Research Article

Microbiological and Physico-Chemical Characteristics of Camel Milk from Southwestern Algeria

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Abstract | This study investigates the physico-chemical and microbiological characteristics of fresh camel milk collected from different regions of Southwestern Algeria. Samples were collected from 48 camels of El Bayadh, Bechar, Adrar and Tindouf. A wide variation was observed in the physico-chemical properties due to variation in feed, lactation period and environmental conditions. Microbiological results indicate that camel milk from Tindouf was the most contaminated with total aerobic flora, psychrotrophic flora, total and thermos-tolerant coliforms, faecal streptococci, total yeasts and moulds. Whereas camel milk from El Bayadh was the least contaminated with total aerobic flora, psychrotrophic flora, total yeasts and moulds. All samples tested for pathogenicity were negative for pathogenic germs.

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Introduction

Camels milk is an important part of nomads' diets in arid and semi-arid regions. It is a source of energy and nutrients and its high in vitamin C, niacin, unsaturated fatty acids and essential amino acids that are necessary for human nutrition. In Southwestern Algeria, camel breeds are diverse from one region to another as they differ in the ecological zones in which they live as well as in the way they are raised. These differences may contribute to the different physico-chemical characteristics of camel milk. Furthermore, milk inevitably contains a microflora, the nature and importance of which are influenced by the animal's health, milking practices and milk storage conditions (Larpent, 1997). In this context, our study aims to characterize dromadory milk from four regions of Southwestern Algeria in terms of physiochemistry and microbiology

Materials and Methods

Sampling

Milk samples were taken from 48 camels (average weight 455±14 kg; age 10-14 years) From each region, 12 camels were randomly selected. The

Sahraoui breed was present in Tindouf, Adrar and Bechar and the Targui breed in the El Bayadh region (Figure 1). The camels of Tindouf and Adrarwere bred in an extensive system fed with *Acacia radiana*. The camels of Bechar and El-Bayadhwere bred in a semi-intensive mode, where they were provided with morning and evening pasture; they fed barley and oat hay. Milk samples from these camels were taken at the beginning and middle of the lactation phase. The collection was done in the evening. The samples were refrigerated in a freezer until transport to the laboratory.

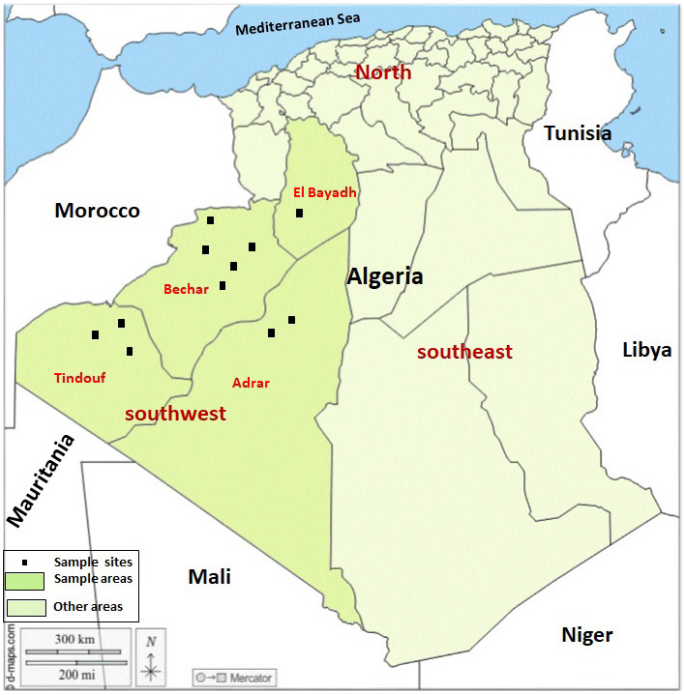

Figure 1: *Camel milk collection site.*

Determination of physico-chemical parameters

The pH measurement of camel milk was carried out using the pH meter (AOAC, 2000), while the titratable acidity was measured by the titration method using a strong base (AOAC, 2000). The density of the samples was measured with a thermo-lacto-densimeter. Total solids were determined by (AOAC, 2000). The Gerber method was used to determine the fat content of milk (Marshall, 1993) and the standard Kjeldahl method was used to determine the protein content (IDF Standard, 2001). Estimation of ash content was carried out after drying the milk samples by incineration at 550°C in a muffle furnace (AOAC, 2000).

