensory traits.
Keywords : *Kaddid*; lactic acid bacteria; microbiology; meat; functionality.

CARACTÉRISATION MICROBIOLOGIQUE, PHYSICO-CHIMIQUE ET TÉCHNO-FONCTIONNELLE DU *KADDID* SALÉ ET SÉCHÉ PRODUIT DANS LE SUD-OUEST ALGÉRIEN

Résumé

Description du sujet : Le *Kaddid* est une viande traditionnelle salée et séchée, produite dans les pays du Maghreb.
Objectifs : Analyser la qualité des échantillons du *Kaddid* fait-maison produit dans le Sud-Ouest Algerien.
Méthodes : Des échantillons du *Kaddid* de 12-14 jours de maturation ont subi des analyses microbiologique, physicochimique et techno-fonctionnelle.
Résultats : Les analyses microbiologiques ont montré que les *Staphylococcus* à coagulase négative (SCN) tolérant au sel sont la population dominante. Les bactéries lactiques (BL) sont présentes dans tous les échantillons du *Kaddid* même en faibles valeurs, tandis que les coliformes totaux et les levures/moisissures sont moins présents. La caractérisation physicochimique a montré que le pH et l'acidité titrable totale (ATT) ont des valeurs moyennes de 5,55±0,03 et 1,81±0,4% d'acide lactique respectivement. La valeur moyenne de l'humidité : 8,7±3,5% était en corrélation avec un faible a_w : 0,68±0,03. La teneur en protéines et en matières grasses étaient variables entre les échantillons avec des valeurs moyennes de 12,1±2,5% et 10,9±2,1%, respectivement, la teneur en sel était élevée (moyenne 12,2±4%). Les propriétés fonctionnelles ont montré une faible hygroscopicité, une absorption d'eau modérée tandis l'absorption d'huile a éte plus élevée, ainsi que des capacités/stabilité moussantes et émulsifiantes modérées.
Conclusion : La caractérisation des produits carnés traditionnels comme le *Kaddid* permet de préserver leurs particularités tout en assurant la sécurité et ses attributs sensoriels.
Mots clés : *Kaddid* ; Bactéries lactiques ; Microbiologie ; Viande ; Fonctionnalité.

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INTRODUCTION

Countries bordering the Mediterranean Sea such as Algeria, Morocco, Tunisia, Libya and Mauritania referred as Maghreb, produce a range of traditional meat products and only a few of them were characterized. These traditional products represent one of the ancient cultural heritages of the North African and Mediterranean countries. Even today, ethnic meat products are generally homemade as a mean to preserve meat to be consumed in times of scarcity, locally or regional consumed, representing historical and cultural valuable products involving inherited expertise transferred from ancient times[1]. Among traditional products, the appreciation of fermented meats is probably related to their unique and specific sensory properties, convenience and alleged rootedness in a socio-cultural context. Meat products prepared in North African countries are usually dried or cooked because of the weather and are rarely smoked; they are produced from different meat (beef, camel, lamb and goat) depending on the geographic area and present various shapes, size and sensorial features as any part of the carcass is used [1]. Algerian *Kaddid* is a popular food highly appreciated by consumers for its unique salty and spicy taste; its prepared by adding salt, spices to lamb meat cutting into thin strips to facilitate salt diffusion and dried [1, 2]. During periods when meat is available, *Kaddid* is prepared according to the Algerian Saharan method in large quantities, by salting, adding spices (a mix of garlic, hot red pepper, black pepper,coriander, cumin, etc.) and drying; meat strips are then exposed to a ventilated place in the shadeby hanging on a string until thoroughly dried (12 to 14 days). Then, dried product is stored at ambient temperature for up to one year, salt content in the final product being in the range of 7-12% [3]. The climatic conditions, meat used and spices will determine the physicochemical, microbiological, final sensory features and quality of *Kaddid*. Its long preservation is related to the lowering of the water activity (a_w) and salting during processing. As the preliminary step in the elaboration, salting is a critical stage to obtain a product with acceptable sensory quality and self-life. Whatever the salting method (dry salting or brining)during osmotic process, two main simultaneous flows are generated: water loss and salt uptake, the effect of salting method on water exudation and NaCl uptake by the meat being dependent on factors such as temperature, dry salting or brine concentration, product size and solution-to-material ratio [4].Moreover, changes in meat and fat are responsible of the strong flavor of *Kaddid*, proteolysis and lipolysis by meat enzymes and those from the present microbiota will affect the development of typical sensorial characteristics. Preliminary research on the changes of the structural meat proteins and their relation to texture and typical flavor of dry-cured meat products were studied in the 1990s by Toldrá [5]. Extensive hydrolysis of muscle proteins were then confirmed by other authors [6]. Research studies on *Kaddid* have been reported focusing on physicochemical and microbiological quality[3, 7, 8, 9], as well as experimental preparation and optimization of the salting/drying process [6, 4].were carried out. The regional cultural differences vary greatly within the Maghreb region, and even within the same country, giving rise to different style on food, thus the microbiological, physicochemical and functional characteristics of Southwestern Algerian dry-salted *Kaddid* were investigated in this study.

