CHARACTERIZATION OF STAPHYLOCOCCI IN SHE-CAMEL MILK: EVALUATION OF ZOONOTIC AND ENVIRONMENTAL THREATS IN PERIURBAN CAMEL HERDS OF ZIBAN REGION, ALGERIA

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Abstract. The subclinical mastitis is a major scourge in the camel farms.The pathogenic staphylococci are among the dominant causative agents of mastitis.The first part of the present study aims to estimate the prevalence of *Staphylococcus spp.* in overall milk per udder samples (n = 18) randomly selected among three camel herds in the region of Biskra. Following an epidemiological investigation, raw milk underwent bacteriological analysis emphasizing the identification and enumeration of staphylococci. In the second part of study, we investigated the impact of the anatomical position of the udder quarters on the infection rates due to *Staphylococcus spp.* Therefore from six she-camels reared in two farms, 24 raw milk samples were collected. Results show that the high rates and the diversity of isolated *Staphylococcus spp.* reflect inappropriate husbandry practices and illusory health status of the main camel herds. The milk contamination rates recorded at the herds H1 (Loutaya), H2 (Ain El'Kerma), H3 (Oumache) and H5 (Loutaya) do not conform to the limited value in the Algerian Official Journal.Also, it is an indicator of the perennity of subclinical mastitis insidiously. The infection rates and the isolated species of staphylococci are not identical for all the quarters in the same she-camel which were confirmed by the Kendall Tau-B correlation test (p = 0.05). It would be important to apply the standards H.A.C.C.P. either at the herd level, during milk collection and in milk marketing shops. Vulgarization of both herders and consumers would minimize the risk of food-borne illnesses.

Keywords: Subclinical mastitis, Food borne diseases, *Staphylococcus aureus*

Abbreviations

CMT-California Mastitis Test
H-Herd
HACCP-Hazard Analysis Critiacl Control Points
LA-Left Anterior
LP-Left Posterior
MRSA- methicillin-resistant *S. aureus*
No-Absence
NV 30-Novobiocin 30 mg
RA-Right Anterior
RP-Right Posterior
S.aureus- Staphylococcus aureus
SC-She-camel
SCs-She-camels
SCC-Somatic Cell Count
Yes - : presence with negative coagulase
Yes +: presence with positive coagulase

INTRODUCTION

Camel milk is traditionally appreciated for its anti-infectious, anti-cancer, anti-diabetic and more generally as a restorative in convalescent patients (Kanuspayeva, 2007). Periurban camel breeding in Biskra region (North-east of Algeria) is a new option whose purpose is to bring camel milk closer to the consumer (Mammeri et al., 2014; Mammeri, 2016; Mammeri and Khir, 2018).

Nevertheless, subclinical mastitis is a major infection in camel farms managed according to traditional and anarchic methods.Pathogenic staphylococci are among the dominant causative agents of these cases of mastitis (Eyassu and Bekele, 2010; Saleh and Faye, 2011).Also, the presence of staphylococci in milk and the environment is a significant risk factor for public health and other livestock, especially that certain strains of *Staphylococcus aureus* (*S.aureus*) are capable of producing highly heat-stable toxins and can be responsible for milk-borne diseases (Dhanashekar et al. 2012).

Also, *S.aureus* is a well-known colonizer and cause of infection among animals and it has been described from numerous domestic and wild animal species. Among mammals known to harbor *S.aureus*, there are domestic ruminants as: cattle, sheep, goats, dromedaries *(Camelus dromedarius),* dogs, cats, domestic chickens, houbara bustards, and domestic pigeons, while in wild fauna, *S.aureus* is harbored by wild boar (*Sus scrofa),* foxes, Lagomorphs and Rodents (Monecke et al. 2016).

S. aureus causes significant morbidity and mortality, representing the leading bacterial cause of human death in 135 countries and contributing to more than a million deaths in 2019. MRSA alone was responsible for more than 100,000 deaths worldwide in 2019 (Linz et al. 2023).Several studies have described colonization and infections caused by livestock-associated MRSA in humans in contact with livestock. Thus, livestock and other animals may represent an important permanent reservoir for human MRSA infections (Gherardi, 2023). For example, in a recent study done by Belkadi et al.(2022) in eastern Algeria, the overall prevalence of *S. aureus* isolates from 754 samples was 43.61%, with a high rate of *S. aureus* isolation in rabbits (92%). Goats, bovine, dogs, cats, horses, poultry presented a medium prevalence with 31.91%, 25%, 23.75% 21.25%,15% and 15% respectively, while the lowest rate was observed in sheep with 10%. MRSA were isolated in all animal species (29.46%).All detected isolates were multiple drug resistant. A complete resistance (100%) was noted for ciprofloxacin and gentamicin in sheep and horses and to penicillin in dogs.

