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Study of Physicochemical and Microbiological Quality of Fresh Camel Meat from Southern Algeria Stored at Different Temperatures Compared to Dried and Salted Camel Meat (*Kadid*)

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Abstract. As the most consumed source of animal protein in Southern Algeria, this study focused on monitoring the quality of fresh camel meat stored at different temperatures by analyzing some physicochemical and microbiological parameters according to national standards. Dried and salted camel meat, locally called (*Kadid*), was used as a control sample. The microbiological results of fresh camel meat showed a total aerobic mesophilic flora (TAMF) load of 5,8 Log_{10} CFU/g, 3,86 Log_{10} CFU/g for total coliforms, and 2,95 Log_{10} CFU/g for fecal coliforms. All samples analyzed were free of pathogenic bacteria, namely coagulase-positive staphylococci (CoPS), *Listeria monocytogenes*, and *Salmonella* spp. However, coagulase-negative staphylococci (CoNS) species with a load of 3,47 Log_{10} CFU/g were identified as follows: *S. saprophyticus* and *S. epidermidis*. In less than 7 days, sample B stored at room temperature experienced deterioration, with the microbial load exceeding the maximum acceptable threshold (M) set by national regulations, along with changes in physicochemical parameters, rendering the product unfit for consumption. This degradation was faster compared to the sample A stored at a maximum temperature of +10°C. However, for the control sample, the physicochemical results of dried and salted camel meat (*Kadid*) showed an acidic medium (pH=5,26). The analyzed samples had moisture content (MC %), sodium chloride content (SCC %), and total solid content (TSC %) of 10,73%, 0,3% (3g/L), and 89,27%, respectively. From a microbiological points of view, fresh camel meat stored at +10°C meets national legislation requirements for a maximum storage of one month. In contrast, the physicochemical and microbiological characteristics of dried and salted camel meat (*Kadid*) allow it to be preserved for an extended period, even at room temperature. The traditional method of preparing and preserving the meat has proven effective against microbial contaminants. It maintains a balance of physicochemical parameters that enhance preservation and improve the nutritional and organoleptic quality compared to chilled fresh camel meat.

Keywords. Fresh camel meat, *Kadid*, Monitoring, Physicochemical and microbiological properties, Storage temperature, Southern Algeria.

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1. Introduction

Camel meat is esteemed for its nutritional value and distinct flavor, holding significant cultural importance in regions where camels are prevalent [1]. As a rich source of protein, vitamins, and minerals, camel meat serves as a dietary staple in arid and semi-arid areas, where other livestock options may be limited [2-4].

Preservation methods for camel meat are crucial for maintaining its quality and safety. While cooling is commonly employed to extend the shelf life of camel meat, other storage techniques are also utilized in different contexts. Refrigeration or cold storage slows down microbial growth and enzymatic activity, delaying spoilage and maintaining freshness [5-7]. However, in regions with limited access to refrigeration facilities, alternative methods such as drying and salting are employed. On the one hand, the drying method dehydrates the meat, inhibiting bacterial growth and reducing moisture content, thereby prolonging its shelf life [8]. Salting, on the other hand, creates an inhospitable environment for microorganisms by reducing water activity, effectively preserving the meat [9].

These traditional preservation methods not only ensure the availability of camel meat beyond immediate consumption but also contribute to the culinary diversity and cultural heritage of camel-rearing communities [1].

In this context, the study focuses on monitoring some physicochemical and microbiological parameters of fresh camel meat under variable storage conditions, compared to dried and salted camel meat (*Kadid*) used as a control sample.

2. Material and Methods

2.1. Sampling

The sample of fresh camel meat of the Sahraoui breed (*Camelus dromedarius*) was purchased from a butcher shop located in the market of Bechar Djedid, Bechar (Southwest of Algeria). The sample is divided into two parts : the first was stored at a temperature of +10°C (Sample A) and the second at room temperature (+25°C) (Sample B). The choice of theses temperatures is subjective, as the study area is known for its hot climate (arid zone) [10, 11], making it difficult to maintain cooling temperatures between +4 and +6°C. Both samples were monitored for some physicochemical and microbiological parameters compared to dried and salted camel meat (*Kadid*), which was used as a control sample (Figure 1). *Kadid* is a widely consumed product that adapts well to the climate of the study area.

Figure 1. Dried and salted camel meat (*Kadid*) including bones (Original, 2024) (Ph. E. Benyagoub).

2.2. Physicochemical and Microbiological Analyses of Camel Meat

Camel meat samples underwent physicochemical analyses according to national standards by measuring the following parameters: pH, temperature (°C), moisture content (M %), Sodium chloride content (SCC % or g/L), and Total solid content (TSC %). However, a 0,1% peptone salt solution was

used as a diluent in preparing decimal dilutions of the samples for microbiological analysis [12]. The physicochemical and microbiological parameters analyzed are provided in Table 1.

