Journal of Agricultural, Food Science & Biotechnology

JAFSB, 3(3), 215-226, 2025
https://doi.org/10.58985/jafsb.2025.v03i03.80
ISSN (Print): 2959-3417

Research Article

Evaluation of the health quality of milk produced in the peri-urban areas of Chari -Baguirmi and N'Djamena

Wangba Tcheko[1,2*], Panyo'o Akdowa Emmanuel[1], Collinlaw Joseph Ndouyang[3], Edima Hélène Carole[1,4], Koussou Mian Oudanang[2] and Nicolas Yanou Njintang[1]

1. Department of Food Sciences and Nutrition, National School of Agro-industrial Science (ENSAI), University of Ngaoundéré, Ngaoundéré, Cameroon.
2. Livestock Research Institute for Development (IRED), Ndjamena-Chad.
3. Department of Biology, Faculty of Technical and Technological Sciences, University of Pala, Baoré/Pala Mining Road, Chad.
4. Department of Biology, Faculty of Sciences, Ebolowa University, Cameroon.

Article Information
Received: 25 March 2025
Revised: 16 September 2025
Accepted: 18 September 2025
Published: 22 October 2025

Academic Editor
Prof. Dr. Gian Carlo Tenore

Corresponding Author
Prof. Dr. Wangba Tcheko
E-mail: chewangba@gmail.com
Tel: +235-92 36 23 24

Keywords
Milk, milking practices, contamination, hygiene, quality, Chari-Baguirmi, N'Djamena.

Abstract

This study aimed to determine the impact of milking practices on the microbiological quality of milk. The bacteriological quality of raw cow's milk was assessed at various points in the production process. Following these investigations, 240 milk samples were collected at various stages of the production chain, including from the udder of the cow, the containers of the producer, and the containers of the collector in route to the dairy. Germ levels varied depending on the farm and the sampling site. The predominant microbiota was *Staphylococcus aureus*, which accounted for 84.44% of non-compliant microbiota depending on the season. This was followed by total mesophilic aerobic microbiota (FAMT) at 75.73%, yeasts and molds at 63.52%, and the presence of Salmonella *spp*, and *Escherichia. coli* at 36.11% and 20.45% respectively. Contaminated milk can transmit pathogenic microorganisms to humans and pose a serious public health risk. This study highlights the importance of supervising stakeholders and disseminating good hygiene practices throughout the production chain to reduce public health risks.

1. Introduction

Milk is an essential foodstuff that contributes to human health, especially in children and adolescents, due to its major nutrient composition, which includes proteins, lipids, carbohydrates, vitamins and minerals [1]. Indeed, as is the case in all countries of the Sahel, Chad is a major producer of livestock, with a cattle herd size of 24,892,100 heads [2, 3]. Furthermore, the country has a considerable bovine milk production, estimated at 1,119,815 tons per year (FAO, 2018). For instance, in the city of N'Djamena in Chad, livestock farms located within a radius of 65 km are responsible for supplying the city with milk. These farms, which are predominantly pastoral and agro-pastoral in nature, primarily engage in the sale of cow's milk, with goat's milk and, in recent years, camel's milk has also been added to their product range [4].

The consumption of this milk is pervasive, as it is frequently administered to children as a staple food or

consumed by adolescents as a food supplement for breakfast. Furthermore, the milk is also transformed into various dairy products, including *rouaba* (skimmed curdled milk), *rayeb* (whole curdled milk) and *zibdé* (local butter). A survey conducted in 2007 [4], in N'Djamena indicated an average household consumption of 139 kg of local dairy products (curdled milk and fresh milk). Nevertheless, the quality of milk is a significant problem in many developing countries, particularly in peri-urban areas where dairy production is often informal and unregulated [5].

The following section provides a comprehensive overview of the relevant literature on this subject. Furthermore, analyses have demonstrated that even with rigorous precautions, obtaining sterile milk is very rare at least in cows. As noted [6], common germs are invariably present in the udder and are transmitted into milk during the milking process. Consequently, raw or treated milk serves as an optimal culture medium for a wide range of microorganisms, including bacteria, yeasts, molds, and viruses. This can result in product spoilage or even toxic infections in consumers. The quality of milk is a significant public health concern, as substandard milk has the capacity to transmit diseases such as brucellosis, tuberculosis and gastrointestinal infections [7].The central question guiding this study was to identify the risk factors associated with the contamination of raw milk in peri-urban areas of Ndjamena. The study investigated the impact of season and temperature on the quality of milk produced in the peri-urban areas of Ndjamena. These questions are not new and have been the subject of numerous studies. Furthermore, extant research has demonstrated that the quality of milk is frequently varies. Indeed, the factors of variation in milk composition are, among others, the lack of hygiene of producers during milking and the contamination of milk. There is a highly significant correlation between these factors and the absence of temperature control and contamination with pathogenic bacteria [8, 9]. Nevertheless, the predominant issue in the dairy industry is microbiological quality, which poses a significant challenge to conservation and public health [10]. This has been demonstrated by other authors [11]. The quality of milk and dairy products in Central Africa is unsatisfactory with regard to sanitation. The objective of this study aimed to determine the impact of milking practices on milk quality in N'Djamena and Chari-Baguirmi, and identify risk factors for raw milk contamination. The Chari-Baguirmi and Ndjamena regions, akin to the majority of Sahelian cities, function as pivotal hubs for the distribution of milk and dairy products originating from peripheral regions.

2. Materials and methods

2.1. Study area

The location is situated to the north, at a distance of 70 km from N'Djamena. The following towns and villages were considered: Amsakiné, Fadje, Farcha, Attere and Naala (Fig. 1).

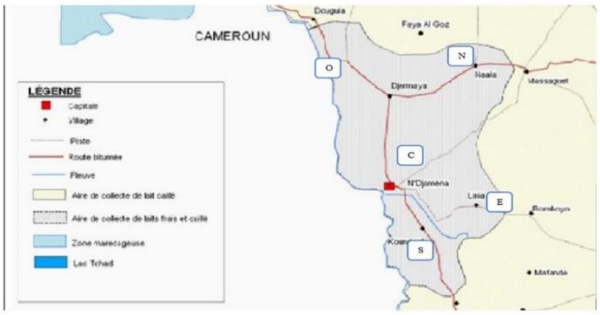

Figure 1. The study area is situated in proximity to the city of N'Djamena (source: CNAR, 2006). Key: **C** (capital); **S** (southern zone); **N** (northern zone); **E** (eastern zone); **W** (western zone).