MATERIAL AND METHODS

1. Samples collection and survey

A preliminary survey was performed on animal (species) meat used for traditional *Kaddid* preparation, manipulation process, salted technique, type of ingredients added and ripening conditions. Samples of homemade *Kaddid* produced by local population were collected from the Southwestern region of Algeria during November 2013, namely Tindouf (one sample) and Béchar (6 samples) provinces. Four hundred (400) g of ready to consume *Kaddid* pieces from each producer were placed in sterile plastic bags and refrigerated transported to the laboratory for further analysis.

2. Microbiological characterization

After leaving during 20 min at room temperature, *Kaddid* samples were ground in a sterilized mortar and transferred (10 g) into a sterile stomacher bag and 90 ml of tryptone-salt-diluent (tryptone, 1g/L; NaCl 0.85g/L;Tween 80, 1 ml/L), was added. After homogenization in a Stomacher (Stomacher Lab-Blender 400, A.J.Seward Lab. London, UK) for 3 min, the suspension was left for 15 min for bacterial revivification. From this stock solution, dilutions were prepared and count of each microbial group was made in duplicate.

Total mesophilic bacteria were determined using plate count agar (PCA) incubated at 30°C during72 h. For lactic acid bacteria MRS-5.4 agar with acetic acid (pH 5.4) for bacilli and M17 agar for cocci were used and incubated microaerobically at 30ºC during72 h. OGA agar supplemented with oxytetracycline and gentamicin was used for yeast/molds counts, incubated at 22°C for 5 days. MacConkey (Biokar, France), Baid Parker (BP) supplemented with egg-yolk emulsion and potassium tellurite (Biokar, France) and meat liver-sodium sulphite (ML-SR; BiolifeItaliana SRL) agar media for enumeration of total coliforms, staphylococci and clostridia, respectively (incubated at 37°C; 24-48 h) were used to investigate the hygienic quality of *Kaddid* samples. In addition, *Escherichia coli* were revealed by gas and indole production, whereas colonies identified as *Staphylococaceae* were subjected to coagulase test. The search for *Salmonella* sp. was performed in three stages, pre-enrichment (peptone water, 20 h at 37°C), enrichment (selenite cysteine and Rappaport Vassiliadis broths incubated at 37°C and 42°C for 24 h, respectively) and then plated on *Salmonella-Shigella* (SS) selective medium (incubated at 37°C; 24 h). Moreover, *Pseudomonas* sp. was searched by using King A and King B pigmentation agar media (30°C; 48 h), isolates growing with/without pigmentation were counted. Furthermore, strains considered as *Enterobacteriaceae* and *Staphylococaceae* were identified by physiological tests and rapid biochemical galleries (API20E and API Staph respectively. Biomerieux, France), whereas five (5) colonies selected as *Pseudomonas* sp, were identified by using physiological and biochemical tests. Physiological and biochemical profile similarities of studied strains were performed by using Database network service (http://www.tgw1916.net/bacteria_Ent.html).