Recently, in a study conducted by Belhout et al. (2023), to identify the *Staphylococcaceae* bacteria composition of the nasal flora and evaluate the presence of methicillin-resistant *Mammaliicoccus* and MRSA in dromedary camels in Algeria, where nasal swabs were collected from 46 camels from seven farms located in two different regions of Algeria (M'sila and Ouargla), three MRSA were found to be st6 and *spa* type t304.

According to Hany et al.(2020), pasteurized camel milk collected from different retail markets in Al-Riyadh, Saudi Arabia, was found to possess a high proportion of MRSA (10%).This prevalence was high in relation to the risk of this microbe and indicates a serious public health problem. Accordingly, authors suggest that the manufacturers should use different temperatures for milk processing, such as 93.8°C

for 0.1 s, 96.2°C for 0.05 s, or 100°C for 0.01 s, to destroy the contaminating MRSA (Hany et al.2020).

For Tizi Ouzou region (North of Algeria), Titouche et al. (2019) showed raw milk and traditional dairy products are often contaminated with enterotoxigenic strains *S.aureus*. Some of these strains carry antimicrobial resistance, leading to a potential risk for consumers by carriage of staphylococcal enterotoxin genes and antimicrobial resistance.Overall, 62 out of 270 samples (23%) were contaminated with *S. aureus*, and 69 *S.aureus* strains were identified.

In a study conducted by Cheikh Ismail et al. (2022), to investigate the consumption patterns of camel milk and perceived benefits and risks among adults in the United Arab Emirates, results show that camel milk consumers preferred it over other types of milk due to its nutritional value (66.4 %) and medicinal properties (39.3 %). Among consumers, 58.4 % reported consuming unpasteurised camel milk. Reasons included the belief that it is fresher (87.2 %), better for the immune system (41.6 %), and higher in nutrients (39.2 %).

Taking into consideration the camels' health status, the zoonotic riks, and the environmental impact of *Staphylococcus spp.*, the aim of our research was to characterize the staphylococci in camel milk of Ziban region. Therefore, bacteriological cultures were performed from milk samples obtained from the four quarters of each she-camel (SC). Furthermore, it was essential to estimate the zoonotic and environmental risks in the visited farms through an epidemiological investigation.

MATERIALS AND METHODS

Study area. The governorate of Biskra is located in the south-east of Algeria (400 km from the capital Algiers) (Fig.1). It extends over an area of 10,261 km^2 and where the city of Biskra is at an average altitude of 124 m. Its latitude is between 34 ° 39 'and 35 ° 24' (North) and its longitude is between 4 ° 99 'and 6 ° 79' (East) (A.N.A.T., 2003). The governorate of Biskra is characterized by a Mediterranean climate with a semi-arid variant; dominated by a dry and cold winter and a hot and dry summer. The most common soil is calci-magnesium type (Chaouch, 2011). This region is more suitable to camelids (*Camelus dromedarius*) breeding than the governorates of North Algeria, since its steppic courses are rich in various plants favored by the dromedary camel (Mammeri et al., 2014). Camels' livestock in Biskra region is important and it is estimated at 5,237 head, versus; 5195 head for cattle, 1191,708 head for sheep and 549,600 head for goats (D.A.S., 2021).

Epidemiological investigation. The present study was started by a field epidemiological survey using a questionnaire at the level of five camel herds (H) located in Ziban region; H1 (Loutaya), H2 (Ain Karma), H3 (Bir Nâam), H4 (Oumeche) and H5 (Loutaya).The choice of these municipalities was due to the importance of camel breeding comparatively to other parts of the governorate. The questions focused on main particularities of visited herds: hygienic profile, SCs' phenotypes, lactations' number, approximate age, soil type, regular milk control, eventual proximity to wild animals and prophylactic measures before milking.