The location is situated to the south and at a distance of 70 km from N'Djamena. The pilot farm is located in the state of Gomaga, Gorogoro, Chad. The location is situated to the east of N'Djamena, at a distance of 12 km. The following individuals are to be noted: Ambatta, Gliouti and Siguété. The location is situated to the east of N'Djamena, at a distance of 14 km. Atdino, Digo and Rangadi are located to the west of N'Djamena, at a distance of 13 km with Amkouma, Fatata and Guelmaya. These selected circuits are conventional areas in which vendors sell milk and dairy products, purchased in the bush or produced in their own camps. The present study was conducted in the pastoral zones of Chari-Baguirmi and N'Djamena in Chad, a region that is of particular significance to the nation as it contains 75% of the national livestock

https://doi.org/10.58985/jafsb.2025.v03i03.80

and supplies the city of N'Djamena with milk [2].

2.2. Assessment of the application of good milking practices

A series of surveys were conducted on a selection of farms to evaluate the risks of milk contamination. The study employed a questionnaire and a checklist that were developed based on the FAO [12] recommendations for good hygiene practices in dairy farming. This study was conducted using a combination of interviews with farm operators and employees, as well as observations. The investigative approach encompassed direct interviews, photographic and video documentation, and voice recordings.

2.3. Sampling

In order to carry out a microbiological characterization of the pathogenic microbiota of milk produced in the target region, samples were collected from fifteen (15) dairy cattle farms including lactating cows in the target region. The factors considered in this study included seasonal variations (dry and rainy), geographical location, and collection point (udders, producer and collector containers). However, four control points were retained in the chain of production, processing and marketing of cow's milk, namely: (i) milk taken from the cow's udders (random choice of 3 cows in the area); (ii) milk taken from the producer's container; (iii) milk taken from the collector's container at the dairy and (iv) milk taken from the reseller's container at the point of sale. A total of 240 samples were collected and distributed over two seasons in equal numbers, this finding indicating 120 samples per season. For the purpose of sample collection, 100 mL of milk was extracted from the udder at three distinct time points (5 a.m., before and after milking). The samples were collected from the udder, the producer's container, and collector's level. The latter were placed in sterile jars and stored in a cooler containing freezing blocks at 4°C. They were then transported quickly to the laboratory of the Institute of Research in Livestock for Development (IRED) in N'Djamena for various analyses.

2.4. Characterization of pathogenic bacteria

In order to assess microbiological quality, it is first necessary to search for and enumerate bacteria indicative of fecal contamination or poor hygiene, as well as certain pathogenic germs, including Salmonella and coagulase-positive Staphylococcus.

2.5. Detection and counts of mesophilic aerobic total microbiota (MTAF)

The following point must be considered: the presence of the indicator was then detected in milk samples by means of decimal dilutions of the samples in question, which were performed using a physiological medium. A volume of 1 mL from each dilution was placed in a sterile, single-use plastic Petri dish, which had been previously labelled. Subsequently, 15 mL of Plate Count Agar (PCA) medium was dispensed into the dish, and the mixture was homogenized on the bench. Subsequent to the solidification of the medium, the Petri dishes were placed in an incubator (Memmert, France) at 37°C for 48 h. The colonies were enumerated using Petri dishes, with a range of 30 to 300 colonies per dish (NF V08-051). The arithmetic mean of the three measurements for each dilution was calculated, and the results were expressed as colony forming units per milliliter (CFU/mL) of milk. The number of microorganisms per milliliter was calculated using the following formula [13].

$$N = \frac{\sum C}{(n1 + 0.1\, n2)d}$$

C: Number of colonies counted per plate
n1: Number of plates counted in the first dilution
n2: Number of plates counted in the second dilution
d: Dilution factor from which the first count was obtained.

2.5.1. Coliform enumeration

The enumeration of fecal coliforms was conducted on crystal violet and neutral red bile (VRBL) lactose agar, in accordance with the prevailing standard NF V08-060. The inoculated Petri dishes were then incubated at 44°C. The total coliform enumeration process involved the utilization of VRBL medium, with the Petri dishes inoculated and incubated at 37°C in accordance with the prevailing standard NF V08-050. The presence of coliforms in the sample is indicative of recent fecal contamination [13]. The enumeration was performed by inoculating the sample with dilutions (10^{-1} to 10^{-7}) of crystal violet and neutral red bile lactose agar (VRBL). For total coliforms, incubation was carried out for 24 to 48 h at 37°C. In contrast, fecal coliforms are incubated at 44°C for 24 to 48 h. Total and fecal coliforms manifest as dark red

https://doi.org/10.58985/jafsb.2025.v03i03.80

colonies on this medium, with a diameter of less than 0.5 mm and a round or lenticular shape [14]. The following section provides a comprehensive overview of the relevant literature on this subject.

2.5.2. Enterobacteria enumeration

In order to detect these bacteria, dilutions up to a million ($1/10^6$) were performed. A quantity of 0.1 mL of each dilution was then spread onto Petri dishes containing MacConkey agar. The mixture was then incubated for 24 to 48 h at 25°C. Following the incubation period, the plates were subjected to quantitative analysis, whereby the number of colonies present was enumerated. The range of colonies enumerated varied from 30 to 300. Dark red colonies with diameters greater than 0.5 mm were selected for enumeration.

2.5.3. Staphylococcus aureus counts

The organism was detected in milk using Baird Parker (BP) agar. A quantity of 0.1 mL of the stock solution and the initial dilutions (10^{-1} and 10^{-2}) were added to the surface. Following a 24 to 48-h incubation period at 37°C, characteristic *Staphylococcus aureus* colonies manifested as black, shiny, and convex, with a surrounding transparent zone that exhibited translucency. Regulations stipulate a contamination threshold of 10 CFU/mL, according to the standard (NF V08-057).

2.5.4. Salmonella spp. detection

The bacterium was detected in milk by preparing a solution in advance; 1 mL of milk was pre-enriched in peptone water for 18 to 24 h at 37°C. The procedure was followed by an enrichment step in Rappaport medium (24 h) and isolation on SS medium (Salmonella-Shigella). A qualitative test was conducted in accordance with the NF V08-052 standard.