Determination of microbiological parameters

For microbiological analysis, the preparation of suspensions and decimal dilutions for microbiological tests were carried out in accordance with ISO 68875 (2010). The bacteriological parameters analysed in this study were total aerobic bacteria, total and thermos-tolerant coliforms, coagulase-positive staphylococci, sulphite-reducing clostridia, salmonella, faecal streptococci, lactic acid bacteria, mould and yeast.

Count in CFU (colony forming units) of, total aerobic bacteria, psychrotrophic, total and thermo-tolerant coliforms, faecal streptococci, coagulase-positive staphylococci, sulphite-reducing Clostridia, Salmonella, acid lactic bacteria, moulds and yeasts.

Total aerobic bacteria

The enumeration was performed according to the French standard (NF EN ISO 4833-2) on skimmed milk agar plates (PCA: Pasteur Institute of Algiers) after incubation at 30±1°C for 72±2 hours.

Psychrotrophs

Psycrotrophs were enumerated according to the Afnor standard (NF ISO 17410) in skimmed milk agar plates (PCA: Pasteur Institute of Algiers) after incubation at 6.5°±1°C for 10 days.

Total and thermotolerant coliform

The counts of total coliforms and thermotolerant coliforms were done according to the Afnor standard (NF ISO 4832, NF V08-060, respectively) on violet red bile lactose agar medium (VRBL: Pasteur Institute of Algiers) after incubation at 30°C and at 44°C for total coliforms and thermotolerant coliforms, respectively.

Faecal streptococci

The faecal streptococci were enumerated by presumptive culture using Roth's broth (Pasteur Institute of Algiers) incubated for 24 hours at 37°C, from positive media, the inoculum is inoculated onto bile esculin azide, agar (BEA: Pasteur Institute of Algiers) used for conformation after incubation at 37°C for 24 h to 48 h (Maury, 1987).

Coagulase-positive staphylococci

The enumeration of coagulase-positive staphylococci was performed as reported by the Afnor standard (NF EN ISO 6888-1) using Baird-Parker agar (Difco), incubation is done at 37°C for 24 to 36 hours. Coagulase positive staphylococci give black, shiny, convex colonies with a clear halo. Confirmation is done by the coagulase test using rabbit plasma (Pasteur Institute of Algiers).

Sulphite-reducing clostridia

The counts of sulphite-reducing Clostridia were performed according to the Afnor standard (NF V08-061) using Tryptone-Sulphite-Cycloserine agar (TSC agar: Pasteur Institute of Algiers). To enumerate sulphite-reducing Clostridia, an aliquot of milk placed in a sterile tube was preheated for 10 min at 80°C and cooled in melting ice to destroy the vegetative forms and activate the spores. From these conditions, 1 ml of each dilution was aseptically put to sterile screw tubes. Approximately TSC agar was added, cultures were incubated anaerobically at 46°C for 24 ± 2 hours, after which only colonies, surrounded by a black halo, were counted.

Salmonella

Salmonella enumeration was performed according to the Afnor standard (NF EN ISO 6785). In general, the search for Salmonella requires 4 successive phases as indicated. Pre-enrichment in buffer peptone water and incubation at 37°C for 16 to 20 hours. The pre-enriched solution inoculates 0.1 ml of the resulting culture into Rappaport Vassiliadis medium and 2 ml into selenite-cystine medium. Incubate the medium with tetrathionate at 43°C and incubate the selenite-cystine at 37°C for two periods of 18 hours to 24 hours. From the culture obtained from the tetrathionate medium, inoculate a Hektoen agar plate (with bismuth sulphite) and inoculate a broth culture from the Rappaport Vassiliadis broth culture green shiny red phenol agar plate. Incubation is at 37°C and examination after 20-24 hours, and if necessary, after 40-48 hours, to check for colonies, presumed to be Salmonella because of their characteristics.

Yeasts and moulds

Yeast and mould counts were performed according to the Afnor standard (NF ISO 21527) using pink dichlo ran bengale chloramphenicol (DRBC) agar. Cultures were incubated at 25°C for five to seven days.