Finally, for each *Kaddid* sample colonies (20-25) from MRS-5.4 and M17 plates were randomly picked and after purification by successive streaking on each media agar plates, Gram and catalase test were performed. Those isolates that were Gram-positive and catalase negative (presumptive LAB) were stored in glycerol at -80°C for further tests and experimentations.

3. Physicochemical characterization

3.1. Determination of pH

Kaddid samples pH was determined according to the method described by Wang et *al*.[10]. Ten (10) g of each sample were homogenized with 90 ml of distilled water (1:10 w/v) in Stomacher and a pH-meter (Hanna Instruments, Italy) was used for the measurement.

3.2. Determination of titratable acidity (TTA)

Ten (10) ml of 1:10 suspension were titrated with 0.1N NaOH using phenolphthalein as indicator and expressed as % of lactic acid on a dry matter basis[11].

3.3. Moisture determination

Five (5) g of each *Kaddid* samples were introduced in an oven (102°C) up to a constant weigh [12]. Dry matter was also calculated.

3.4. Water activity (aw) determination

A water activity meter (AquaLlabLITE, Decagon DevicesInc, WA) at 30°C was used to measure this parameter.

3.5. Salt determination

Sodium chloride content was determined using KSCN and AgNO3, using $FeSO_4$ as indicator [12].

3.6. Protein, fat and ash determination

Kjeldahl method was used, N-total being determined and multiplied by 6.25 for protein content [13]. Fat was determined according to [12], while for ash content 5 g of each sample were placed in a muffle furnace (550°C) until complete combustion, and weight differences were calculated [12].

4. Techno-functional properties

4.1. Hygroscopicity determination

Five (5) g of each *Kaddid* sample were exposed to ambient conditions (temperature and humidity) and the weight gain % after 48 h were recorded [14].

4.2. Water and oil absorptioncapacity (WAC and OAC) and stability

The method described by Beuchat [15].with minor modificationswas used. One-gram of each sample was mixed with 10 ml of distilled water or sunflower oil (Fleurial-Cevital Agro-industries, Algeria) for 30 sec using a vortex mixer. Samples were then allowed to stand (30°C) in a water bath, centrifuged (5000 rpm; 20 min) and supernatants volume were recorded (density of water is assumed to be 1g/ml and that of oil 0.91 g/ml).

4.3. Foaming capacity (FC) and stability (FS) determination

The method described by Padmashree et *al*. [16].was used. For each sample, a suspension was prepared by adding 3.0 g of meat to 300 ml of distilled water, mixed (10000 rpm; 5 min), the homogenized mix was let standing for 30 sec and the suspension volume was measured. FC was expressed as volume %, while at 300 min after stirring FS was calculated.

4.4. Emulsifying capacity (EC) and stability (ES) determination

Yatsumatsu et *al*. [17], methodology was applied. Seven (7) g of meat sample was suspended in 100 ml of water and then 100 ml of sunflower oil was added to it. The mixture was emulsified with a mixer at high rpm for 1 min. Fifty (50) ml of the obtained emulsion was centrifuged (1300 rpm; for 5 min). The emulsifying capacity was calculated as the height of emulsified layer/height of total layer in the tube x 100. ES % was recorded after 300 min.

5. Statistical analysis

The package MINITAB 14 (Minitab Inc. State College, PA, USA) using ANOVA General Linear Models followed by a Tukey's post hoctest, was used, and $p<0.05$ was considered significant. Unless otherwise indicated, all values were the means of two independent trials ± standard deviation. No significant differences were observed between individual replicates.

RESULTS

1. Survey results

According to the survey, *Kaddid* is used as ingredient to flavor Algerian traditional dishes. *Kaddid* preparation is generally done during the *Al-Adha* feast celebration when lamb meat isavailable in excess at home, except for sample 4 that was from camel meat. It was found that the preparation method of the samples was similar. The meat (mostly fatty sheap cuts) was cut into strips, dried-salted and spiced. Spices added varied in the different samples, however all samples contained at least one spice usually black and/or red pepper, cumin and/or a cocktail of spices. The results showed that the dry-salting/spicing step was applied by rubbing onto the strips by hands and then treated meat strips were hang to dry in the shade, with the exception of sample 2 which was dried in the sun. A preparation steps is shown in Figure 1.