2.5.5. Clostridium perfringens determination

The presence of sulfite-reducing anaerobes was detected through a meticulous procedure. In this procedure, 1 mL of milk was introduced into 9 mL of TSC (Tryptose sulfite cycloserine) medium. The medium was initially homogenized, heated at 80 °C for 10 min in a water bath, and subsequently incubated at 37°C for 48 h (AFNOR, 1999, Maury, 1987).

2.6. Yeast and mold analysis

In order to achieve this, a series of dilutions ranging from 1/100 to 1/1000 were inoculated into Petri dishes containing Sabouraud chloramphenicol medium. The sample were then incubated at 30°C for three days. The enumeration and subsequent reporting of the number of colonies were conducted on a per gram basis of the dairy product. The acceptable limit of 103 CFU/g of sample has been established by AFNOR (1999), and Maury (1987).

2.7. Statistical analyses

The analysis of variance was employed to elucidate discrepancies between the samples, which were based on factors such as season, farm, and collection point. This approach was undertaken to ascertain the extent to which these factors influenced germ counts. The application of correspondence analysis enabled the demonstration of variability not only between.

2.7.1. Qualitative chi-square test ($\chi 2$)

The chi-square test is a statistical procedure that aims to determine whether the observed frequencies in a contingency table are significantly different from the expected frequencies under the assumption of independence between the variables. This assumption can be expressed as either the null hypothesis (H0), which states that the variables are independent, or the alternative hypothesis (H1), which states that the variables are associated. A chi-squared non-conformity test was applied in order to discriminate the number of microorganisms present at the udder, production, and harvest. The following formula was used.

$$X^2 = \frac{(N_{ob} - N_{th})^2}{N_{th}}$$

With N_{ob}: observed number; N_{th} = theoretical or expected number.

3. Results and discussion

3.1. Assessment of the application of good milking practices in peri-urban livestock farming areas of N'Djamena.

3.1.1. Assessment of the hygiene of livestock farming personnel

The following investigation focuses on the frequency with which individuals are involved in the milking process in the designated target areas.

The following report presents the distribution of milking actors according to gender in the different

https://doi.org/10.58985/jafsb.2025.v03i03.80

regions surveyed. The survey's findings indicated that the study population was predominantly male, particularly among those engaged in milking activities. Consequently, the demographic composition of the sample is 84% men's and 16% women's, with the remainder identifying as Muslim (Fig 2).

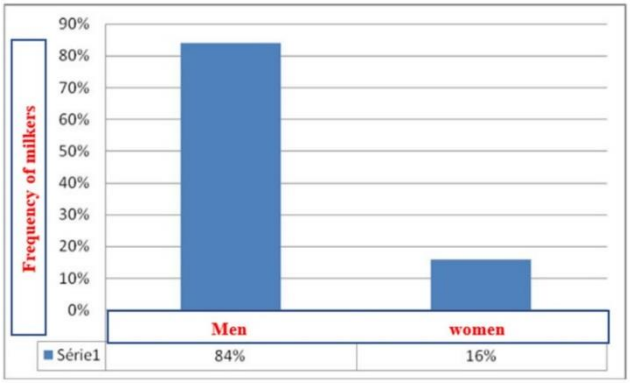

Figure 2. Stakeholders involved in cow milking.

It is acknowledged that these milking figures are subject to variation depending on geographical, cultural and socio-economic contexts. This observation was made by [15], who reported that men and women have different roles in dairy production in Africa**.** The milking of animals is often the responsibility of men, due to the traditional division of labor in households. In contrast, women are more involved in the processing and sale of dairy products. Moreover, it can be emphasized that social and cultural norms can influence the roles of men and women in dairy production [16]. A further significant rationale pertains to the notion that females, particularly those in the juvenile and adolescent stages, demonstrate a conspicuous lack of concern for the survival of calves. This is evidenced by their reluctance to milk calves, a practice widely regarded as a crucial aspect of their care. Moreover, there is a prevalent belief that these females would readily dispose of the milk obtained from the milking process, thereby underscoring their apparent indifference towards the well-being of the calves. In Chad, the livestock farming has historically been a family endeavor, with the primary stakeholders typically being the farmer's sons or cousins. With the exception of the pilot farm, we were able to meet a number of staff members who were engaged in the milking process. The following section provides a comprehensive overview of the relevant literature on this subject. However, the number of workers employed on the farm is insufficient to implement good milking practices as required by the *Codex Alimentarius* standard. Those engaged in the milking process demonstrated an inadequate level of good practices. However, the implementation of adequate hygiene practices in the context of dairy farming necessitates the expertise of skilled labors. The survey of stakeholders in the target areas revealed a lack of adherence to appropriate milking attire, with key issues including the absence of overalls and mufflers. Indeed, these stakeholders appear to neglect optimal milking hygiene practices.

3.1.2. Cleaning and disinfection of the udder before and after milking

Cow cleanliness significantly impacts under health particularly regarding the potential for contamination due to environmental mastitis. The necessity for corrective action is contingent on the observation of contaminated areas, which are known to be affected by waste and pathogenic germs. The survey revealed that 96.30% of the participants exhibited an unsatisfactory level of milking hygiene practices, while 3.70% demonstrated an unsatisfactory level of basic hygiene standards. These results are of concern with regard to animal health and the quality of the milk. Under cleaning and disinfection are pivotal steps in preventing mammary infections and enhancing milk quality [17].

Bacterial contamination caused detrimental effects on animal health and the quality of the milk. This observation is consistent with the findings of [18], who demonstrated that cleaning and disinfecting can markedly reduce the risk of mammary infections. It was observed that the actors (private farms) cleaned the udders, but not in a satisfactory manner, because the cleaning of the udders was not accompanied by a single towel wipe. Following the milking process, there is a failure to clean or disinfect the cow's udders. This observation was made by the author [19], who demonstrated the correlation between hygiene management and milk quality in a semi-extensive livestock system. As illustrated in Fig. 3, the data demonstrate the percentage of farmers who cleaned

https://doi.org/10.58985/jafsb.2025.v03i03.80

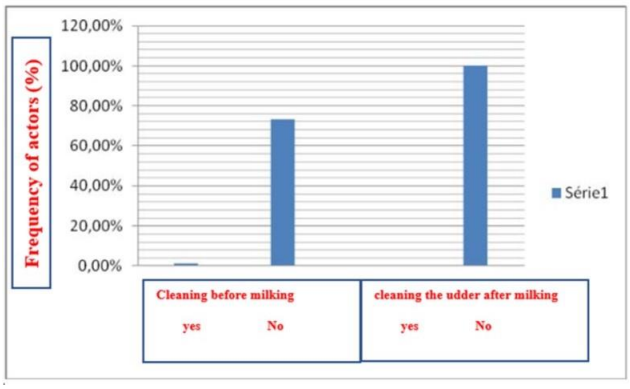

Figure 3. Udder cleaning before and after milking.