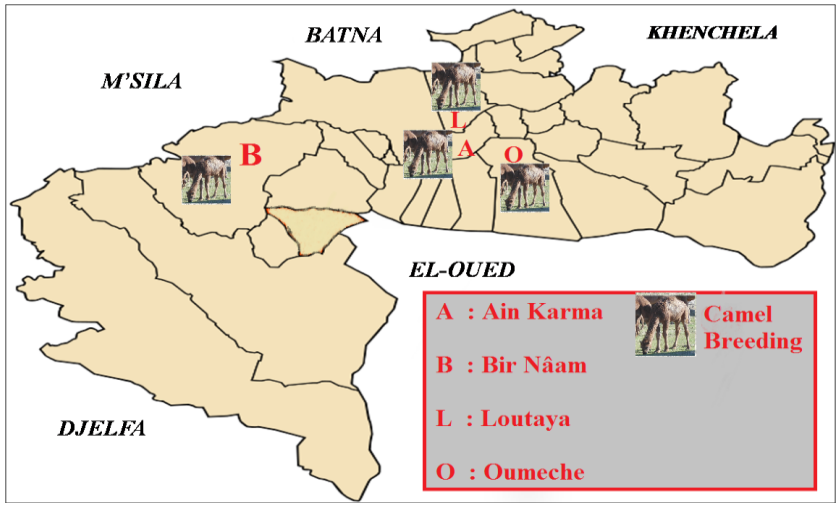

Figure 1. Distribution of sampled camel herds in study area

Characterization of staphylococci in total udder raw milk

Inclusion criteria of SCs in study: SCs were randomly chosen, but before taking the milk samples, it was necessary to be sure that none of sampled SCs has received antibiotic or equivalent antimicrobial treatments during the last month, to ensure reliability results of bacteriological cultures, also that none of selected SCs shows symptoms of clinical mastitis, because we focused only on the cases of subclinical mastitis characterized often by insidious signs.

*Sampling equipment and reagents:*We used; sterile plastic bottles of 50 ml; an insulated cooler with ice cubes, 70° alcohol and towel paper.

SCs' sampling scheme: For the first study; of the global prevalence of *Staphylococcus spp*., six samples of raw milk, were collected from the four teats of each selected SC, in parallel to the epidemiological survey within H1(Loutaya), H2 (Ain Karma) and H3 (Oumeche).Thus,18 samples of overall milk (mixed of four quarters milk) were collected for the first study.While, for the second study focusing on *Staphylococcus spp*. comparative bacteriological cultures among different udder quarters, a total of 24 raw milk samples were taken from six SCs (separately from 4 quarters) at two herds; (H4) Oumeche and (H5) Loutaya.

Milk collection protocol: A prior appointment was necessary with the camel herders in order to collect milk. Samples were taken early in the morning between 5 and 7 o'clock. Before collecting milk, it was necessary to fasten SCs in the better way, to ensure the safety of the personnel.Generally, we practice a means of ancestral use called (*Aâgal*), which is a form of solid rope with which one knots a tie at the joint of one of the front knees of the SC.The milking was done manually after rinsing udder via the 70° alcohol, as recommended by Mialot (1983) to reduce the risk of contamination by microorganisms on the teats skin, as well as the hands of the milkers. Each milk sample was collected in a 50 ml sterile plastic bottle, than identified and transported to the laboratory of microbiology at Hakim Saâdane Hospital.

*Material and culture media:*In addition to routine equipment and reagents from the microbiology laboratory, it was used for culture; Chapman's medium, Giolitti Cantonii's medium and necessary reagents for biochemical identification.

Microbiological analyzes process:

- Isolation of staphylococci on Chapman's medium after incubation at 37° C for 24h to 48h.
- Microscopic identification and Gram coloring.
- Study of biochemical characters; catalase test, coagulase test, mobility mannitol test, nitrate reductase test and novobiocin sensitivity test (NV 30).
- Counting and identification of staphylococci species, were based on the standards of AFNOR (Guiraud and Rosec, 2004) and England Public Health Protocol (2014).

Statistical analysis. Results of the epidemiological survey and microbiological analyzes were introduced into *SPSS 20*. statistical software (IBM, 2011), in order to firstly apply a descriptive statistical analysis, then a Tau-B Kendall correlation test at (p = 0.05) was performed, aiming to compare the percentages of *Staphylococcus spp.* between all the udder quarters, in SCs of (H4) and (H5).

RESULTS AND DISCUSSIONS

Herds' structure and epidemiological data

All questioned camel herders (N = 5) declared that they don't practice milk control, either as part of state campaigns or through a private network.Generally, the average number of camels in visited herds is 36.6 heads; with a minimum of 16 heads (H5) and a maximum of 62 heads (H3). The ratio; SCs' number/total camels number, is very variable; (20/34 = 58.82%) for H1, (20/40 = 50%) for H2, (26/62 = 41.93%) for H3, (7/31 = 22.58%) for H4 and (11/16 = 68.75%) for H5 (Tab. 1).The variability of this ratio according to considerable differences is a proof of the disproportionate structure of the camel herds, which would be due, mainly; either to a high rate of stillbirth, to problems in reproduction (infertility, abortions, frequent return to heat, insufficient ratio of reproductive males' number/SCs' number... etc), to the sale of camels in case of need or to mortalities in herd due to various pathologies,

The dominant phenotypes are : the *Sahrawi* followed by the *Targui*. Generally, the *Sahrawi* phenotype is most dominant in Ziban region, while some *Targui* heads are scattered from one herd to another. The breeding sites in the study area are generally of argillaceous or sandy soils (Tab.1).