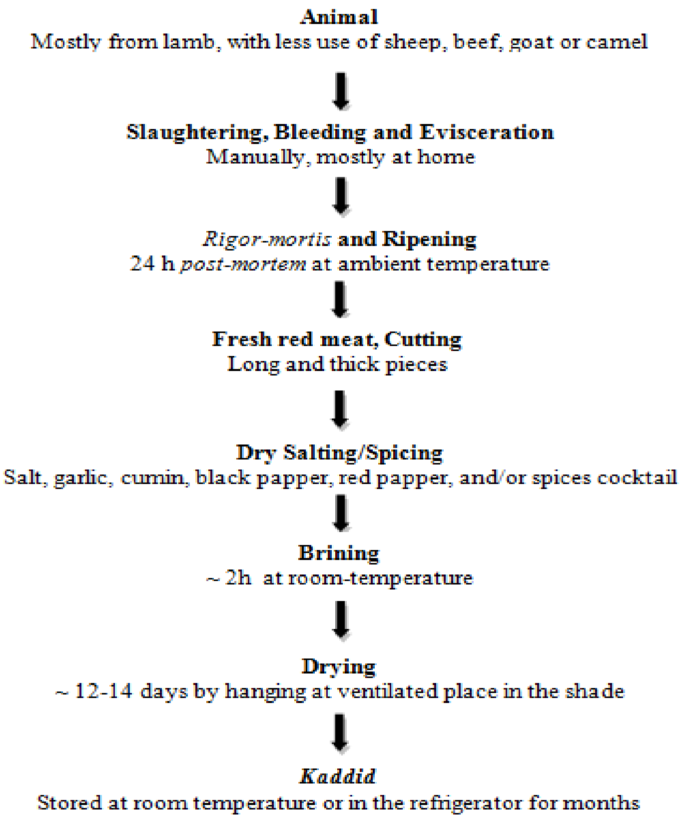

Figure 1: Diagram of Southwestern Algerian *Kaddid* preparation

2. Microbiological characterization

Homemade Algerian *Kaddid* after 12-14 days of drying in the shade showed average counts for total mesophilic bacteria of 4.47±0.2 log CFU/g. Lactic acid bacteria (LAB) were present in all *Kaddid* samples with lower counts, values of 1.57±0.1 and 2.20±0.1 log CFU/g for MRS-5.4 and M17 media were found, the highest numbers were recorded for *Kaddid* sample 7 (Table 1).

Table 1: Microbiological characterization of homemade Algerian *Kaddid* (log CFU/g)

Sample	Total bacteria*	LAB		Staphylococci	Total coliforms	Clostridia	Yeast & molds
		MRS-5.4	M17				
SK1	4.24±0.2	1.25±0.1	2.05±0.1	2.54±0.2	1.85±0.2	-	1.15±0.1
SK2	4.71±0.1	1.70±0.1	2.32±0.2	3.12±0.2	1.98±0.2	1.30±0.1	1.25±0.1
SK3	4.08±0.1	1.18±0.2	1.85±0.2	2.85±0.1	1.89±0.1	1.69±0.1	1.07±0.1
SK4	4.24±0.2	1.32±0.2	2.08±0.1	2.92±0.2	1.32±0.2	-	< 1.00
SK5	4.37±0.1	1.80±0.1	2.25±0.1	3.17±0.1	1.65±0.2	-	1.45±0.1
SK6	4.70±0.2	1.75±0.1	2.35±0.1	3.32±0.2	2.07±0.2	-	< 1.00
SK7	5.01±0.2	2.03±0.2	2.54±0.1	3.40±0.2	2.10±0.1	-	1.50±0.1
Average	4.47±0.2	1.57±0.1	2.20±0.1	3.04±0.2	1.83±0.2	-	1.26±0.1

*mean ± standard deviation; (-): no detection. SK: *Kaddid* sample which were from: SK1, SK2, SK3 (Béchar city), SK5 (BeniOunif), SK6 and SK7(Igli) from Béchar province, and SK4 from Tindouf province.