Lactic acid bacteria

The counts of lactic flora were performed according to the Afnor standard (NF ISO 15214) using DeMan, Rogosa, Sharpe (MRS) agar. Incubation was done at 25°C for 72 hours.

Statistical analysis

RGui software (version 3.5.1) was used to perform the statistical analysis. The results are expressed as mean ± standard error. The ANOVA test was employed to compare means and the differences were considered statistically significant at $p < 0.05$.

Results and Discussion

Results of physico-chemical analysis

Table 1 lists the average values of the physico-chemical parameters.

pH

pH by definition is the measure of the activity of the H+ ions contained in a solution. pH measurement provides information on the acidity of milk.

The results of the pH determination are given in Table 1, which shows that camel milk samples are slightly acidic and varied between 6.27 and 6.50. The difference in pH value was not significant ($p>0.05$) between them. Our results were close to those of Raghvendar *et al.* (2004), Maha *et al.* (2019), El-Hosseny *et al.* (2018), and Hadef *et al.* (2018). At the same moment, they are higher than those reported by Siboukeur (2007), Merzouk *et al.* (2013) and Legesse *et al.* (2017). However, higher pH value was reported by Khaskhli *et al.* (2005). Several researchers attributs the low pH of camel milk to itshigh concentration of volatile fatty acids and even to its high vitamin C content (Mal and Pathak, 2010; Siboukeur, 2007). In addition to that, pH of milk can vary with availability of water and fodder quality to the animal.

Titratable acidity

The determination of the acidity of a milk makes it possible to appreciate the quantity of acid produced by lactic acid bacteria.

The mean values of acidity measured in this study were 17.66°D, 17.83°D, 18.75°D and 19.96°D for the samples from Tindouf, El-Bayadh Bechar and Adrar respectively, the difference in the acidity of the camel milk samples was significant ($p<0.05$). The acidity of the Adrar samples was significantly higher than that of the other samples. Our results are in line with the findings of Sboui *et al.* (2009) in Tunisia, Boudjenah, (2012), Siboukeur (2007) in Algeria and Khaskheli *et al.* (2005) in Pakistan which were 17.2 °D± 1.03, 17°D, 18.2 °D and 18 °D, respectively.

However, they are different from those reported by some authors, particularly by Raghvendar *et al.* (2004) and Jaydeep *et al.* (2014). Sanayei *et al.* (2015) reported

Table 1: *Physico-chemical analysis of camel milk.*

		Bechar	Tindouf	El Bayadh	Adrar	P-value
pH	**Mean±SD**	**6,50±0,19**	**6,27±0,17**	**6,43±0,08**	**6,39± 0 ,41**	0.174
	Min	6,26	6	6,28	5,55	
	Max	7,04	6,45	6,55	6,89	
	cv	2,95%	2,78%	1,38%	6,55%	
Titratable acidity D°	**Mean±SD**	**18,75±2,35**	**17,66±0,77**	**17,83±0,71**	**19,96±1,08**	0.00073
	Min	18,5	17	17	18	***
	Max	23	19	19	21,5	
	cv	12,58%	4,40%	4,02%	5,44%	
Density	**Mean±SD**	**1,027±0,004**	**1,025±0,004**	**1,031±0,01**	**1,032±0,02**	0.00011
	Min	1,020	1,020	1,030	1,027	***
	Max	1,032	1,030	1,033	1,035	
	cv	0,46%	0,44%	0,13%	0,23%	
Total solids content (%)	**Mean±SD**	**13,03±1,19**	**11,52±1,52**	**14,81±1**	**13,22±0,94**	$5.36e^{-07}$
	Min	11,4	9,58	13,01	11,3	
	Max	14,8	13,43	14,81	14,49	***
	cv	9,17%	13,21%	6,79%	7,11%	
Fat content (%)	**Mean±SD**	**4,30±2,4**	**4,45±0,56**	**3 ,08±0,33**	**3,03± 0,71**	0.0107
	Min	1,1	4	2,6	1,8	*
	Max	8,1	5,4	3,9	4,1	
	cv	55,83%	12,59%	10,94%	23,72%	
Total protein (%)	**Mean±SD**	**3,90±0,24**	**6,23±0,95**	**3,45±0,57**	**3,97±0,31**	$3.87e^{-15}$
	Min	3,5	4,01	2,89	3,77	***
	Max	4,2	7,8	4,62	4,3	
	cv	6,28%	15,39%	16,54%	3,32%	
Lactose (%)	**Mean±SD**	**3,85±0,39**	**3,80±0,40**	**4,35±0,44**	**3,34±0,23**	$1.28e^{-06}$
	Min	3,24	3,07	3,69	2,92	***
	Max	4,52	4,29	4,83	3,63	
	cv	10,23%	10,58%	10,33%	6,98%	
Ashes(%°	**Mean±SD**	1,80±0,13	2±0,11	1,53±0,10	1,81±0,12	$8.67e^{-06}$
	Min	1,51	1,82	1,14	1,59	***
	Max	1,97	2,18	2,04	2	
	cv	7,59%	5,65%	20,63%	6,97%	