Table 1

Summary of epidemiological data of surveyed camel herds in study area

Region/ Herd	Total camels number (head)	She-camels number (head)	Enclosure hygienic level	Constant bacteriological milk contol	Possible contact with wild fauna	Possible contact with Humans
Loutaya (H1)	34	20	Insufficient	None	Yes	Yes
Ain Karma (H2)	40	20	insufficient	None	Yes	Yes
Bir Nâam (H3)	62	26	insufficient	None	Yes	Yes
Oumeche (H4)	31	7	insufficient	None	Yes	Yes

Loutaya (H5)	16	11	insufficient	None	Yes	Yes

Sampled SCs are characterized, successively, by a mean number of lactations and a mean approximate age (year) of; 2.5 and 6.5 (H1), 1.67 and 6.33 (H2), 3 and 9.5 (H3), 2 and 9 (H4) and finally 1.33 and 7.33 for (H5). It is observed that for the two raised parameters, the herd (H3) holds the highest values.Regarding the hygienic profile, all visited herds had been estimated with insufficient status (Tab.1).This ranking is mostly due to; high promiscuity among animals that was observed in the five herds, the lack of conformity for housing and welfare standards (weight/area adequacy, soil hygiene), the practice of milking which is carried out manually with insufficient washing or sterilization of the hands and udders (Fig.2.A), the dominance of argillaceous soils which are generally muddy and less clean than sandy soils (Fig.2.B), and the doubtful refrigeration of collected milk. Although they are well washed, milking containers are mainly made of plastic, which contrasts with the standards of the dairy industry. Indeed, stainless tools are more suitable for the collection and preservation of milk.

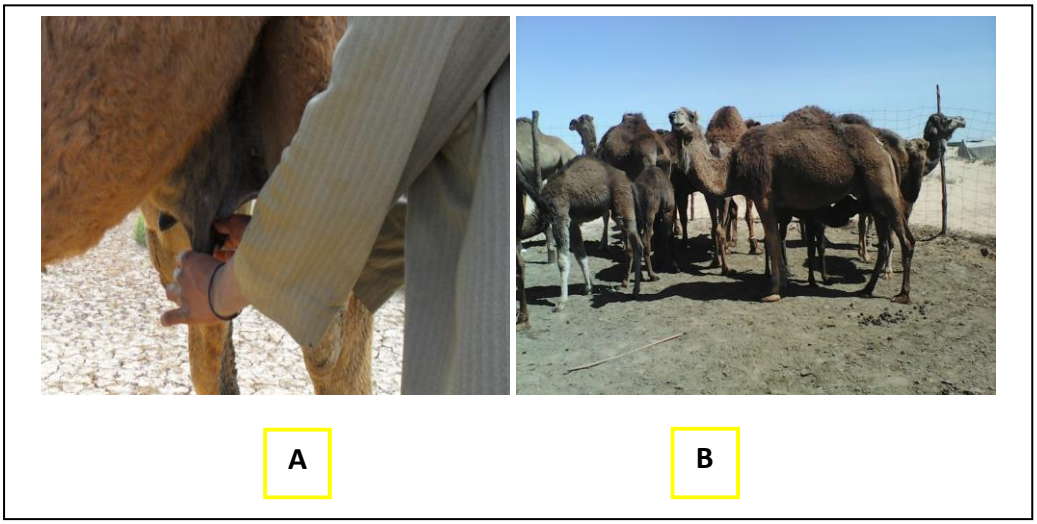

Figure 2. Hygienic profile in periurban camel herds of study area
A: manual milking, **B:** enclosure conception and soil type

According to Srairi et al. (2005), the instantaneous visual classification of the farm hygienic profile is not sufficient to conclude on the real microbiological status of the herd.This could even confuse the survey by producing classification or judgement biases (Vaubourdolle, 2007).However, it could be considered as a form of provisional prioritisation of farms while waiting for the results of the laboratory analyses. It would be more ideal to rank farms according to their breeding profiles, after linking the results of the microbiological analyzes to the findings of the surveys on farms (Srairi et al., 2005).