When safety of *Kaddid* samples was investigated, a high presence of staphylococci with average counts of 3.04±0.2 log CFU/g were shown, most of them being coagulase-negative and preliminarily identified as *Staphylococcus (S)xylosus*. In addition, lower counts of total coliforms (1.83±0.2 log CFU/g) were found, most of them belonged to *Citrobacter* (13 strains) and to a lesser extent to *Klebsseila* and *Edwardsiella* genera (data not shown).Clostridia were only detected in two samples (2 and 3) and absence of *Salmonella* was found (Table 1).

3. Physicochemical parameters

Homemade Southwestern Algerian *Kaddid* samples after drying process exhibited an average pH value of 5.50±0.03, indicating that the samples were moderately acid (Table2). When total titratable acidity (TTA) was evaluated, an average value of 1.81±0.4 lactic acid % was determined.

Table 2: Physicochemical characterization of dry-salted *Kaddid*

Parameters	Samples							
	SK1	SK2	SK3	SK4	SK5	SK6	SK7	Average*
pH	5.67	5.55	5.60	5.45	5.57	5.40	5.31	5.55±0.03
TTA (%)	1.9	1.2	1.0	2.5	1.4	1.8	2.9	1.81±0.40
Moisture (%)	7.2	12.1	14.9	9.0	5.5	6.3	6.4	8.7±3.50
a_w	0.67	0.73	0.74	0.71	0.65	0.66	0.67	0.68±0.03
Salt (%)	12.3	9.2	6.5	10.6	18.3	16.0	12.7	12.2±4.00
Protein (%)	9.6	10.5	13.8	10.5	16.4	11.9	11.6	12.1±2.50
Fat (%)	13.4	8.6	9.5	7.1	14.2	6.9	16.7	10.9±2.10
Dry matter (%)	92.8	87.8	85.0	91.0	94.5	93.7	93.5	91.2±3.50
Ash (%)	2.6	9.7	5.2	4.2	10.4	6.8	6.7	6.5±2.60

*mean ± standard deviation; SK: *Kaddid* samples which were from: SK1, SK2, SK3 (Béchar city), SK5 (BeniOunif), SK6 and SK7(Igli) from Béchar province, and SK4 from Tindouf province.

The moisture content was variable among samples; SK3 exhibiting the highest value (14.9%), whereas SK6 and SK7 showed the lowest content (6.3 and 6.4%). Water activity (a_w) results were in the range between 0.65 and 0.74.On the other hand, when salt concentration was determined, values ranged from 6.5% to 18.3% (average value 12.2±3.7%), the highest content being found for SK5 and SK6, which correlated with the lowest a_w values among analyzed samples.

In addition, protein results showed values between 9.6% and 16.4% (average 12.1±2.5%), the lipid fraction was variable among samples showing an average value of 10.9± 2.1%, while average ash content of samples was 6.5±2.6%.

4. Techno-functional characterization

Results showed hygroscopicityof *Kaddid* samples with values between 2.28 and 2.47% (Table 3). When functional properties of salted and dried samples were examined, water absorption capacity (WAC) showed an average value of 2.20±0.3 mL/g, while a higher (3.64±0.1 mL/g) average value for oil absorption capacity (OAC) was obtained. In addition, foaming **(**FC) showed an average value of 2.21±0.4% with SK1 showing the highest value of (3.22%), whereas the average value found for foaming stability (FS) was 90.7%.When emulsifying capacity and stability were determined, high EC (92-95%) and ES (99%) were obtained.