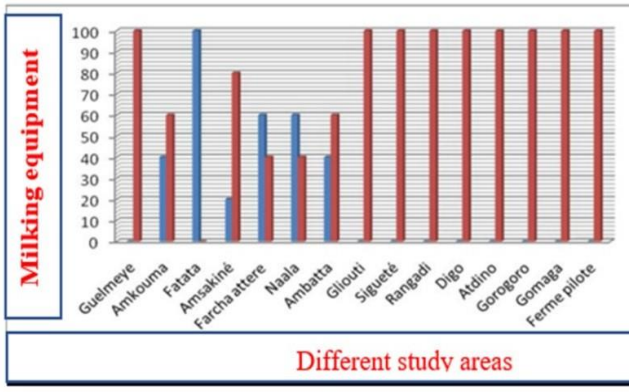

Figure 4. Nature of milking equipment at the udder (Blue: Conformity; Red: Non-conformity).

the cows' udders.

3.1.3. Hygiene assessment of milking and packaging equipment (a- Milking equipment)

It is evident that the milking equipment employed varies significantly between geographical locations. Fig. 4 illustrated that the percentages of different equipment utilized at the udder level.

As illustrated in Fig. 5, 34.67% of stakeholders utilize plastic milking equipment, 29.33% employ enamel milking equipment, and 36% use calabash as their milking instrument of choice. The immediate consequences of this practice are two-fold. Firstly, there is a potential for biological contamination of the milk due to the difficulty in washing and disinfecting these containers. Secondly, there is a potential for chemical contamination due to the primary use of this equipment [20]. In a similar manner, it has been demonstrated that enamel milking equipment has the potential to become detached from its container, resulting in the onset of rust. This process, in turn, has the capacity to induce contamination of the milk. The utilization of specific materials can compromise the hygiene and organoleptic qualities of products. This material, such as the calabash, is steeped in cultural history. Furthermore, wooden equipment provides a favorable environment for the growth of microorganisms because it does not dry quickly after, washing and disinfection thus promoting the proliferation of microorganisms. As reported by the author [21], the cleaning and sterilization of gourds can be a challenging process, with the potential to result in contamination and, consequently, a deterioration in product quality. In addition, the utilization of appropriate and sterilizable milking equipment is strongly recommended, with the aim of

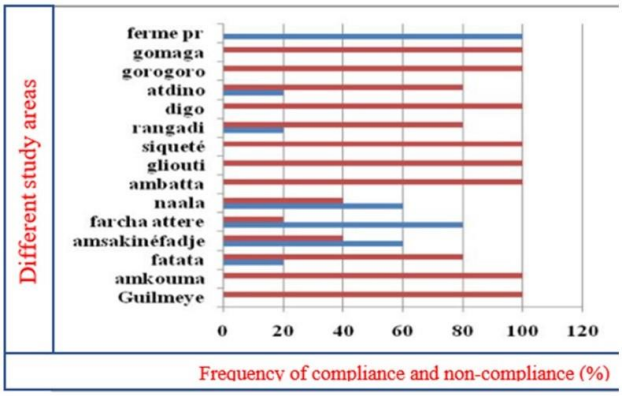

Figure 5. Nature of collection containers (Blue: Conformity; Red: Non-conformity).

averting potential complications and ensuring optimal milk quality and animal well-being.

Figs 4 and 5 illustrate the frequency of compliance and non-compliance with regard to milking equipment and collection. The study area appears to be characterized by pervasive non-compliance. Conversely, the maintenance of hygienic practices during the milking process has been demonstrated to enhance the bacteriological quality of the ensuing product, thereby constituting a pivotal stimulus for eliciting the neuroendocrine reflex associated with milk ejection [22]. In the context of dairy farming, several practices have been identified as contributing to the risk of contamination, including inadequate hand washing, failure to keep the calf away, inadequate restraint of the tail and hind legs, and insufficient disinfection of the udder both before and after milking. The Food and Agriculture Organization (FAO) has identified the adoption of effective collection and transportation methods as a means of mitigating these risks [23]. However, in the majority of cases, such practices are found to be non-compliant.

https://doi.org/10.58985/jafsb.2025.v03i03.80

Table 1. FAO's (2018) main recommendations for good hygiene and dairy farming practices.

Variables	Recommendations
Animal hygiene	Clean animals regularly to prevent contamination
Milking Hygiene	Use clean and sterilized milking equipment
Cleaning and disinfection	Regularly clean and disinfect milking equipment and premises
Milk Storage	Store milk in clean, sterilized containers at an appropriate temperature
Insect and Rodent Control	Implement measures to control insects and rodents in the premises
Staff training	Train staff on good hygiene and milking practices
Quality control	Implement a quality control system to ensure milk quality

Table 2. Microbiological parameters of milk collected and sold in N'Djamena and Chari-Baguirmi.

Variables	Seasons	N (ob)	Worse			Production			Collection		Khi-deux
			Frequency (%)	N (th)	N (ob)	Frequency (%)	N (th)	N (ob)	Fréquency (%)	N (th)	
Mesophilic aerobic bacteria	Dried	33	73,33	36,94	37	82,22	32,19	25	83,33	25,86	2,472
	Rains	37	82,22	33,06	24	53,33	28,81	24	80,00	23,14	
Total coliforms	Dried	7	15,56	8,18	7	15,56	7,67	9	30,00	7,16	1,438
	Rains	9	20,00	7,8	8	17,78	7,33	5	16,67	6,84	
Coliforms fecal	Dried	11	24,44	12,3	12	26,67	12,79	8	26,67	5,9	1,831
	Rains	14	31,11	12,7	14	31,11	13,21	4	13,33	6,1	
Escherichia coli	Dried	6	13,33	8,08	6	13,33	6,46	9	30,00	6,46	3,389
	Rains	9	20,45	6,9	6	13,33	5,54	3	6,67	5,54	
Staphylococcus aureus	Dried	28	84,44	34,27	38	84,44	40,07	21	70,00	22,67	0,041
	Rains	27	60,00	30,73	38	84,44	35,93	22	73,33	20,33	
Salmonella.spp	Dried	19	42,22	18,22	14	31,11	16,92	21	70,00	18,87	2,225
	Rains	9	20,00	9,78	12	26,67	9,08	8	26,67	10,13	
Clostridium perfringens	Dried	3	6,67	2,07	7	15,56	3,79	0	0,00	0,69	2,773
	Rains	3	6,67	3,93	4	8,89	7,21	2	6,67	1,31	
Yeasts and molds	Dried	24	53,33	3,96	24	53,33	24,9	22	73,33	21,14	0,127
	Rains	27	60,00	27,04	29	64,44	28,1	23	76,67	23,86	