lower values of acidity in Iranian Indian camel milk, which were 15.4 °D, 14.4° and 12 °D, respectively. On the other hand, Konuspayeva (2007) and Faye *et al.* (2008) in Kazakhstan, and Siboukeur (2007) in South-eastern Algeria reported higher values which were 26°D, 24.4°D and 21°D. Variations in acidity values are generally due to variation in feed, environmental conditions and the lactation period and it could be also due to hygienic conditions, milking and the initial load of microbial flora present in raw camel milk (Alhaj and Alkanhal, 2010; Abutarboush, 1996). According to Badaoui (2000), this acidity comes mainly from proteins, phosphates and dissolved CO_2. It then acquires a so-called developed acidity because it is due to production lactic acid by microorganisms.

Density

Density is the ratio of the masses of a volume of milk to the same volume of water at 20°C. This mass results from the various densities of the constituents of milk: water, fat, proteins, sugars, etc. The quantity of these different constituents not being constant, the density of the milk is therefore variable. Fat and defatted dry matter particularly influence the density

According to the density results given in Table 1, The mean values were 1.032 in the Adrar samples, 1.027 in the Bechar samples, 1.025 in the Tindoufsingles and 1.031 in the El Bayadhsingles (Table 1). The difference between the mean values of the densities was significant (p>0.05). The results obtained in the current work are in consonance with findings reported by Sanayei *et al.* (2015), Maha et al. (2019) and Legesse *et al.* (2017) which were 1.030, 1.026 and 1.025, respectively. However, they differ from those reported by Siboukeur (2007), Alloui-Lombarkia *et*

al. (2007) and Sboui *et al*. (2009) which were 1.023, 1.038 and 1.020, respectively. This variation in density can be associated to many factors like diet, breed, watering frequency, milking frequency, lactation stage and the animal's age (Siboukeur, 2007; Legesse et al., 2017).

Total solids content

The total solids content of milk designates all its constituents other than water.

Results show that the mean total solids content of camel milk collected in El-Bayath (14.81%) was significantly higher than milk collected in Adrar (13.28%) followed by camel milk collected in Bechar (13.02%). However, the mean total solids content of milk collected in Tindouf (11.52%) was the lowest. Some similar studies have given very close values to our findings (Mohamed et al., 2014; Sanayei *et al*., 2015) while others have given lower values which were ranged from 9.99% to 10.9% (Seher *et al*., 2013; Ahmed *et al*., 2014; Maha et al., 2019; Hadef *et al*., 2018).

Several authors have shown that this variation in total solids content is attributable to the animals' access to variable water quality and quantity (Khaskheli *et al*., 2005). In addition, Ereifej *et al*. (2011) reported that the content of camel milk is affected by genetic variability and geographical origin. Furthermore, transitioning from a water-rich diet to a dehydrate diet results decrease in total dry matter content from 8.8 to 14.3% and that under deprivation or insufficient watering. Camel milk's water content increases from 87 to 91% in a physiological response to water stress to ensure the survival of the camel (Yagil and Etzion, 1980).

Fats

Milk fat is considered a source of energy. It acts as a solvent for fat-soluble vitamins and provides essential fatty acids (Farah *et al*., 2004).