Dominant staphylococci species in entire milk of H1, H2 and H3

According to the identification criteria of AFNOR (Guiraud and Rosec, 2004) and England Public Health (2014), the eight species of *Staphylococcus* identified at the level of all herd according to different counting, are; *S. aureus, S.*

saprophyticus, *S. cohnii*, *S. warneri*, *S. xylosus*, *S. capitis*, *S. epidermidis*, and *S. hominis* (Tab.2 ; Fig.3).

Table 2

Distribution of identified staphylococci species according to she-camels in herds H1, H2 and H3

She-camel code	***Staphylococcus spp.***							
	S.saprophyticus	*S.cohnii*	*S. warneri*	*S.capitis*	*S.epidermidis*	*S. xylosus*	*S. hominis*	*S.aureus*
H1SC1	**Yes-**	**Yes-**	**Yes-**	No	No	No	No	**Yes+**
H1SC2	No	No	**Yes-**	**Yes-**	**Yes-**	**Yes-**	No	No
H1SC3	No	No	**Yes-**	**Yes-**	**Yes-**	**Yes-**	**Yes-**	No
H1SC4	No	No	No	No	**Yes-**	No	**Yes-**	No
H1SC5	No	No	No	No	**Yes-**	No	**Yes-**	No
H1SC6	No	No	No	No	No	No	No	**Yes+**
H2SC1	No	No	No	No	No	No	No	No
H2SC2	No	No	No	No	No	No	No	No
H2SC3	No	No	No	No	**Yes-**	No	**Yes-**	No
H2SC4	**Yes-**	**Yes-**	**Yes-**	No	No	No	No	No
H2SC5	No	No	No	No	No	No	No	**Yes+**
H2SC6	**Yes-**	**Yes-**	**Yes-**	No	No	No	No	No
H3SC1	No	No	No	No	**Yes-**	No	**Yes-**	No
H3SC2	**Yes-**	**Yes-**	**Yes-**	No	No	No	No	No
H3SC3	No	No	No	No	**Yes-**	No	**Yes-**	No
H3SC4	No	No	No	No	**Yes-**	No	**Yes-**	No
H3SC5	No	No	No	No	**Yes-**	No	**Yes-**	No
H3SC6	**Yes-**	**Yes-**	**Yes-**	No	**Yes-**	No	**Yes-**	No
H4SC1	No	No	**Yes-**	**Yes-**	**Yes-**	No	No	No
H4SC2	No	No	**Yes-**	**Yes-**	**Yes-**	No	**Yes-**	No
H4SC3	No	No	**Yes-**	**Yes-**	**Yes-**	No	No	**Yes+**
H4SC4	No	No	No	No	No	No	No	No
H4SC5	**Yes-**	**Yes-**	**Yes-**	No	No	No	No	No
H4SC6	**Yes-**	**Yes-**	No	No	No	No	No	No
H5SC1	No	No	**Yes-**	**Yes-**	**Yes-**	No	No	No
H5SC2	No	No	**Yes-**	**Yes-**	**Yes-**	No	**Yes-**	**Yes+**
H5SC3	No	No	No	No	No	No	No	No
H5SC4	No	**Yes-**	**Yes-**	No	No	No	No	No
H5SC5	No	No	No	No	No	No	No	No

H5SC6	**Yes-**	**Yes-**	No	No	No	No	No	No

No: Absence, **Yes -:** presence with negative coagulase,
Yes +: presence with positive coagulase, **H**: Herd, **SC**: She-camel.

Overall, 20.83% (n=5) of the surveyed SCs were found to be carriers of *S. aureus*. SCs from H1 (Loutaya) showed the highest rate of *S.aureus* infection (2/6 in herd: H1SC1 and H1SC6), while she-camels from H2 (Ain Karma), H4 (Bir Nâam) and H5 (Loutaya) showed a lower rate (1/6 for each herd).Whereas no SC from H3 (Oumeche) was positive for *S.aureus* (Tab.2). Thus, several SCs carried *S. aureus*, indicating the existence of subclinical mastitis cases in the camel herds visited, as well as the non-compliant marketing of raw camel milk as it was reported by Aggad et al. (2009), especially since this type of milk is often consumed without being heated or boiled, in order to take advantage of its sanitary and therapeutic virtues (Mammeri et al., 2014; Mammeri, 2016; Mammeri and Khir, 2018).