α= 0.05; with 3 columns (N(ob) uds; N(ob) production; N(ob) collection) and 2 lines (dry season and rainy season); ddl = [3 (columns)-1]x[2(lines) -1]=2x1=2; χ^2(table) = 5.991.

Moreover, the recommendations are grounded in the FAO guidelines for hygiene in dairy farming, with the overarching aim of ensuring milk quality (Table 1). It is important to note that effective hygiene practices in dairy farming are essential for ensuring the quality and safety of the produce, as well as for the wellbeing of consumers.

3.2. Microbiological characteristics of milk

The microbiota enumerated are regarded as indicators of overall milk quality and hygiene practices. The results furnished assessments of cumulative contamination, from the production to the storage of raw milk (Table 2). The predominant microbiota identified as *Staphylococcus aureus*, with a contamination level of 84.44%. The counted microbiota was found to be non-compliant depending on the season, with the total mesophilic aerobic microbiota following in second place, achieving 83.33% for samples studied during the dry season.

The presence of *Staphylococcus aureus* in milk is considered to be a significant public health risk. The counts yielded values significantly higher than the established international standards (NF V08-057: 10^2 CFU/mL) and the findings of several. studies. This observation is consistent with the findings of Claeys *et al*. (2019), who reported that the prevalence of *Staphylococcus aureus* in raw milk can vary depending on geographical location, season and milking practices.

The presence of yeasts and molds at levels of 63.52% is indicative of product contamination and degradation, with these values exceeding the

https://doi.org/10.58985/jafsb.2025.v03i03.80

acceptable limit of 3.10^2 CFU/mL. Author [24],demonstrated that the presence of yeasts and molds in milk is attributable to a number of factors, including the quality of the raw material, storage conditions, and handling practices. The presence of strains of Salmonella and Escherichia coli was detected in 36.11% and 20.45% of all sampled areas, respectively. It is evident that the values obtained are not in accordance with the regulatory values stipulated for milk (NF V08-052 and NF V08-054). Despite the inherent risks associated with *Salmonella spp.* contamination, the study revealed a prevalence rate of 58% in the analyzed samples. The presence of these organisms in milk has been linked to improper milking and handling practices [25].

As per reports [26], the contamination is attributed to the utilization of contaminated water. The variation in molds and yeasts is contingent on the collection point, season, and farm. In this study, a major contamination frequency of 76.67% was observed in the samples, analyzed in the rainy season. These microorganisms are likely to be implicated in the uncontrolled fermentation of dairy products.

The present study demonstrated that milk consumed in N'Djamena and its surrounding areas undergoes several changes related to milking, transport distance, and collection by vendors and resellers. These factors have been shown to have a profound effect on the quality of the milk, with subsequent changes in its physicochemical properties.

Mesophilic aerobic bacteria have been shown to be a reliable indicator of the hygienic quality of raw milk, thus serving as a critical factor in determining the shelf life of raw milk. As demonstrated by the AFNOR standard (2019), a high level of mesophilic aerobic bacteria may necessitate corrective actions to reduce contamination.

The statistical analysis conducted throughout the microbiological study indicated a substantial correlation between the prevalence of bacteria and season.

As the chi-squared (χ^2) value calculated based on the seasons remains significantly higher than the chi-squared (table) value of 5.991 at $\alpha = 0.05$ and ddl = 2, the present study provides a variation of the calculated (χ^2) value that is higher than that of the table. The chi-squared distance ranged from 0.041 to 3.389. The hygienic quality of milk and dairy products is susceptible to microbial contamination, depending on the method of milking and production. This underscores the potential risks associated with the consumption of milk and dairy products from these farms. Consequently, there is a compelling need for systematic heat treatment of milk prior to use, in conjunction with stringent water control measures during the equipment washing stage [20].

3.3. Physicochemical parameters: pH, temperature variation, and milk density at 20°C.

As illustrated in Table 3, there is a demonstrable variation in the pH, temperature and density of fresh milk depending on the farming area and season. Preliminary findings suggest that the pH level fluctuates between 6.50 and 6.60 at the udder level and within the producer's container. This result corroborates the requirements of the standard (ISO 6731:2010) specific to milk, whose value is between 6.5 and 6.7. The study demonstrates that the pH ranged from 6.10 to 6.40 in the various samples collected from the collectors. This observation is consistent with those of [27], who emphasized that low milk pH, below 6.5, can influence its quality and stability. These results are consistent with those reported by the author [28] , who demonstrated that the pH of milk approaches neutrality. The density of the substance was between 1.028 and 1.034 g/mL. The temperature measurement facilitated the adjustment of the density. readings. These values are consistent with the densities typically observed for milk. As demonstrated [29], the density of milk can fluctuate based on the source and quality of the milk. The temperature ranged from 31.05 to 34.46°C. This temperature range is considered to be optimal for the development of several types of germs (mesophilic bacteria). Consequently, it is imperative that milk is subjected to refrigeration (to 4°C) as a stabilization treatment to prevent microbial proliferation. The average density was 1.031 g/mL at 20°C. The variations observed around this mean values were negligible, ranging from 1.028 to 1.033 g/mL. The present study demonstrated that the density of milk ranged from 1.026 to 1.030 g/mL.

The correlation study between the variables (physicochemical parameters) and the factors (F) or

https://doi.org/10.58985/jafsb.2025.v03i03.80

Table 3. Variations in pH, temperature and density of fresh milk according to breeding areas.