The results presented in Table 1 revealed that the average fat content of camel milk from Adrar, Bechar, El Bayadh and Tindouf was 3.03%, 4.30%, 4.45% and 3.08%, respectively. The difference between the mean values was significant ($p>0.05$), where camel milk from El Bayadh had the highest fat content, followed by camel milk from Bechar, but camel milk from Adrar had the lowest fat content. These results are between the extreme values, noted for the Somali breed (56 g/l; Karue, 1994) and for the Wadahbreed (24.6 g/l; Mehaia *et al*., 1995). According to Kamoun (1994), the fat content of milk is affected by the animal's hydration status and the type of forage fed. Lipids and lipoid compounds make up the majority of milk fat, which is an important source of energy. It's also a good source of vital fatty acids and fat-soluble vitamins (Khaskheli *et al*., 2005).

Total protein

Camel milk proteins are very diverse in terms of composition and properties (biological, technological and functional). Protein is considered the main component of milk, which has a significant impact on its nutritional value and technological suitability (Gizachew *et al*., 2014).

The results summarised in Table 1 shows that the greatest protein content in camel milk was 6.23% in Tindouf samples, followed by Bechar and Adrar camel milk. Adrar and Bechar camel milk protein content is nearly same, with a non-significant difference ($p>0.05$). In contrast, the lowest protein content was 3.4% in El Bayadh camel milk. These values are similair to those provided by Mehaia *et al*. (1995) for Saudi camel milk. In addition, the results obtained in our study are higher than the values obtained by (Sboui *et al*., 2009; Kamoun, 1994; Attia et al., 2000; Wangoh et al., 1998; Kamal *et al*., 2007), which were (34.15 g/l, 34.3 g/l; 30.72 g/l, 30.8 and 33.1 g/l). However, the differences observed in protein content can be due to a variety of factors, including geographical location, samples collected from different breeds, age of animal and also lactation stage. Several authors have reported that the grass-based diet decreases the protein content of milk. According to Wolter (1997), a wheat-based diet induces a moderate increase in milk protein content compared to a preserved or grazed grass-based diet.

Lactose

Lactose is a major carbohydrate in milk (Meiloud *et al*., 2011). Naturally present in milk. Lactose is made up of glucose and galactose, two simple sugars used directly by our body as a source of energy. This study shows that camel milk from El Bayadh region has the highest lactose content of 4.34%, followed by camel milk from Bechar and Tindouf. However, a low level of lactose content was in camel milk from Adrar, which is 3.34%.

Our results are close to many results stated by Konuspayeva *et al.* (2009), Abdul Raziq *et al.* (2011), Maha *et al.* (2019), which were4.46%,3.11%, and 4.37%, respectively. Higher lactose contents were reported in similar studies which exceed 5% (Khan and Appanna, 1964; El-Agamy, 1983; Gnan and Sheriha, 1986; Farah and Ruegg, 1989). In contrast, lower lactose content (2.56%) is also reported in the findings of Ali-Gorban and Izzeldin (1997). These differences observed in lactose content are explained by the difference in breed between regions and also the stage of lactation and hydration status. According to Khaskheli *et al.* (2005), the large variation could be since camels usually graze on halophilic plants, e.g., Atriplex, Acacia. These variations in lactose content in our study are responsible for the variations in the taste and flavour of camel milk.

Ash

Milk minerals form only a small part of the dry substances, but they are interesting because of their calcium and phosphorus. Milk is one of the most important sources of calcium in nutrition human.

The ash content of the milk collected in Tindouf is around 2.18% and, therefore, appears to be high compared to milk from the regions of El Bayedh, Adrar and Bechar; several research report lower value then these results such as 0.87% (Maha et al., 2019) and 0.7% (Abdul Raziq *et al.*, 2011). The high ash contents observed in our results are explained by camel grazing in the desert having halophilic plants.

Result of microbiological analysis

Tables 2, 3, 4 provides the counting of the various microbial flora in fresh camel milk samples.

Total aerobic flora

Total aerobic flora is a spoilage agents this flora is a good health indicator. The results of the total aerobic flora count in raw camel milk (Table 2) show that camel milk from Tindouf is the most contaminated with these germs with an average of $(2.50\pm1.06)10^5$cfu/ml. It is followed by camel milk from Bechar and El Bayedh with average contamination values equal to (1.45 ± 0.79) 10^5cfu/ml and $(7.7\pm3.61)10^4$cfu/ml, respectively. Incontrast, the lowest mean contamination reaches $(1.77\pm1.7)10^4$ cfu/ml in camel milk from Adrar. In this context, almost similar results were previously reported by Younan and Abdurahman (2004) (10^3-10^5 cfu/ml). On the other hand,