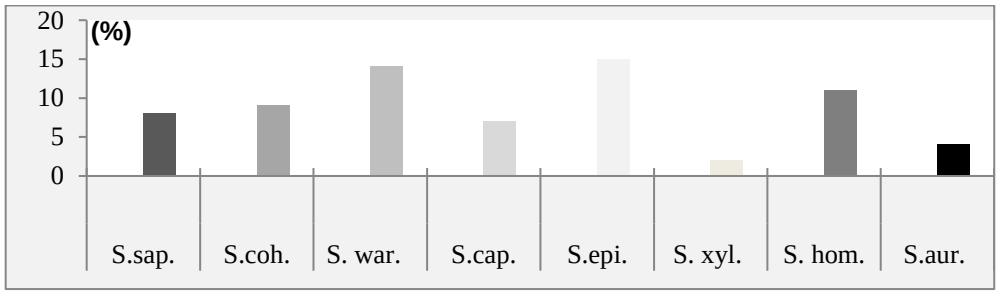

Figure 3. Distribution and counting results of identified staphylococci species on she-camels in whole herds (H1, H2 and H3)

Comparison of staphylococci species enumeration percentages in herds H1, H2 and H3. In the three visited herds, the dominant *Staphylococcus spp.* are : *S.epidermicus*, *S.warneri*, *S.hominis*, while *S.aureus* and *S.xylosus* are the least recorded (Fig. 3).The high levels and diversity of *Staphylococcus spp.* isolated reflect inappropriate herd management and an illusory health status of the rest of the camel herd. In fact, the dominance of the genus *Staphylococcus* has often been observed in microbiological analysis of milk throughout the world. For example, in a study of subclinical mastitis in Saudi Arabia (N=30); *S.aureus* accounted for 16.6%, while other staphylococci accounted for 63.3% of the bacteria isolated from camel milk (Saleh and Faye, 2011).In another study conducted in Ethiopia (N=161), coagulase-negative staphylococci accounted for 39.6% and *S.aureus* for 4.2% of bacteria isolated from camel milk (Eyassu and Bekele, 2010).

Comparison of staphylococci species enumeration percentages according to udder quarters anatomical position in H4 and H5. It is remarkable that the distribution of *Staphylococcus spp.* differs quantitatively from one quarter to another, and even if this distribution is random, it would certainly have an effect on the risk of contamination from one quarter to another for the consumer or for the calve. The infection rates and the isolated species of staphylococci are not identical for all the quarters in the same SC which were confirmed by the positivity of Kendall Tau-B

correlation test between the right anterior (R.A), the right posterior (R.P) and the left posterior (L.P) mammary quarters, and on the other hand between the R.A and the left anterior (L.A) mammary quarters (p=0.014).The milk contamination rates of *S. aureus* recorded at the herds H4 (Bir Nâam) and H5 (Loutaya) do not conform to the limited value in the Algerian Official Journal (*S.aureus* = null) for raw milk.Also, it is an indicator of the perennity of subclinical mastitis insidiously (Fig. 4 and Fig. 5).Lancelot et al., (1997) suggest a favourable role for the anatomy of the camel, characterized by a narrow and limited pelvis, to ensure better protection of the hindquarters compared to the forequarters on the one hand, and compared to the anatomy of cattle on the other hand. According to a study conducted in Saudi Arabia by Saleh and Faye (2011), the high values for SCC as well as CMT scores, observed for the posterior quarters of SCs, were lower than those usually observed in cows where the posterior quarters are most exposed to infection.

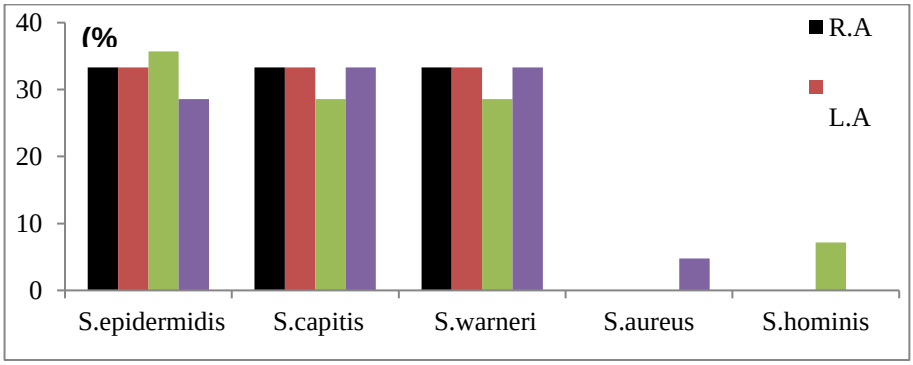

Figure 4. Average *Staphylococcus spp.* counts in raw milk from H4 distributed according to udder quarters (%); (R.A : Right anterior ; L.A : Left anterior ; R.P : Right posterior ; L.P : Left posterior)