Table 1. Physicochemical and microbiological analysis of camel meat.

Physicochemical parameters	**Analytical method**	**References**
pH; and Temperature (°C)	pH meter, and thermometer, respectively.	JORA n.23, [13].
Moisture content (MC %); and Total solid content (TSC %)	The direct drying method at 105°C (Thermogravimetric approach).	JORA n.1, [14].
Sodium chloride content (SCC % or g/L)	Argentometric titration method (Mohr's method).	Soderberg, [15]; Benyagoub and Mammeri [1].
Microbiological parameters	**Bacterial isolation technique and temperature of incubation**	**References**
TAMF	The pour plate technique on PCA agar medium at 30°C.	JORA n.65 [16].
Fungal flora	The spread plate technique on Sabouraud 4% chloramphenicol dextrose agar medium at 25°C for 3 to 5 days	JORA n.48, [17]; JORA n.52, [18].
Total coliforms and fecal coliforms	The pour plate technique on MacConkey agar medium for TC and FC at 30 and 44°C, respectively.	JORA n.72, [19].
SRC	Anaerobic culture in tube using Meat-liver agar medium at 46°C.	JORA n.51, [20].
Coagulase-positive Staphylococci (CoPS)	The spread plate technique on Baird-Parker agar medium at 37°C.	JORA n.68, [21]; JORA n.14, [22].
Salmonella spp.	-Selective enrichment media: RVB, and SCB at 41,5 and 37°C, respectively. -Isolation step on Petri dishes using Hektoen agar, and SS agar medium at 37°C.	JORA n.44, [23].
Listeria monocytogenes	-Selective broth media: Half Fraser broth, and Fraser broth at 30 and 37°C, respectively. -Isolation step on Petri dishes using PALCAM agar medium at 37°C.	Benyagoub and Mammeri [1]; Benyagoub *et al.* [3]; Corry *et al*. [24].
Pseudomonas spp.	The spread plate technique on Cetrimide-Nalidixic acid agar medium at 37°C.	Benyagoub and Mammeri [1]; Benyagoub *et al*. [3].

TAMF: Total aerobic mesophilic flora; TC: Total coliforms; FC: Fecal coliforms; SRC: Spores of sulfite-reducing *Clostridia*; RVB: Rappaport-Vassiliadis broth; SCB: Selenite cystine broth; SS agar: *Salmonella-Shigella* agar medium; JORA: *Official Journal* of the People's Democratic *Republic* of *Algeria.*

2.3. Identification of Isolates

The presumed isolates of *Staphylococcus aureus*, *Salmonella* spp., *Listeria monocytogenes* and *Pseudomonas* spp. underwent a series of identification tests following standard microbiological methods. These methods included phenotypic characterization through macroscopic examination on agar and microscopic examination in the fresh state, followed by Gram staining, coagulase test, catalase test, urease test, oxidase test, and esculin hydrolysis test [1, 3, 6, 25-28].

2.4. Interpretation of Microbiological Analyses

The quality of the camel meat samples was assessed based on the contamination limits 'm' and 'M' as defined by the *Official Journal* of the People's Democratic *Republic* of *Algeria* [29]. All analyzes were

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performed in duplicate. Results for the microbial parameter were expressed as Log_{10} CFU/g, and graphical presentations were generated as curve using Origin 2018 software.

3. Results

3.1. Quality of Fresh Camel Meat

The results of the microbiological quality of fresh camel meat at reception are shown in Figure 2.

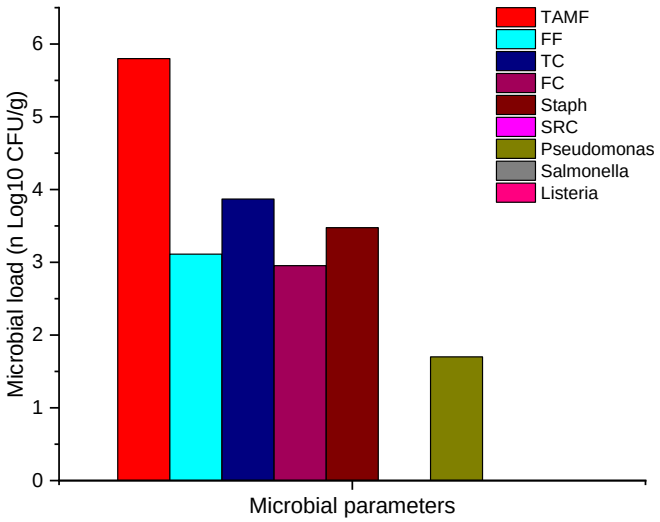

Figure 2. Microbiological analysis of fresh camel meat (Source: Own study). TAMF: Total aerobic mesophilic flora; FF: Fungal flora; TC: Total coliforms; FC: Fecal coliforms; Staph: Staphylococci; SCR: Spore of sulfite-reducing *Clostridia*; Listeria: *Listeria monocytogenes*.