Table 2: *Enumeration of total aerobic flora and psychrotrophic flora in camel milk.*

		Tindouf	El Bayadh	Adrar	Béchar	P-value
Total aerobic flora (cfu/ml)	**Mean±SD**	**$(2,50\pm1,06)10^5$**	**$(7,7\pm3,61)10^4$**	**$(1,77\pm1,7)10^4$**	**$(1,45\pm0,78)10^5$**	$1.42e^{-09}$ ***
	Min	$1,35.10^5$	$2,5.10^4$	1.10^3 $4,70.10^5$	$7,4.10^4$	
	Max	$4,5.10^5$	$1,31.10^5$	96,04 %	3.10^5	
	cv	42,4%	46,88 %		53,79%	
Psychrotrophic flora (cfu/ml)	**Mean±SD**	**$(3\ ,58\pm0,99)10^4$**	**$(7,68\pm6,78)10^3$**	**$(11,5\pm6,78)10^3$**	**$(22,08\pm17,97)10^3$**	**$8.26e^{-07}$** ***
	Min	$2,3.10^4$	$1,45.10^3$	1.10^3	5.10^3	
	Max	$5,6.10^4$	2.10^4	$2,3.10^4$	$6,7.10^4$	
	cv		88,28%	58,9%	81,38%	

Table 3: *Enumeration of total coliforms, thermotolerant coliforms and faecal streptococci in camel milk.*

		Tindouf	El Bayadh	Adrar	Béchar	P value
Total coliforms (cfu/ml)	**Mean±SD**	**$(1,74\pm0,35)10^5$**	0	**$(1,45\pm0,63)10^3$**	**$(2,74\pm0,54)10^3$**	$2e^{-16}$
	Min	$1,32.10^5$		10^2	$2,02.10^3$	
	Max	$2,4.10^5$		$4,3.10^3$	$3,66.10^3$ 19%	
	cv	20%		43,44%		
Thermotolerant coliforms (cfu/ml)	**Mean±SD**	**$(1,50\pm0,39)10^5$**	0	**$(0,51\pm0,46)10^3$**	**$(1,63\pm0,93)10^3$**	$2e^{-16}$
	Min	1.10^5		0	$1,1.10^2$	
	Max	$2,01.10^5$		$1,3.10^3$	$2,6.10^3$	
	cv	26%		90,19%	57,05%	
Faecal streptococci	**Mean±SD**	**$(71,5\pm70,83)10^2$**	0	**$(20,25\pm11,97)10^2$**	**$(7,25\pm5,10)10^2$**	0.00155
	Min	$1,4.\ 10^2$		9.10^2	1.10^2	
	Max	$2.\ 10^4$		4.10^3	$2,5.10^3$	
	cv	99,06%		59%	70,34%	

Table 4: *Enumeration of fungal flora and lactic acid bacteria in camel milk.*

		Tindouf	El Bayadh	Adrar	Bechar	P value
Yeasts and molds (cfu/ml)	**Mean±SD**	**(35,67±15,98)10^2**	**(13,61±10,80)10^2**	**(8,63±3,22)10^2**	**(12,91±5,37)10^2**	1.79e-^{10}
	Min	8,13 .10^3	1,57 .10^3	4,4 .10^3	5,63.10^3	
	Max	6,15 .10^4	3,58 .10^4	14 .10^3	23,2.10^3	
	cv	44,79 %	79,35%	37,31%	41,59%	
Lactic acid bacteria (cfu/ml)	**Mean±SD**	**(2,99±1,83)10^5**	**(19,25±5,10)10^5**	**(37,95±10,46)10^5**	**(23,81±2,28)10^5**	<2e-^{16}
	Min	1 .10^5	11 .10^5	25 .10^5	20,36 .10^5	
	Max	6 .10^5	26 .10^5	55 . 10^5	26,7 .10^5	
	cv	61%	26,49**%**	27,56%	9,57%	

a higher bacterial load was given in other studies by some authors, namely Semereab and Molla (2001), Benkerroum *et al.* (2003), Sela *et al.* (2003), El-Ziney and Al-Turki (2007). This high microbial load in camel milk from Tindouf and Bechar would be due to poor hygienic conditions during milking. In contrast, the low counts of total aerobic flora in camel milk from El Bayadh could probably be attributed to proper handling of the samples during milking.