Table 3: Techno-functional characterization of *Kaddid* samples

Parameters	**Samples**							
	SK1	**SK2**	**SK3**	**SK4**	**SK5**	**SK6**	**SK7**	**Average***
Hygroscopicity (%)	2.47	2.28	2.40	2.42	2.56	2.47	2.46	2.43±0.2
Water absorption capacity (WAC) (ml/g)	2.03	2.35	1.26	2.68	2.65	2.83	1.66	2.20±0.3
Oil absorption capacity (OAC) (ml/g)	2.89	3.86	3.78	4.01	3.64	3.73	3.60	3.64±0.10
Foaming capacity (FC) (%)	3.22	3.00	1.66	2.60	1.66	2.00	1.33	2.21±0.40
Foaming stability (FS) (%)	90	90	90	90	95	90	90	90.7±0.0
Emulsifying capacity (EC) (%)	94.6	94.6	93.3	92.0	95.3	93.3	92.0	93.6±1.2
Emulsifying stability (ES) (%)	99.8	99.3	99.6	99.8	99.6	99.9	99.7	99.7±0.0

*mean ± standard deviation; SK: *kaddid* samples which were from: SK1, SK2, SK3 (Béchar city), SK5 (BeniOunif), SK6 and SK7(Igli) from Béchar province, and SK4 from Tindouf province.

DISCUSSION

The results of the survey showed that the method of preparation of *Kaddid* from South-West Algerian region was similar from those from other regions of Maghreb countries. However slightly different processes for salting and drying were traditionally applied. Indeed Bennani et *al*. [9] described Moroccan *Kaddid* as also prepared from beef, spiced and sun-dried, whereas Similarly, Zaier et *al*. [7] reported that Tunisian *Kaddid* is generally prepared by brining or dry-salting of beef or lamb meat. A comparative study conducted by Ayanwale et *al*. [14] on the nutritional quality, functional properties and organoleptic features between fresh meat of poultry, chevon and beef as well as those dried in the shade or in the sun showed that there were no significant differences between meat physicochemical composition and drying methods. Otherwise, sun-drying showed superior functional properties and a high level of acceptability compared to shade-drying.

When microbiological results were analyzed, total bacterial counts were one log cycle lower compared to *Kaddid* dry in the sun and brining [2, 3] but higher than laboratory-prepared Moroccan *Kaddid* [9]. The presence of LAB were similar to that reported for Tunisian *Kaddid*, in which 1.75 log CFU/g was reached during the second week of dried in the sun [7], while a higher LAB counts were reported for Northeastern Algerian *Kaddid* [7]. The somewhat lower LAB counts here may be assigned tohigh NaCl concentration and spices, as reported for other traditional salted products such as Iberian dry-fermented sausages,Turkish “*Pastirma*” and Algerian “*KhliaaEzir*” [18, 19, 20]. However, several LAB species were reported to adapt to high NaCl concentration [21, 18], particularly *Lactobacillus sakei* previously identified from *Kaddid* that resisted up to 15% of NaCl [8]. The high presence of coagulase-negative staphylococci in the samples was in coincidence with a pattern of *Staphylococcus* genus as abundant population in salted and cured meat [22],and no detection of *Salmonella* was also reported for Moroccan, Tunisian and Algerian *Kaddid* [2, 3, 7, 9]. The prevailing presence of *Staphylococcus* is due to their tolerance to high salt concentration, this being challenging for coagulase-positive *S. aureus*. However, when coagulase test was carried out, most of the analyzed staphylococci were coagulase-negative identified as *S.xylosus*.These *Staphylococcus* species are responsible for lipid and protein transformation with a great impact on sensory characteristics of the meat product [23]. Indeed, *S. xylosus* was characterized from Tunisian *Kaddid* to be used as a starter culture [24].

Coliforms population in this study was higher than that reported for Northeastern Algeria *Kaddid* after dried stage which may be dueto the high lactic acid accumulation by the higher LAB presence [2]. The survival of these microorganisms during the production of dry cured meats is not only relevant for product shelf-life, but also for food safety, as *Enterobacteriaceae* family includes pathogens and biogenic amines producers [25]. The low counts of clostridia detected agree with the unfavorable conditions (high salt, low water activity and acidity) in *Kaddid* samples. Moreover, the low numbers of total coliforms and clostridia of Algerian Kaddid here evaluated, represent hygienic indicators during processing and product handling.