The results obtained showed that the camel meat sample had satisfactory hygienic quality, as the analyzed sample was free of *Salmonella* spp., *L. monocytogene*s, and coagulase-positive Staphylococci. The load of TAMF, total coliforms (TC), fecal coliforms (FC), and coagulase-negative staphylococci (CoNS) was 5,8 Log_{10} CFU/g, 3,86 Log_{10} CFU/g, 2,95 Log_{10} CFU/g, and 3,47 Log_{10} CFU/g, respectively.

3.2. Kinetic of Camel Meat Quality at Different Storage Temperatures

The results of the evolution of the physicochemical and microbiological parameters of fresh camel meat stored at different temperatures over time are provided below.

3.2.1. Physicochemical Analysis

3.2.1.1. Test Samples

The results of the evolution of pH, total solid content (TSC %), and moisture content (MC %) are presented in Figures 3 and 4.

Regarding the pH parameter, sample B experienced significant changes in pH from 5,38 to 6,7 shifting from initially slightly acidic to an alkaline medium (Figure 3). Sample A experienced a slight change in pH from 5,38 to 5,7, in contrast to the acidic pH recorded for the control sample (*Kadid*) (5,26) (Figure 5).

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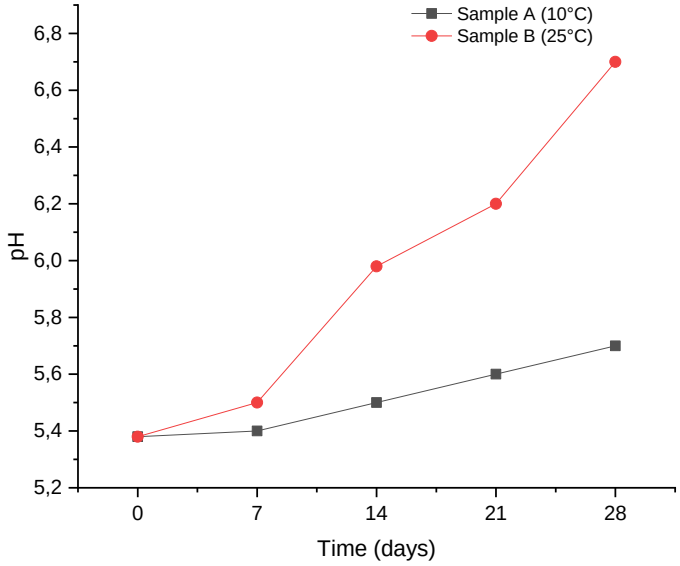

Figure 3. pH evolution of fresh camel meat stored at different temperatures over time (Source: Own study).

Figure 4 showed an increase in the rate of TSC over time and consequently a decrease in moisture content. Sample B stored at +25°C experienced an increase in TSC of up to 38% compared to sample A stored at +10°C (25,5%), thus a decrease in moisture content from 78% to 74,5% and from 78% to 62% for samples A and B stored at +10°C and +25°C, respectively.

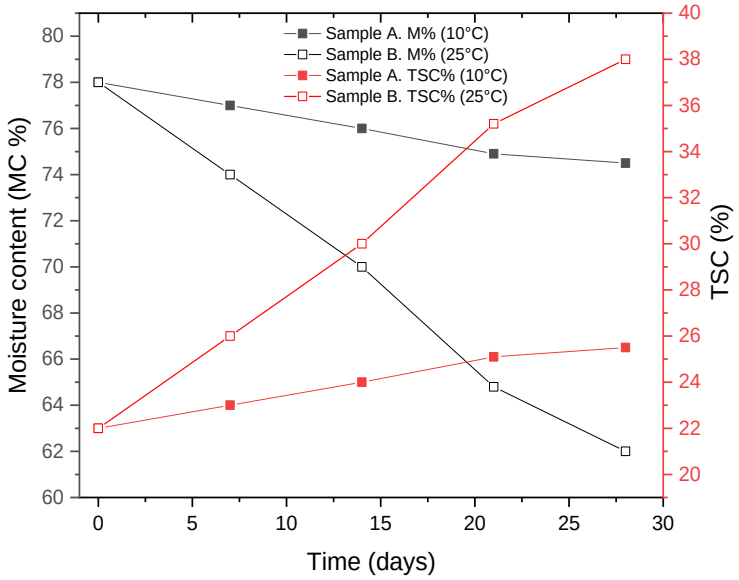

Figure 4. Evolution of total solid content (TSC %) and moisture content (MC %) of fresh camel meat stored at different temperatures over time (Source: Own study).