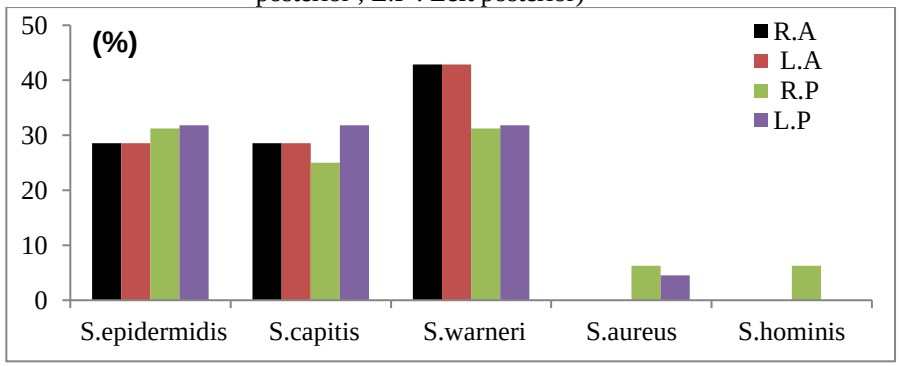

Figure 5. Average *Staphylococcus spp.* counts in raw milk from H5 distributed according to udder quarters (%); (R.A : Right anterior ; L.A : Left anterior ; R.P : Right posterior ; L.P : Left posterior)

Evaluation of environmental interactions and zoonotic threats in camel periurban herds. The Fig.6 shows the possible contact pathways between camels and wildlife on the one hand, and between camels and components of the urban environment on the other hand, which could be a major factor in the perpetuation and transmission of *Staphylococcus spp.*According to Mammeri (2022), the complex

ecological and emblematic positions, of the dromedary camel, seem to make it an inescapable reservoir of contagious diseases, especially that it puts itself incidentally in first line of contact with the wild fauna, compared to the other domestic species.

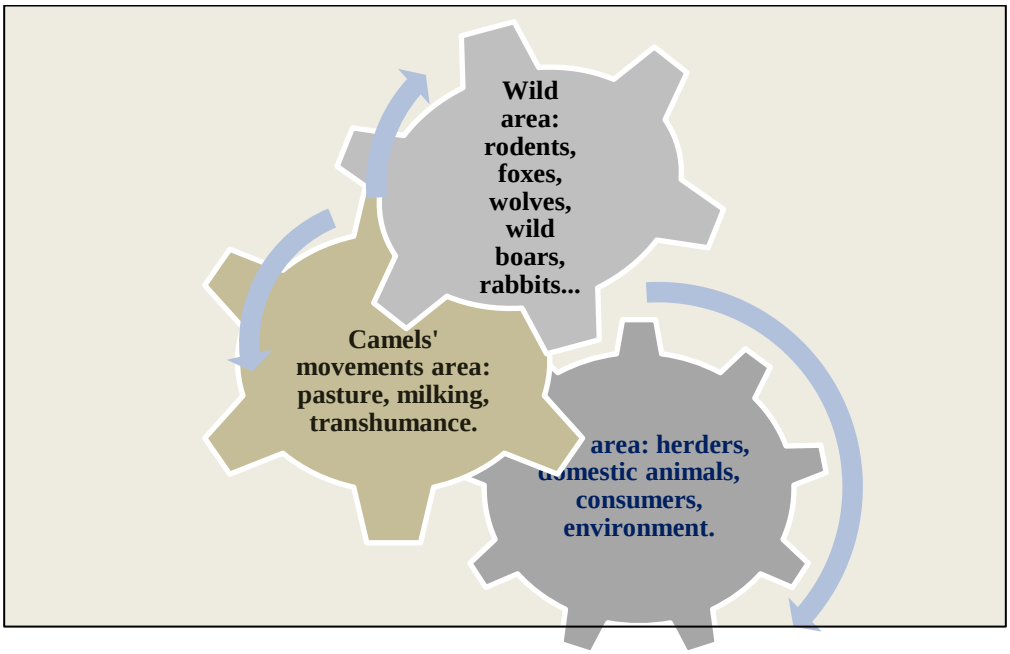

Figure 6. Eventual interactions between camels, wild area and city area in periurban breeding system (Mammeri A. conception)

Milking hygiene was generally poor on the camel farms visited.The elimination of the first sprays before milking was generally done on the enclosure's floor, in the absence of litter, thus presenting a risk factor for contamination of the camel's lying surface. These hygiene failures are risk factors for subclinical mastitis. The observations of the present study corroborate those of several authors who indicate that these factors are closely related to the development of mammary infections (Eyassu, 2007; 2009; Eyassu and Bekele, 2010; Boufaida, 2012).