N°	Villages	Seasons	pH			Temperature variation (°C)			Density (g/mL)	
			Worse	Production	Collection	Worse	Production	Collection	Production	Collection
1	Ambatta	Dried	6,13±0,15	6,00±0,25	6,45±0,15	30,57±0,12	30,73±0,24	37,80±0,01	1,03	1,03
		Rains	5,97±0,07	5,97±0,20	5,95±0,05	33,90±0,36	33,17±1,36	31,05±1,05	1,03	1,03
2	Amkouma	Dried	6,13±0,19	6,03±0,09	6,60±0,01	31,73±0,72	31,80±0,70	32,35±0,05	1,03	1,03
		Rains	6,50±0,10	6,23±0,19	5,90±0,10	30,50±0,06	30,40±0,21	30,55±0,15	1,03	1,03
3	Amsakiné	Dried	5,80±0,12	6,03±0,38	5,70±0,10	31,93±0,07	31,90±0,25	39,35±0,05	1,03	1,03
		Rains	6,33±0,17	6,47±0,13	6,15±0,35	30,57±0,09	31,53±1,24	30,25±0,15	1,03	1,03
4	Atdino	Dried	6,63±0,07	6,43±0,22	5,90±0,10	31,73±0,62	31,43±1,43	33,20±0,80	1,03	1,03
		Rains	6,23±0,19	5,97±0,03	6,15±0,25	31,43±1,08	31,07±0,72	31,00±0,20	1,03	1,03
5	Digo	Dried	6,13±0,19	6,43±0,09	6,15±0,25	30,73±0,64	31,40±1,40	30,25±0,25	1,03	1,03
		Rains	6,10±0,17	6,23±0,19	6,10±0,10	30,37±0,23	31,80±1,31	30,27±0,13	1,03	1,03
6	Farcha attere	Dried	6,10±0,17	5,90±0,06	6,35±0,05	32,30±0,45	32,13±0,22	39,05±0,35	1,03	1,03
		Rains	6,20±0,12	6,20±0,21	6,05±0,05	31,33±0,89	32,13±1,04	31,35±0,75	1,03	1,03
7	Fatata	Dried	6,23±0,26	6,07±0,12	6,00±0,01	30,37±0,09	31,13±0,63	32,40±0,01	1,03	1,03
		Rains	6,30±0,17	6,40±0,06	6,00±0,01	30,57±0,03	32,00±1,14	32,40±0,01	1,03	1,03
8	Ferme pilote	Dried	6,23±0,22	5,90±0,10	5,95±0,05	30,97±0,73	30,83±0,60	31,45±0,95	1,03	1,03
		Rains	6,20±0,12	5,93±0,07	5,85±0,05	31,00±0,35	31,07±0,47	31,80±0,60	1,03	1,03
9	Gliouti	Dried	5,93±0,03	5,83±0,03	5,95±0,05	31,10±0,67	30,63±0,22	38,70±0,01	1,03	1,03
		Rains	6,20±0,06	6,20±0,20	6,10±0,30	30,30±0,10	31,23±0,68	31,85±0,55	1,03	1,03
10	Gomaga	Dried	5,80±0,12	6,33±0,18	5,75±0,05	31,50±0,60	30,13±0,13	31,20±1,20	1,03	1,03
		Rains	6,17±0,12	5,87±0,18	5,80±0,10	31,43±0,99	31,27±0,68	30,01±0,01	1,03	1,03
11	Gorogoro	Dried	6,43±0,09	6,20±0,25	5,95±0,05	30,83±0,60	32,20±0,99	30,45±0,05	1,03	1,03
		Rains	6,20±0,15	6,17±0,19	5,85±0,05	30,60±0,12	30,60±0,15	31,05±1,05	1,03	1,03
12	Guelmeye	Dried	6,30±0,17	5,87±0,13	5,80±0,10	31,80±1,35	30,43±0,03	33,75±1,25	1,03	1,03
		Rains	6,13±0,26	6,03±0,12	5,85±0,05	32,40±0,44	31,53±1,34	30,36±0,04	1,03	1,03
13	Naala	Dried	6,47±0,07	6,37±0,15	5,85±0,05	31,10±0,40	31,97±0,30	38,40±0,20	1,03	1,03
		Rains	6,30±0,15	5,80±0,25	5,90±0,10	30,97±0,38	30,97±0,68	31,60±1,60	1,03	1,03
14	Rangadi	Dried	6,07±0,12	6,53±0,07	5,70±0,10	31,77±0,64	31,07±0,67	30,01±0,01	1,03	1,03
		Rains	6,23±0,12	6,07±,09	5,75±0,35	31,47±0,79	31,37±1,32	30,35±0,25	1,03	1,03
15	Sigueté	Dried	6,07±0,18	5,67±0,03	5,80±0,01	30,57±0,03	30,77±0,07	39,80±0,01	1,03	1,03
		Rains	6,33±0,17	6,57±0,09	5,85±0,05	32,43±0,38	32,33±0,96	32,10±2,10	1,03	1,03
	X±SE	n=30	6,20±0,03	6,12±0,04	5,97±0,04	31,28±0,15	31,37±0,13	32,80±0,59	1,03±0,003	1,029±0,00

Note : Mean ± standard error

principal components demonstrated that two components were retained, to which all the variables relate best (Figs 6 and 7). The aforementioned axes were designated as F1 and F2. The findings of this study indicate a positive correlation between the pH and temperature at collection, as well as the density at production, and principal component F1. In addition, a positive correlation was observed between the temperature at the udder and production, as well as the density at collection, and principal component F2. This finding indicates that the physicochemical parameters were predominantly distributed across two principal axes, PC1 and PC2. However, the most significant correlation was evident between the

https://doi.org/10.58985/jafsb.2025.v03i03.80

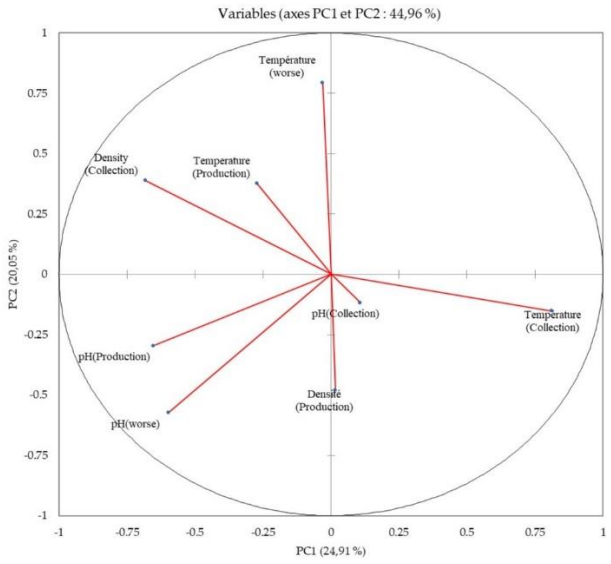

Figure 6. Correlation graph between the physicochemical parameters and the main components (PC1 and PC2).

