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2 ***Microbiological quality assessment of "dègué" produced and sold in N'Djamena***
3 ***municipality, Chad .***
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7 **RÉSUMÉ :**

8 **Introduction :** Le dègué est un aliment lacto-céréalié traditionnel largement consommé en Afrique de
9 l'Ouest et introduit à N'Djamena (Tchad), où sa production reste essentiellement artisanale et peu
10 contrôlée. Cette étude descriptive et transversale, menée d'octobre 2022 à mars 2023 dans cinq
11 arrondissements de N'Djamena, avait pour objectif d'évaluer la qualité microbiologique des dègués
12 produits et vendus dans la ville.

13 **Matériel et Méthodes :** Une enquête sociodémographique a été conduite auprès de 247 personnes
14 (15 producteurs, 13 vendeurs et 219 consommateurs) et 60 échantillons de dègué (38 de production
15 artisanale et 22 de marque DJAMIL) ont été analysés aux laboratoires du Centre de Contrôle de
16 Qualité des Denrées Alimentaires (CECOQDA) et de l'IREDA (Institut de Recherche en Elevage pour le
17 Développement). Les analyses ont porté sur le dénombrement de la flore aérobie mésophile totale,
18 des coliformes totaux, des entérobactéries, d'*Escherichia coli*, de *Staphylococcus aureus*, de *Bacillus*
19 *cereus*, des levures/moisissures, ainsi que sur la recherche de *Salmonella* spp.

20 **Résultats et discussion :** Les résultats de l'enquête révèlent un niveau de connaissance en hygiène
21 alimentaire globalement moyen à faible (37,24 % des enquêtés jugés « mauvais »). Sur le plan
22 microbiologique, 72 % des échantillons de dègué artisanal se sont révélés non conformes aux critères
23 réglementaires retenus, contre seulement 19 % pour les dègués de marque DJAMIL. La flore aérobie
24 mésophile totale, les coliformes, les entérobactéries et *Bacillus cereus* étaient les paramètres les plus
25 fréquemment hors normes dans les produits artisanaux. Aucun échantillon, quel que soit le type de
26 dègué, n'a révélé la présence de *Salmonella* spp.

27 **Conclusion :** Ces résultats traduisent des conditions d'hygiène insuffisantes dans la filière artisanale
28 de production du dègué à N'Djamena et soulignent la nécessité de renforcer la formation des
29 producteurs, la chaîne du froid et le contrôle sanitaire régulier de ce produit très consommé,
30 notamment par les enfants et les jeunes.

31 **Mots-clés :** dègué, qualité microbiologique, hygiène alimentaire, produits laitiers, N'Djamena, Tchad
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ABSTRACT

Background : Dègué is a traditional fermented milk-and-cereal food widely consumed in West Africa and now found in N'Djamena (Chad), where its production remains largely artisanal and poorly controlled. This descriptive, cross-sectional study, conducted from October 2022 to March 2023 in five districts (arrondissements) of N'Djamena, aimed to assess the microbiological quality of dègué produced and sold in the city.

Material and methods : A sociodemographic survey was carried out among 247 individuals (15 producers, 13 vendors, and 219 consumers), and 60 dègué samples (38 artisanally produced and 22 of the DJAMIL brand) were analyzed at the laboratories of the Food Quality Control Center (CECOQDA) and the IRED (Livestock Research Institute for Development). The analyses covered enumeration of total aerobic mesophilic flora, total coliforms, Enterobacteriaceae, *Escherichia coli*, *Staphylococcus aureus*, *Bacillus cereus*, and yeasts/molds, as well as detection of *Salmonella* spp.

Results and discuss : Survey results revealed an overall moderate-to-low level of food hygiene knowledge (37.24% of respondents rated as "poor"). Microbiologically, 72% of artisanal dègué samples were found non-compliant with the regulatory criteria applied, compared with only 19% of DJAMIL-brand dègué samples. Total aerobic mesophilic flora, coliforms, Enterobacteriaceae, and *Bacillus cereus* were the parameters most frequently out of standard in artisanal products. No sample, regardless of dègué type, tested positive for *Salmonella* spp.

Conclusion : These results reflect inadequate hygiene conditions in the artisanal dègué production chain in N'Djamena and highlight the need to strengthen producer training, the cold chain, and regular health inspection of this widely consumed product, particularly among children and young people.

Keywords : dègué, microbiological quality, food hygiene, dairy products, N'Djamena, Chad

1. Introduction

Dègué is a cereal-based dairy food that is widely consumed in Burkina Faso, Benin, Mali, Côte d'Ivoire, and Senegal. Eaten by all segments of society, it is recognized for its probiotic properties. Although it is a fermented food, fermentation in the manufacturing process only concerns the milk added to the pre-cooked lumps of millet flour. It is a beverage prepared and sold fresh on a daily basis, along roadsides, near areas of activity, in markets, and in shops, by small processing units (Tankoano *et al.*, 2017).