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3.2.1.2. Control Sample (Kadid)

The physicochemical results for the control sample (*Kadid*) are presented in Figure 5.

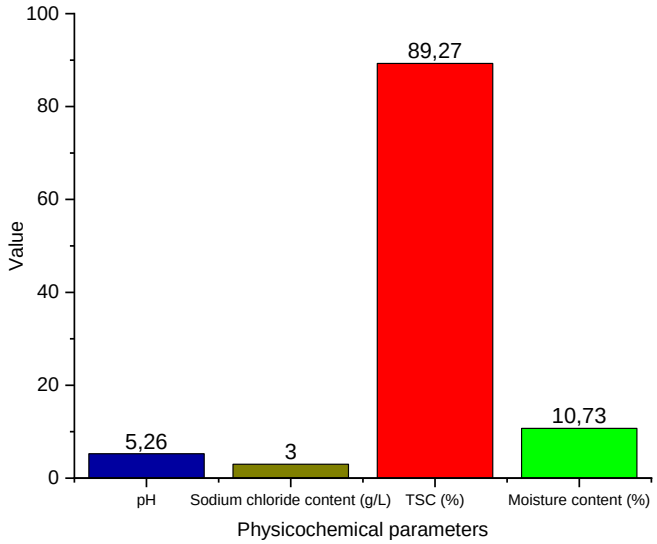

Figure 5. Physicochemical parameters results of dried and salted camel meat sample (*Kadid*) (Source: Own study).

The physicochemical results of dried and salted camel meat (*Kadid*) showed an acidic medium (pH=5,26). The analyzed samples had moisture content, sodium chloride content, and total solid content (TSC %) of 10,73%, 3g/L (0,3%), and 89,27%, respectively.

3.2.2. Microbiological Analysis

The results of the evolution of microbiological parameters, namely Total Aerobic Mesophilic Flora (TAMF), fungal flora, total and fecal coliforms, sulfite-reducing *Clostridia*, staphylococci, *Pseudomonas* spp., and the pathogenic bacteria *Salmonella* spp. and *Listeria monocytogenes* are presented in Figures 6, 7, 8, 9 and 10.

3.2.2.1. Test Samples

3.2.2.1.1. TAMF and Fungal Flora

Figure 6 showed a significant change in TAMF and fungal flora load for the fresh camel meat sample (B) stored at +25°C (from 5,88 to 8,33 Log_{10} CFU/g, and 3,11 to 4,5 Log_{10} CFU/g) compared to the second sample (A) stored at 10°C (from 5,8 to 6,5 Log_{10} CFU/g, and 3,11 to 3,85 Log_{10} CFU/g), respectively.

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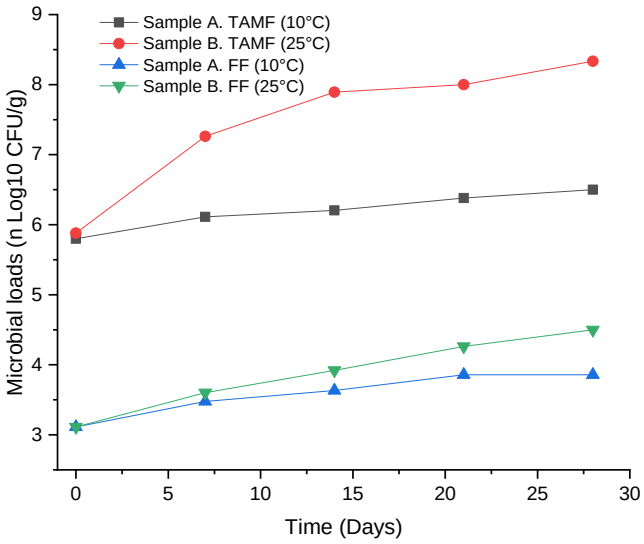

Figure 6. Evolution of TAMF and fungal flora of fresh camel meat stored at different temperatures over time (Source: Own study). TAMF: Total aerobic mesophilic flora; FF: Fungal flora.

3.2.2.1.2. Total Coliforms and Fecal Coliforms

Figure 7 showed shows a significant increase a high evolution in the load of total coliforms (TC) and fecal coliforms (FC) for sample B (+25°C) compared to sample A (+10°C), reaching loads of 5,9 and 5,3 Log_{10} CFU/g, respectively. Initially, camel meat sample quality meets national regulations, but during meat storage, samples are exposed to contamination that develops over time. After 4 weeks of storage, sample A stored at +10°C experienced a fecal coliforms load exceeding national regulations, while this result was obtained after less than a week of storage for sample B stored at +25°C.