As regard zoonotic threat, we could not neglect the possible contact of SCs' udder with Humans that would include mainly; milking staff, household members or the treating veterinarians.In fact, the manual milking method without rigorous hands' and teats' disinfection, the use of insufficiently sterilized water, the use of a single wipe for all SCs and on a daily basis without substitution, the unsanitary conditions of the stall, would be the main risk factors promoting the occurrence of mastitis and food-borne diseases.Furthermore, the non-use of disposable sterile gloves, which could reduce contamination of teats by the milker's hands, is a factor to be taken into consideration. Indeed, bacteria adhere much less to these gloves than to the skin of chapped hands (Lévesque and Hetreau, 2007). The sources of contamination with *S.aureus* on the farm are: teat skin and skin superinfections, hands, milker's nose and throat infections, poorly cleaned and disinfected milking equipment (Billon and Sauve, 2009).

Several camel zoonotic diseases are due to the consumption of raw SC's milk traditions, as well as to the clumsy culinary habits of the population living in a

nomadic way (Mammeri, 2022). In terms of epidemiology, *S.aureus* is considered as the main cause of mastitis, and is often associated with human food poisoning outbreaks (Mihaela et al., 2010). Although *S.aureus* is a highly pathogenic bacterium in raw milk, it should be noted that it is destroyed by pasteurisation (Fatet, 2004), but the enterotoxin it produces is resistant to pasteurisation, dehydration, freezing and various proteolytic enzymes, and in some cases it is responsible for food poisoning resulting in nausea, abdominal and muscular pain, diarrhoea, headache and even hypertension.

S.aureus, as well as other related species such as *S. intermedius* and *S. hyicus*, are major pathogens in the animal kingdom giving rise to furunculosis in dogs (*S. intermedius*) which is often recurrent and sometimes difficult to treat. Indeed, *S. intermedius* is more adapted to certain animal hosts (dog, pigeon, horse, etc.) and is rarely found in processed foodstuffs, although a few rare cases of food poisoning due to this species have been reported in the literature (Guiraud and Rosec, 2004). Mastitis of cows, ewes and goats (due to *S.aureus* most often), abscess disease of sheep (*S. aureus subspecies anaerobius*) or exudative dermatitis of piglets (*S.hyicus*) have a significant economic impact (Institut Pasteur de France, 2012).

Among the risk factors for subclinical mastitis in camels, Eyassu and Bekele (2010) reported that the constant passage of camels near broken and thorny branches of plants grazed by the dromedary favours injuries. This factor corroborates our findings during the survey (Fig.7) and could be added to the almost permanent stay of the camels on hard and stony ground (Fig.2.A). Environmental conditions could amplify the risks of udder infection by the potential contact with wild fauna (rodents, rabbits, canids…) while grazing or resting in open spaces where wild animals may live (Fig.6; Fig.7).

Figure 7. Camels of study area grazing in the wild interface

CONCLUSIONS

Subclinical mastitis could be considered as one of the most frequent and costly diseases affecting camels, as it usually occurs in an insidious form, without symptoms or visible alterations in the milk. Biologically, they are only detected by

certain analytical, microbiological and immunological methods in raw milk.Thus, when it is not detected early, it would cause inestimable economic losses and expensive treatment costs. The contamination of milk by *S. aureus* alerts us to the existence of high risks of contamination or food poisoning in the human sphere of livestock staff and potential consumers, especially since she-camel milk is often consumed in its raw state, for cultural and therapeutic reasons.

In order to reduce the risk of udder infections, good hygienic measures are urgently needed; regular milk recording to establish prophylactic treatment plans and good follow-up of mastitis chronic cases; rapid treatment of udder injuries.The application of H.A.C.C.P. is necessary at all stages of the milk production chain.In addition, consumers' education on the obligation to boil raw milk before consumption is essential to minimise the potential risk of food-borne diseases.

The development of camel breeding in Ziban region deserves more efforts, either from the public authorities concerned, through extension sessions, census trips, and the setting up of a sufficient number of she-camel milk processing or pasteurisation infrastructures, or from the breeders who should be better informed about respect of the hygienic norms.

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