Physicochemical results for pH values were similar to that reported for Moroccan *Kaddid* [3, 9], whereas final pH between 5.74-5.95 after 14 days of drying were obtained respectively for Tunisian and Southeastern Algerian *Kaddid* [2, 7]. In addition, pH values in the range of 5.0-5.6 for traditional dry salted *Biltong* (South African) and *Charque* (Brazilian) were reported [26, 27].Since the average pH of fresh lamb meat is 5.90 [28], the reduction of 0.4 pH units occurred in this study resulted similar to the pH decrease obtained by Zaier et *al*. [7] for beef-made *Kaddid*. The reduction of pH in dry salted meat products is correlated with lactic acid production by LAB during drying process, this contributing to pathogen and spoilage growth prevention during initial stages when moisture is still high enough to support growth. Results of TTA were variable among *Kaddid* samples and as expected, higher TTA values correlated to low pH exhibiting by samples, these results resulting higher than that of 0.97% reported for fresh beef [7]. In addition to acidification by LAB, Bennani et *al*. [9] reported that lipolytic activity due to pathogens/spoilage microorganisms might be responsible for *Kaddid* acidification through free fatty acids released. Fat degradation is likely to occur during the first stages of *Kaddid* processing, when pH is still near neutrality and a_w is elevated for bacterial growth. The a_w results in this study agree with that reported for Moroccan *Kaddid* and dry *Biltong*[3, 26], while higher a_w values (0.96-0.97) were reported for *Charque* [27]. According to these values, *Kaddid* can be classified in the limit of low and intermediate moisture product, however meat products with a_w between 0.60 and 0.91 were considered among intermediate moisture food [29].

When salt concentration average value of Algerien *Kaddid* (12.2±3.7%) was compared to Moroccan *Kaddid*, lower values were reported found for the latter (10.21±1.68) [3]; lower salt values (5.5-7.9%) were also informed for dry *Biltong* samples [26]. Salting process of meat was reported to be dependent on the applied method, dry salting or brining; water content of dried salted beef meat decreased more rapidly during the first stages when dry salting was used; salt uptake and water exudation from meat are mutually dependent [30]. In dry salting, when salt is sprinkled on meat surface, a large gradient of salt concentration between meat and the superficial juice is established leading to water uptake from the meat tissue to get equilibrium. Indeed, when the amount of water exudate is high, a water loss from the muscle tissue is produced [31]. Although differences were reported for dry salting and brining, both methods give muscle tissues of acceptable shelf-life, since microbial quality is similar and a_w is low [31]. Moreover, changes of meat muscle fibers due to dehydration were reported during salting process; protein denaturation occurred and precipitation/solubilization are dependent on time and NaCl concentration, this being related to weight and texture changes throughout the process [32]. Using scanning electron microscopy, Bampi et *al*. [27] observed more space between the bundles of muscle fibers in salted meat compared with parallel and close to each other fibers in fresh meat, which was attributed to a higher dehydration that increased meat volume by higher porosity due to changes in capillary pressure of the meat structure.

Protein content of *Kaddid* in this study was higher than that previously reported for Algerien product [3]. Since a value of 19.32-21.9% fortotal protein of for fresh lamb meat was reported [28]**,** a reduction during drying and salting process after 12-14 days must be occurred. On the contrary, chevon (goat) meat strips subjected to sun-drying increased protein content of dried samples [14], the presence of salt in *Kaddid* samples may explain the different results. In addition, protein degradation by proteolytic bacteria as well as meat endogenous enzymes may affects structural myofibrillar and sarcoplasmic proteins, reducing protein content of salted dried samples. LAB and staphylococci present in the meat have a role in protein degradation [23], the latter being the dominant population during salt-drying rocess, as observed in Tables 1 and 2.

In addition, although a fat content of 4.7% for lamb lean meat was reported [33], higher fat concentration was shown among *Kaddid* samples, this being related to the used lamb cuts with more lipids content their preparation. In addition, ash values correlated with the rich source of the minerals (iron and zinc) oflamb as a red meat [33]. Also, the high ash values may also be explained by the presence of a large amount of added salt.