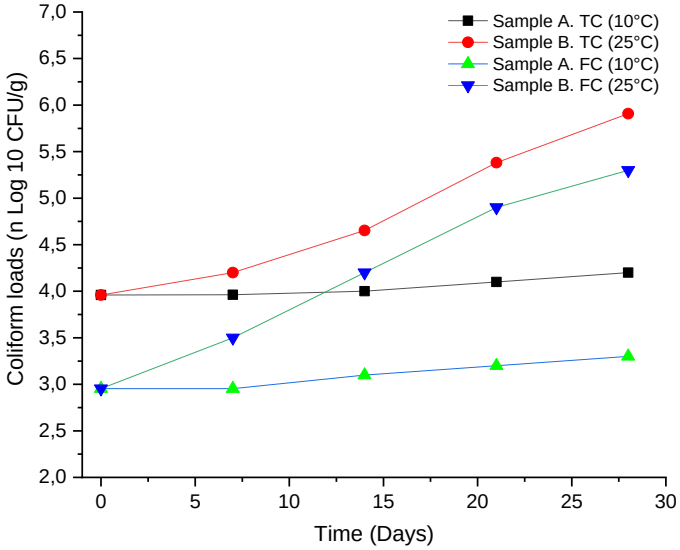

Figure 7. Evolution of total and fecal coliforms in fresh camel meat stored at different temperatures over time (Source: Own study). TC: Total coliforms; FC: Fecal coliforms.

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3.2.2.1.3. Pathogenic Bacteria

Figure 8 shows a significant increase in the load of coagulase-negative staphylococci species in sample B, stored at +25°C, compared to sample A stored at +10°C. *Pseudomonas* spp. loads were within the 'm' limit set by national regulations [29] for both samples (A and B). Furthermore, both samples were free of *Salmonella* spp. and *L. monocytogenes* (Table 2).

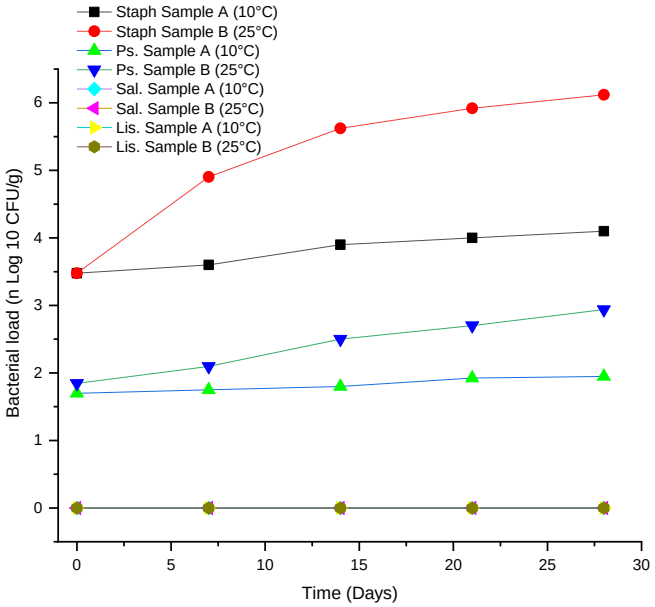

Figure 8. Evolution of pathogenic bacteria contaminating fresh camel meat stored at different temperatures over time (Source: Own study). Staph: Staphylococci; Ps: *Pseudomonas* spp.; Sal: *Salmonella* spp.; Lis: *Listeria monocytogenes*.

Table 2. Identification of pathogenic bacterial species isolated from fresh camel meat.

Fresh camel meat samples	*Salmonella* spp.	*L. monocytogenes*	Coagulase-positive staphylococci (CoPS)
Sample A	-ve	-ve	-ve CoPS
Sample B			+v CoNS, VP+, γ- hemo (*S. saprophyticus*, *S. epidermidis*)

CoPS: Coagulase-Positive Staphylococci; CoNS: Coagulase-Negative Staphylococci; -ve: Negative culture of presumed isolate on selective medium; +ve: Positive culture of presumed isolate on selective medium; VP+: Voges-Proskauer test; γ- hemo: γ- hemolytic; Source: Own study.

3.2.2.1.4. Sulfite-Reducing Clostridia (SRC)

Figure 9 shows a change in the load of spores of sulfite-reducing *Clostridia* for sample B stored at +25°C with a maximum load of 6 spores of SRC/g. However, sample A, stored at +10°C, experienced contamination after 21 days of storage, with a load of 2 spores of SRC/g.