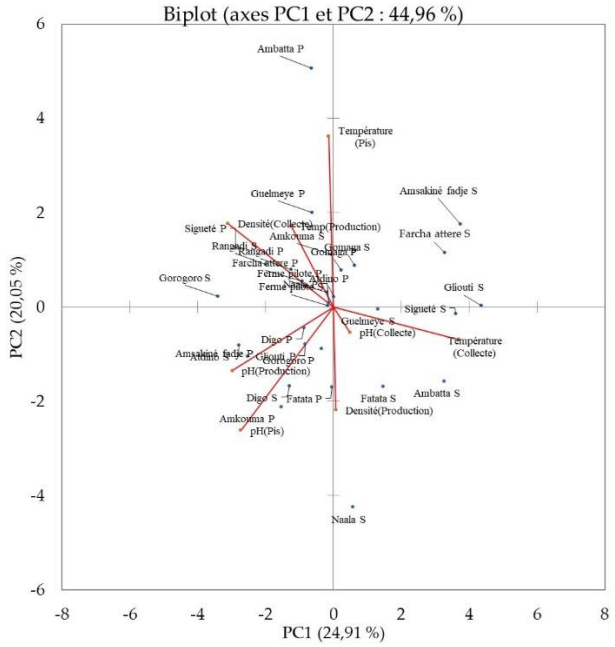

Figure 7. Graph of correlations between physicochemical parameters of milk and breeding areas S: Dry; P: rains.

temperature at collection on the PC1 axis (r = 0.811) and that at the udder on the PC2 axis (r = 0.793). This is evidenced by the sum of the frequencies of the two axes PC1 and PC2, which was found to be 44.96%. Thus the correlation circle demonstrates a low degree of correlation on both axes.

The Pearson test was utilized for continuous variables whose objective is to measure the linear correlation between the variables, following a normal distribution of the data. The Pearson correlation matrix demonstrated that the physicochemical parameters of milk exhibited negligible intercorrelations (Table 4). At the 5% significance level, two statistically significant positive correlations were identified between the pH at the udder and that at production (r = 0.368) and the temperature at the udder and the temperature at production (r = 0.505). The aforementioned correlations elucidate the parallels between udder and production conditions. Conversely, two additional statistically significant negative correlations were identified between the pH at production and temperature at collection (r = -0.368) and between the temperature at collection and density at collection (r = -0.553). The data demonstrate that the conditions for production and collection are. different. Consequently, the decline in pH at the production stage was accompanied by an increase in temperature during the collection stage. This phenomenon can be attributed to the actions of fermentative microorganisms, responsible for hydrolases production. Evidence has demonstrated that fermented milk can function as a bioreactor. Moreover, an increase in temperature at the point of collection was concomitant with a reduction in milk density. This evidence supports the hypothesis that milk is inherently unstable during the collection process due to microbial proliferation [30]. The primary components conveying information are F1 and F2 for all eight, whose eigenvalues decrease (Table 5). The predominant characteristics of the milk consumed in N'Djamena can thus be classified into two or three principal categories. The first three factors (F1, F2, and F3) had eigenvalues of 1.993, 1.604, and 1.554, respectively.

4. Conclusions

The impact of milking and collection practices on the quality of milk consumed in N'Djamena and its surrounding areas is based on two major aspects: physicochemical and microbiological qualities. These parameters are crucial and fundamental in assessing the quality and safety of the product. It is imperative to acknowledge the significance of physicochemical parameters, including pH, temperature, and chemical composition of milk, in determining the quality of the product under consideration. The microbiological

https://doi.org/10.58985/jafsb.2025.v03i03.80

Table 4. Pearson correlation matrix between the physicochemical parameters of milks.

Variables	pH (Worse)	pH (Production)	pH (Collection)	Température (Worse)	Temperature (Production)	Temperature (Collection)	Density (Production)	Density (Collection)
pH (worse)	**1**							
pH (Production)	**0,368**	**1**						
pH (Collection)	0,074	-0,053	**1**					
Temperature (worse)	-0,298	-0,069	-0,136	**1**				
Temperature (Production)	0,059	0,236	0,194	**0,505**	**1**			
Temperature (Collection)	-0,280	**-0,368**	0,095	0,021	-0,022	**1**		
Density (Production)	0,277	0,211	-0,115	-0,036	0,188	0,300	**1**	
Density (Collection)	0,193	0,095	-0,131	0,174	0,105	**-0,553**	-0,202	**1**

Table 5. Main factors or components and physicochemical parameters of milk.

Components	F1	F2	F3	F4	F5	F6	F7	F8
Eigen value	1,993	1,604	1,554	1,129	0,713	0,402	0,305	0,301
Variability (%)	24,911	20,047	19,425	14,117	8,911	5,022	3,810	3,757
Cumulative %	24,91	44,96	64,38	78,50	87,41	92,43	96,24	100,0

analyses of the milk samples collected from the bush and subsequently marketed in Chari-Baguirmi and N'Djamena and its surrounding areas revealed that the product did not comply with international regulations, as it was found to be highly contaminated. The substandard quality of the milk may be attributable to contamination during either the milking or distribution process. In summary, to enhance the product safety, it is imperative to implement certain corrective measures. These include the improvement of hygiene practices during the process of milking, as well as the training of individuals involved in the chain in good hygiene practices. In addition, it is imperative to evaluate the performance evaluation of the interventions and monitor the quality of milk, to ensure a high quality product.

Authors' contributions

Formal analysis, investigation, validation, writing – original draft, W.T.; writing, review and editing, investigation, conceptualization; supervision, P.A.E.; writing, review and editing; software, C.J.N.; conceptualization, funding acquisition, writing, E.H.C.; review and editing, project administration, M.O.K.; N.Y.N.

Acknowledgements

The authors of this article would like to express their gratitude to ENSAI of the University of Ngaoundéré (Cameroon) and to the Institute of Livestock Research for Development (IRED-Chad).

Funding

This research received no external funding.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of interest

The authors state that there is no conflict of interest.