Moure et *al*. [34] classified functional properties of foods according to the mechanism of action on three main groups: those properties related with hydration (absorption of water and oil, solubility and wettability), properties related with protein surface (emulsifying and foaming activities, formation of protein-lipids films and whipability) and those related with structure and rheological characteristics. Hygroscopicityis the phenomenon of attracting and holding water molecules via either absorption or adsorption from the surrounding environment, gaining weight. Algerien *Kaddid* showed average value of 2.43% which was lower than that reported by Ayanwale et *al*. [14] for sun-dried beef and goat meat (3.15% and 4.75%, respectively).This property describes how readily the salted dried samples take moisture during storage, this parameter being greatly dependent on the environment relative humidity. However, due to the hygroscopic nature of salt, increases in salt concentration, increase the amount of salt particles for absorbing water molecules from the meat samples [35], therefore salted meats would be less hygroscopic compared to dried meat. On the other hand, water absorption capacity of salted and dried *Kaddid* samples were higher than the values for oil absorption capacity (OAC), agreeing with those reported for goat dried meat in which OAC was twice that of WAC [14]. Molecular changes underwent by proteins in dried salted meat and the new distribution of proteins clusters allows absorbing more water than fresh/high moisture meat tissue, thus salted meat would be more juicy and tender. On the contrary, salted meat would allow a greater absorption of oil into its structure, due to lipid oxidation during exposure to air during drying and salting; OAC was related to the degree of hydrophobicity of the food system [34]. As found in this study, SK4 and SK6 with lower fat content exhibited highest values of WAC and OAC, this being in coincidence with the increase of protein solubility and water/oil absorption ability in defatted foods; WAC would be significantly improved by fermentation, among other treatments [34]. Furthermore, the foaming (FC) and emulsion (EC) capacities evaluated in *Kaddid* samples showed average value of 2.21±0.4% and 90.7%, respectively. Higher values were reported by Ayanwale et *al*. [14]for sun-dried beef and goat meat (4.08 and 5.11%, respectively). These functional properties are related to proteins behavior during preparation and storage of foods [34]. A foam is a dispersion of gas bubbles in a liquid or semi-solid phase, depending on the surface-active properties of the involved proteins; strong forces at the interphase between the air bubbles and water would allow hydrophobic interactions [14, 36]. In addition to salted meat proteins hydrophobicity, low FC found in *Kaddid* samples may be related to the low protein values obtained, since foam stability (FS) is dependent on protein content and environmental temperature; the higher the amount of protein acting as a surfactant, the higher the FS [36]. The emulsifying capacity (EC) shows the ability of a protein to help in the formation of an emulsion, this depending on protein capacity to absorb in the interfacial area of oil-water. Results from this study showed high EC (>92%) and an emulsifying stability (ES) greater than 99% after 300 min. The ability of proteins to act as emulsifiers varies with their molecular properties, such as molar mass, hydrophobicity, conformation stability, charge and physicochemical factors as salt, pH and temperature [37]. In coincidence with this study, EC is correlated with the presence in the protein surface of hydrophobic residues; the more the protein is hydrophobic, the higher the protein concentration at the emulsion/oil interface, the lower the interfacial tension and the more stable the emulsion [38].

CONCLUSION

Algerian *Kaddid* is a traditional meat product produced generally from fresh lamb meat pieces by adding dry salt/spices onto strips and then hang to dry in the shade. The microbiological characterization of samples showed the coagulase negative *Staphylococcus* to be the dominant population, while LAB were also present in low numbers in all *kaddid* samples. In correlation, *Kaddid* is moderately acid and in the limit of low and intermediate moisture meat product. Samples showed a high salt, ash and fat content, and low protein values.

Because of the changes underwent by meat proteins during dried salted process, functional properties of meat samples showed low hygroscopicity, moderate WAC while high OAC, these features contributing to meat hydration and low/moderate foaming and emulsifying capacity. Functional properties related to protein behavior, were in correlation with the low protein values obtained in analyzed *Kaddid* samples. Fermentation by using selected LAB would have a high impact on physicochemical, functional, safety and sensory attributes. Characterization of ethnic meat products of Maghreb countries will contribute to their valorization. In addition, fermentation

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