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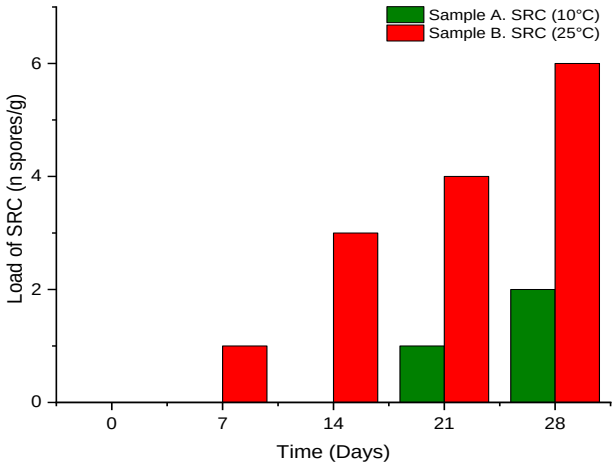
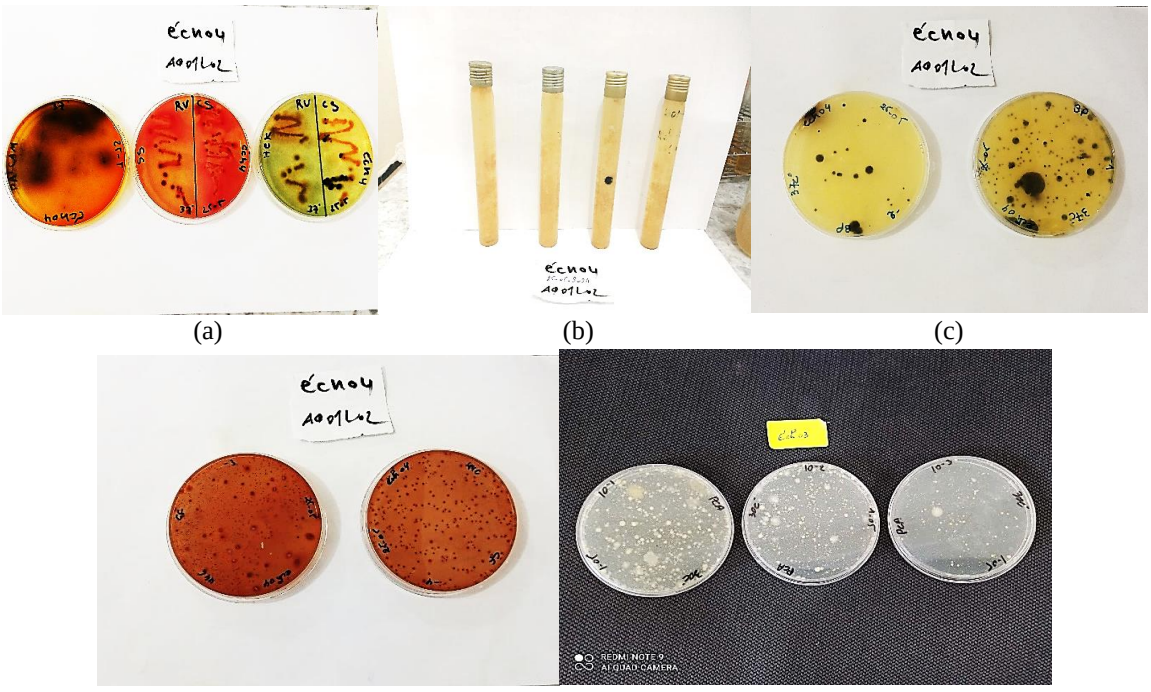


Figure 9. Evolution of spores of sulfite-reducing *Clostridia* contaminating fresh camel meat stored at different temperatures over time (Source: Own study). SRC: Spores of sulfite-reducing *Clostridia*.



(a) (b) (c)

(d) (e)

Figure 10. Isolation of microbial species from fresh camel meat (Original, 2024) (Ph. E. Benyagoub). (a): Suspected presence of *Salmonella* spp. on SS agar medium, and *Listeria monocytogenes* on Palcam agar medium; (b): Sulfite-reducing *Clostridia* on Meat-liver agar medium; (c): Staphylococci on Baird-Parker agar medium; (d): Total coliforms and fecal coliforms on MacConkey agar medium; (e): TAMF on PCA medium.

3.2.2.2. Control Sample (Kadid)

The microbiological results for the control sample (*Kadid*) are presented in Figures 11 and 12.