References

1. Haug, A.; Høstmark, A.T.; Harstad, O.M. Bovine milk in human nutrition-A review. Lipids Health Dis. 2007, 6, 25. https://doi.org/10.1186/1476-511X-6-25
2. MEPA. Recensement General de l'élevage au Tchad.2015
3. FAO. Rapport sur le Recensement General de l'élevage au Tchad. Fao.org. 2018

https://doi.org/10.58985/jafsb.2025.v03i03.80

4. Koussou, M.O.; Grimaud, P.; Mopaté, L.Y. Hygienic and physico- chemical quality of local milk and milk products sold in milk bars in Chad. J. Live. Vet. Med. Trop. Count. 2007, 60(1-4), 45-9. https://doi.org/10.19182/remvt.9976
5. Giulia, N.; Alejandro, G.; Ram, P.D.; Bill, V.; Silvia, A.; Emma, B.; Delia, G. Milk quality and safety in the informal sector in Assam, India: Governance, perceptions, and practices. Cogent Food Agric. 2022, 8, 1, 2137897. https://doi.org/10.1080/23311932.2022.2137897
6. Jean-Baptiste, C.; Patrick, G.; Jacques, B.; Alain, O.; Philippe, P.; Dominique, P. Effect of mastitis and related-germ on milk yield and composition during naturally occurring udder infections in dairy cows. Anim. Res. 2002, 51 383–393. INRA, EDP Sciences, https://doi.org/10.1051/animres:2002031
7. WHO. Brucellosis. Organisation mondiale de la santé, 2018.
8. Stewart, S.; Billon, P.; Mien, G.A. Proceeding of the 32nd Annual Meeting National Mastitis Council: 1993, 125-132.
9. Sawadogo. Microbiological quality of raw milk in peri-urban areas of Ouagadougou, Burkina Faso. J. Food Protec. 2016, 79(10), 1544-1551.
10. Duteurtre, G.; Meyer, C. Marché urbain et développement laitier en Afrique Subsaharienne. 2002. Montpellier: Cirad.-233p.
11. Edima, H.; Awono, E.; Ndjouenkeu, R. An analysis of the milk quality in Cameroon. A study in Adamawa region. J. Sci. Res. Rep. 2013, 2(1), 337-46.
12. FAO et FIL. Guide de bonnes pratiques en production laitière. FAO Production et santé animales – directives no 8. 2012. Rome.
13. Guiraud, J.P. Microbiologie alimentaire. Technique et ingénierie, Paris: Dunod, série Agro-alimentaire. 387-43, 2003.
14. Lebres, A.D.; Hamza, A. Cours national d'Hygiène et de microbiologie des aliments « Microbiologie des laits et produits laitiers. Institut Pasteur d'Algérie, 2002.
15. Kristjanson, P. Women's empowerment and livestock development: A review of the literature. J. Dev. Stud. 2014, 50(5), 673-686.
16. Njuki, J. Women's roles in livestock production and their impact on household food security: A review. J. Agric. Econ. 2016, 67(3), 557-573.
17. Ruegg, P. Importance of cleanliness of udders and teasts of prevention of mastitis. J. Dairy Sci. 2017, 100(10), 8530-8538.
18. Oliveira, L. Effect of teat disinfection on the risk of mastitis in dairy cow. J. Dairy Res. 2020, 87(2), 143-149.
19. Delgado-Pertiñeza, M.; Alcalde, M.J.; Guzmán-Guerrer, O.J.L.; Castel, J.M.; Mena, Y.; Caravaca, F. Effect of hygiene-sanitary management on goat milk quality in semi-extensive systems in Spain. Small Rum. Res. 2003, 47 (1), 51-61. https://doi.org/10.1016/S0921-4488(02)00239-0
20. Edima, H.C.; Awono, E.T.; Biloa, D.M.; Tchoumkeu, H.B.; Etoa, F.X. Evaluation of the good hygienic pratices on the production of *kindirmou* and *lebol*. Int. J. Curr. Microbiol. Appl. Sci. 2014, 3(9), 247-253.
21. Kelly, P.T. Milking equipment sanitation and milk quality: A review. J. Dairy Sci. 2019, 102(5), 4654-4666.
22. Labussière, J.; Bennmederbel, B. Description of the main parameters characterizing milk production, mammary morphology and milk emission kinetics of sheep milked once or twice a day with or without Sever Cuesta. Valladolid. 1976, 625-652.
23. FAO. Guide pour hygiène en l'élevage laitier. Organisation des Nations Unies pour l'alimentation et l'agriculture.
24. Muiz, O.A.; Obinna, T.E.; Doctor, M.N.M.; Rasheed, A.A.; Chibundu, N.E. Bacterial and yeast communities in raw milk from three dairy animal species in Nigeria. Lett. Appl. Microbiol. 2022, 0, 1–9. https://doi.org/10.1093/lambio/ovac010
25. Rubiela, C.; Adriana, P.; Geraldine, L.Á.; Camila, A.Z.; Olimpo, O.; Isolation and identification of Salmonella spp. in raw milk from dairy herds in Colombia. Braz J Vet Res Anim Sci. 2021, 58, e172805. https://doi.org/10.11606/issn.1678-4456.bjvras.2021.172805
26. Jay, J.M. Modern Food Microbiology. 6th Edn. Aspen Publishers, 2000.
27. Walstra, P.; Wouters, J.T.M.; Geurts, T.J. Dairy Science and Technology. 3rd edn CRC Press, 2018.
28. Aydogdu, T.; O'Mahony, J.A.; McCarthy, N.A. pH, the fundamentals for milk and dairy processing: A Review. Dairy. 2023, 4, 395–409. https://doi.org/10.3390/ dairy4030026
29. Puneet, P.; Nicolas, L.; John, T.T.; Eoin, M.; Frank, B.; Shane, V.C.; Alan, L.K.; Laurence, S. Effect of temperature on raw whole milk density and its potential impact on milk payment in the dairy industry. Int. J. Food Sci. Technol. 2021, 56, 2415–2422. https://doi.org/10.1111/ijfs.14869
30. Habanabakize, E.; Koki, B.; Christian, C.; Patrick, C.; Elsa, V. A typology of smallholder livestock production systems reflecting the impact of the development of a local milk collection industry: Case study of Fatick region, Senegal. Pastoralism: Res. Pol. Pract. 2022, 12, 22. https://doi.org/10.1186/s13570-022-00234-8