Psychrotrophic flora

Psychrotrophic bacteria are defined as group of different bacterial species that are able to grow at 7°C or less regardless of their optimal temperature of growth they have the ability to produce heat stable extracellular and/ or intracellular hydrolytic enzymes, which caused the spoilage of milk.

The range of psychrotrophic flora in Tindouf camel milk was 2.3.10^4cfu/ml to 5.6.10^4 cfu/ml, and the mean value was (3.58±0.99)10^4cfu/ml. Furthermore, thepsychrotrophic flora in Becher camel milk was 5.10^3 cfu/ml to 6.7.10^4 and the mean value was (22.08±17.97)10^3 cfu /ml. Similarly, in Adrar camel milk, thepsychrotrophic flora varied from 1.10^3cfu/ml to 2.3.10^4cfu/ml and the mean value was (11.5±6.78)10^3 cfu/ml whilein El Bayadh camel milk, thepsychrotrophic flora varied from1.45.10^3cfu/ml to 2.10^4cfu/ml and the mean value was (7.68±6.78)10^3cfu/ml. Thus, Tindouf camel milk had the highest psychrotrophic flora content, followed by Bechar camel milk, Adrar camel milk and El Bayadh camel milk**.** The difference in thepsychrotrophic flora count in camel milk (Adrar, Bechar, El-Bayadh and Tindouf) was statistically significant.

Our results were lower than reported by Maha et al. (2019) which was 9.84 x 10^7cfu/ml. Contamination of milk by psychrotrophic bacteria is primarily a hygiene problem. These germs are widely distributed in nature. They are the usual hosts of soil, plants, water and manure. Farm feedwater is often highly contaminated. They can also be carried by air laden with fodder dust or other food. Their presence in raw milk is due to pollution, the importance of which depends on the conditions of cleanliness of the milking, the quality of the cleaning and rinsing water, or the method of feeding livestock. The multiplication of psychrotrophic bacteria is accompanied by a notable metabolic activity. Among these, many, in particular *Pseudomonas*, produce lipolytic or proteolytic enzymes. Some have both characters. When their development is important, these enzymes can be responsible for defects and spoilage of the milk, in particular of unpleasant flavors (Odongo *et al.*, 2016).

Total coliforms

Total coliforms are lactose-fermenting enterobacteria producing gaz at 30°C, their presence in milk is an indication of unsanitary production and\or improper handling of either milk or milk utensils.

Camel milk from Tindouf had the highest number of total coliforms (1.74±0.35)10^5cfu/ml, which was followed by camel milk from Bechar and camel milk from Adrar (2.74±0.54)10^3 cfu/ml and (1.45±0.63)10^3 cfu/ml. At the same moment, El Bayadh camel milk did not contain total coliforms. The number of total coliforms in all the different camel milk was significantly different from each other. Our findings were almost equivalent to results given by Elhosseny *et al.* (2018). However, El-Ziney and Al-Turki (2007) noted lower levels of contamination rates. On the contrary, Benkerroum *et al.* (2003) determined a high average count. The presence of coliform bacteria in milk does not always indicate direct faecal contamination, but it does serve as a warning sign of sloppy milking and subsequent handling procedures.

Thermotolerant coliforms

Thermotolerant Coliform counts reveal the presence or absence of a faecal contamination. The counts of thermotolerant coliforms in the milk samples collected in Tindouf, Bechar, Adrar and El Bayadh are presented in Table 3. These results showed that camel milk from Tindouf had the highest contamination levels $(1.50\pm0.39)10^5$cfu/ml, while camel milk from Adrar had the lowest levels $(0.51\pm0.46)10^3$. However, El Bayadh camel milk did not contain thermotolerant coliforms. The average levels of thermotolerant coliforms observed in this study were lower than those noted by Maha et al. (2019) ($3.2.10^6$ cfu/ml). This contamination was attributed to non-compliant milking and to the rapid and massive multiplication of faecal flora initially present in raw milk that can be transmitted by the milker's hands, by the animal during milking, by the tail and by splashing (Hamama, 1989; Faye and Loiseau, 2002). These germs were absent in the El Bayadh samples, suggesting that certain elements present in milk, such as proteins and antimicrobial peptides produced by the lactic acid bacteria have inhibited this flora.