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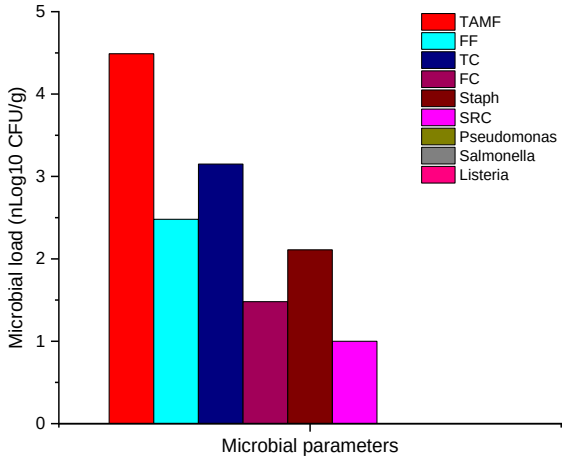
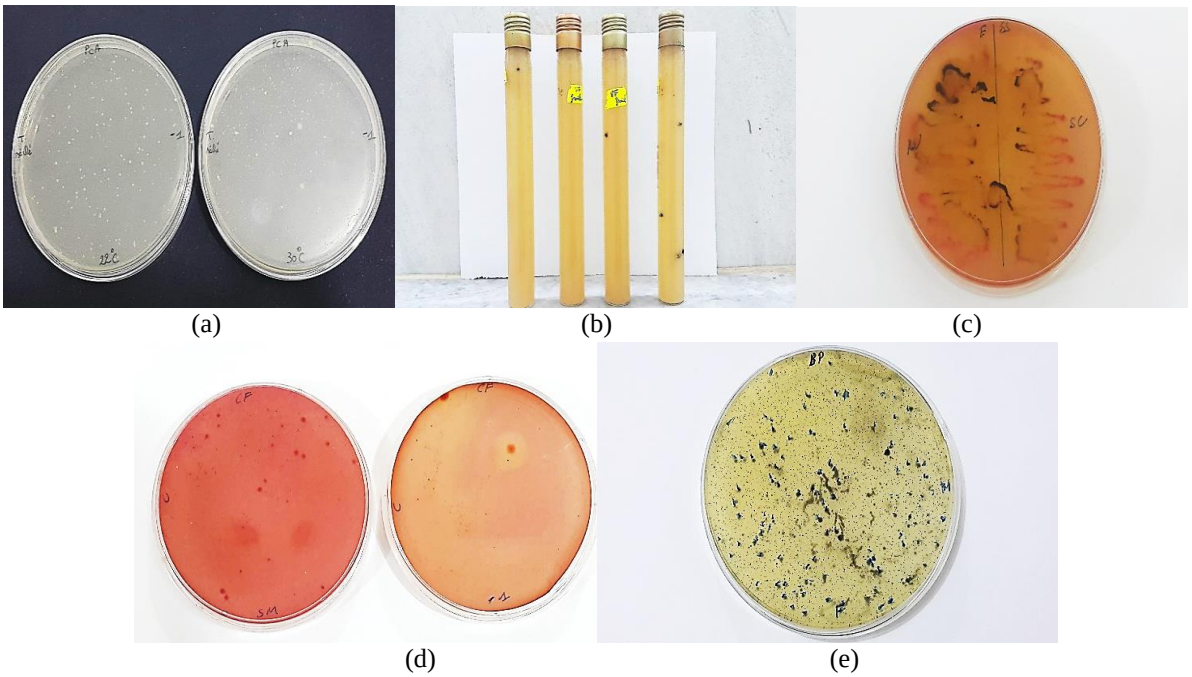


Figure 11. Microbiological analysis of dried and salted camel meat (Control sample) (Source: Own study). TAMF: Total aerobic mesophilic flora; FF: Fungal flora; TC: Total coliforms; FC: Fecal coliforms; Staph: Staphylococci; SCR: Spore of sulfite-reducing *Clostridia*; Listeria: *Listeria monocytogenes*.

The microbiological results of dried and salted camel meat showed a TAMF load of 4,49 Log_{10} CFU/g, 3,15 Log_{10} CFU/g for total coliforms, and 1,48 Log_{10} CFU/g for fecal coliforms. The control sample was free of coagulase-positive staphylococci (CoPS), *Listeria monocytogenes*, *Pseudomonas* spp. and *Salmonella* spp.



(a) (b) (c)

(d) (e)

Figure 12. Isolation of microbial species from dried and salted camel meat (Original, 2024) (Ph. E. Benyagoub). (a): TAMF on PCA medium; (b): Sulfite-reducing *Clostridia* on Meat-liver agar medium; (c): Suspected presence of *Salmonella* spp. on SS agar medium; (d): Total coliforms and fecal coliforms on MacConkey agar medium; (e): Staphylococci on Baird-Parker agar medium.

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4. Discussion

This study focused on monitoring some physicochemical and microbiological parameters of fresh camel meat stored under two different temperatures, compared to dried and salted camel meat (*Kadid*) used as a control sample.