Faecal streptococci

Faecal streptococci refers to streptococci commonly present in the faeces of humans and animals. All have the Lancefield group D antigen can generally be considered in practice as specific indicators of human faecal pollution.

The Table 3 shows the results of the faecal streptococcal count. Camel milk from Tindouf shows maximum levels of faecal streptococci $(71.5\pm70.83)10^2$cfu/ml, whereas camel milk from Bechar shows minimum faecal streptococci levels $(7.25\pm5.10)10^2$cfu/ml. However, El Bayadh camel milk did not contain faecal streptococci. The results showed that Tindouf camel milk, Bechar camel milk, Adrar camel milk and El Bayadh camel milk were significantly different. The mean faecal streptococci count of raw camel milk observed in this study was higher than that recorded by Kaindi *et al.* ($1.7x10^2$cfu/ml). These faecal streptococci germs are widespread in nature (Waes, 1973), and are indicators of faecal contamination and unhygienic handling.

Yeasts and moulds

The count of yeasts and molds reflects the hygienic quality of the products as well as the conditions of packaging and sale.

The results of the yeast and mould counts are presented in Table 4. The results showed that Tindouf camel milk had the highest yeast and mould count $(35.67\pm15.98)10^2$ cfu/ml. In contrast, Adrar camel milk showed the lowest yeast and mould count $(8.63\pm3,22)10^2$ cfu/ml, but El Bayadh camel milk and Bechar camel milk werein between the yeast and mould levels of all the different camel milk which were significantly different fromeach other. The yeast and mould content of the Moroccan camel milk was found to be high, with an average of 4.6 log cfu/ml, but that of the Saudi Arabian camel milk was found to be low (1.9 log cfu/ml). Lavoie *et al.* (2012) show that on the farm, the barn and milking parlour settings are significant sources of fungus in milk.

Lactic flora

The original flora of milk is defined as all the microorganisms found in milk at the exit of the udder, the dominant genera are essentially mesophilic. These are micrococci, but also lactic streptococci and lactobacilli.

The results of lactic acid bacteria counts are presented in Table 4. The results showed that Adrar camel milk had the highest lactic acid bacterial count $(37.95\pm10.46)10^5$ cfu/ml, while Tindouf camel milk showed the lowest lactic acid bacterial count $(2.99\pm1.83)10^5$cfu/ml. However, the El Bayadh camel milk values and the Bechar camel milk range were between these values. The number of lactic acid bacteria in all the different camel milk was significantly different from each other. Our results were lower than those reported by Benkerroum *et al.* (2003) (10^7cfu/ml). The lactic flora that proliferates in milk ferments lactose which leads to the production of acid and carbon dioxide.

Pathogenic flora

The contamination of milk and by pathogenic germs can be of endogenous origin, and it then follows a mammary excretion of the sick animal, it can also be of exogenous origin, it is then a question of a direct contact with infected herds or of a contribution of the environment (water) or related to humans.

Salmonella, coagulase-positive staphylococci and sulphate-reducing clostridia spores were not found in any of the samples tested in this study. Various published studies have reported the absence of pathogenic flora in raw camel milk (Konuspayeva,

2007; Omer and Eltinay, 2008; Merzouk *et al*., 2013).

Conclusions and Recommendations

This paper examined the physico-chemical and microbiological characteristics of raw camel milk collected in four regions of Southwestern Algeria. The findings revealed that the physico-chemical parameter of camel milk vary from one region to another. These differences in camel milk contents were linked to internal factors like breed, age, lactation stage, and external factors such as environmental conditions and geographical origin. The results of the microbiological analysis indicate that camel milk from El Bayadh has good microbiological properties compared to camel milk from other regions.

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Novelty Statement

Due to the large area of southern Algeria and the great distance between the regions, most studies on the quality of camel milk are limited to one, but our study includes all regions of southwestern Algeria

Author's Contribution

Nafissa Sahel: Carried out the experiment , took the lead in writig the manuscript.
Fadela Chougrani: Conceived the idea and directed the project.
Abderrahim Cheriguene: Developed and followed experimental methodology.
Zineb Hamani: Aided in interpreting the results.

Conflict of interest
The authors have declared no conflict of interest.

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