The results of the physicochemical and microbiological parameters of fresh camel meat comply with national regulations [29], and corroborate our previous studies on fresh camel meat in Bechar (Algeria) [1, 3, 30]. They are consistent with findings from other studies such as those reported by Babiker and Yousif [31], Arabi *et al.* [32], Tegegne *et al.* [33], Benaissa *et al.* [34], and Abd-Allah *et al.* [35]. This compliance is due to adherence to hygiene rules at various stages of meat production, from slaughter to retail sale, and maintenance of the cold chain. However, the level of meat contamination depends on factors such as contamination introduced by the hands of operators, including abattoir personnel, tools, and work surfaces during slaughter and cutting operations, as well as the development and growth of microbial contaminants during cooling, storage, and distribution [3]. Therefore, the chemical composition of meat varies depending on factors such as animal species, breed, age, sex, feeding type and body weight [3, 30, 35, 36]. Additionally, factors like pre-slaughter stress, post-mortem treatments, and muscle physiology can also affect meat quality [35, 37].

This study demonstrated that fresh camel meat, due to its composition and nutritional quality, as well as being less exposed to microbial contamination due to the specific skinning method of camels [34], unlike meats from other animal species, can remain microbiologically safe for a maximum of one month at temperatures up to +10/12°C [30].

Sample B stored at room temperature experienced rapid deterioration within 7 days, with the microbial load exceeding the maximum acceptable limit (M) set by national regulations. According to Abd-Allah *et al.* [35], the decrease in pH value of meat after slaughter is mostly attributed to the breakdown of glycogen with the formation of lactic acid. During cold stotrage, the increase in pH value of red meat could be due to the breakdown of proteins, leading to a rise in ammonia and free amino groups-compounds that cause alkaline reactions. Additionally, the decrease in moisture content might be due to water loss (mainly through evaporation) during storage [35].

However, according to the results obtained by Abd-Allah *et al.* [35], camel meat can be stored at +4ºC for up to 10 days, and up to 4 months at -10ºC while maintaining its nutritional and sensory quality.

Microbial contamination can not only affect the quality of fresh meat but also shorten its shelf life, causing economic losses and health risks to consumers [32].

Regarding storage condition, Arabi *et al.* [32] reported significant variation in the loads of coliforms, *E. coli*, and *S. aureus* in fresh camel meat, influenced by the season and the age of the animal. The microbial load of meat increases in the hot season due to higher teperatures, as well as in older animals due to a lower pH value compared to younger animals. Meat with a high ultimate pH is more susceptible to microbial growth, even under the best management conditions and practices [32].

According to several studies, the lean composition of camel meat affects its storage requirements, as lower fat content results in a shorter shelf life compared to fattier meats [38]. Camel meat is more prone to drying out and becoming tough if not stored properly. Without adequate fat to help preserve moisture and protect against spoilage, camel meat may spoil more rapidly if not stored properly [3, 39]. For the control sample, the results of dried and salted camel meat (*Kadid*) showed interesting physicochemical and microbiological properties (Low moisture content, and high sodium chloride content) that contribute to the preservation of this product while maintaining its high nutritional and organoleptic quality for a long period. These results have been confirmed by several studies, including those conducted by Benyagoub and Mammeri [1], Benyagoub and Bessadet [40], Belguith *et al.* [41], Boubakri *et al.* [42], Hamani *et al.* [43], and Dissanayake *et al.* [44]. *Kadid* preparation techniques promote the balance and dominance of beneficial bacterial species, such as lactic acid bacteria [3, 45, 46], which are better adapted to the physicochemical properties of this product. This adaptation leads to good storage suitability even at room temperature, as confirmed by previous studies [1, 40].

The integration of diverse processing and preservation methods can maintain and even enhance both sensory and nutritional quality outcomes. Therefore, there is a need for additional research into the

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synergistic combinations of preservation techniques to ensure that the nutritional integrity of meat remains uncompromised for long periods [36, 44, 47].

Conclusion

The obtained results showed that even at the maximum temperature of +10°C, the hygienic quality of camel meat was stable and met the requirements of the current national regulations for a storage duration of up to one month. In contrast, the sample stored at room temperature experienced rapid deterioration, and within less than 7 days, the sample no longer complied with national regulations. For this, proper packaging, temperature control, and handling are crucial to ensure that camel meat remains fresh and flavorful for as long as possible.

For the control sample (*Kadid*), the results of this study suggest that drying camel meat can serve as a barrier against microbial contaminants and pathogenic bacteria more effectively than refrigeration. Considering that the study area has a Saharan climate with temperatures exceeding +50°C during the summer season, controlling refrigeration temperatures becomes challenging. Drying provides conditions conducive to preserving the product, such as low water activity and high salt concentration, thereby enhancing its sensory and nutritional quality through the addition of spices. Consequently, it extends the shelf life of camel meat even when stored at room temperature.

Acknowledgments

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Conflict of interest

The authors have no conflicts of interest to declare.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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