In developing countries, inadequate food hygiene can be the cause of infectious diseases (cholera, typhoid), food-borne toxin-infections and poisoning, or transient disorders in consumers (diarrhea, gastroenteritis). This is particularly true for raw milk and its traditional derivatives, which are fragile, perishable products, rich in water and nutrients (Marnissi *et al.*, 2013). One of the major constraints to promoting the dairy sector is precisely this perishability: about four hours after milking, milk already begins to deteriorate (Mutwedu *et al.*, 2018). Because of its high moisture content, the risks of infection linked to various handling steps, its near-neutral pH, and the diversity of its nutrients, milk is an excellent growth medium for many microorganisms (Mutwedu *et al.*, 2018).

Assessment of the microbiological quality of a food relies on testing for germs of hygienic interest, indicators of fecal contamination, as well as pathogenic and toxin-producing germs (Marnissi *et al.*, 2013). Microbiological quality control of food remains essential, as it prevents the marketing and consumption of dangerous or non-compliant products; this control is based on regulated analyses, governed by national or international standards that generally require the absence of any pathogenic germ or microbial toxin, as well as a low total microbial load (Guergouri, 2020).

Dègué was introduced in Chad, more specifically in N'Djamena, where it is produced by individuals. It is packaged in unlabeled plastic bottles and sold mainly in shops, and is consumed by a significant portion of the population of N'Djamena. In Chad, milk production is carried out by extensive pastoral or agro-pastoral livestock farms, which mainly sell cow's milk, but also goat's and camel's milk. This production follows seasonal variations in pasture availability: the high-production season corresponds to the rainy season (July to October), while the period preceding the arrival of the rains is the most difficult (Vias Franck, 2018 ; Pabamé and Frédéric, 2021).

The demographic growth of the Chadian population in general, and of the city of N'Djamena in particular, has favored the development of income-generating activities linked to dairy products,

including dègués. N'Djamena is indeed the largest center of milk and dairy product consumption in the country (Doutoumet *al.*, 2013). The city's supply basin relies on a set of livestock farms located within a radius of 120 km, mainly supported by cattle and dromedary herders (Koussou & Patrice, 2013). Over the past two decades, the privatization of large dairies and the abandonment of state monopolies have strengthened the competitiveness of local sectors (Gaba, 2001), favoring the emergence of small private dairy businesses (milk bars, cheese factories, and yogurt makers) whose shared vision is the promotion of local milk (Doutoumet *al.*, 2013; Vias Franck, 2018). However, the local dairy products thus marketed do not always offer consumers a formal health guarantee (Koussou, Duteurtre *et al.*, 2007).

It is in this context that the present study is situated, its main objective being to assess the microbiological quality of dègués produced and sold in the municipality of the city of N'Djamena.

2. General background on milk and dairy products

2.1. Milk

2.1.1. Definition

Milk is the whole product of the total and uninterrupted milking of a healthy, well-fed, and non-overworked dairy female. It must be collected cleanly and must not contain colostrum (Konte, 1999). It is also defined as the normal mammary secretion of dairy animals, obtained from one or more milkings, without any addition or removal, and intended for consumption as liquid milk or for further processing (Koussou *et al.*, 2007 ; FAO/WHO, 1999).

2.1.2. Production

In Chad, milk production is carried out by extensive pastoral or agro-pastoral livestock farms, which mainly sell cow's milk, but also goat's and camel's milk, with seasonal variations linked to pasture availability (Vias Franck, 2018). Estimates put national production at 20 million liters in 2001. In 2002, it reached 223,475 tonnes of milk, broken down as follows: 159,300 t/year for cows, 33,000 t/year for goats, 21,800 t/year for camels, and 9,375 t/year for sheep. The system of milk and dairy product production and marketing remains, in Africa in general and in Chad in particular, of a traditional type (Doutoumet *al.*, 2013).

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116 2.1.3. Chemical composition

117 The chemical composition of milk varies mainly according to factors linked to the animal (genetics,
118 physiological stage, health status) or to the environment (season, feeding, milking) (FAO, 1995,
119 Béninga, M.B., 2011). Table I presents the chemical composition of milk from different ruminants.

120 **Table I: Chemical composition of milk from different ruminants (in g/l)**

121 2.2. Dairy products

122 2.2.1. Definition

123 A dairy product is a product obtained through some treatment of milk, which may contain food additives and
124 other ingredients functionally necessary for its processing (FAO/WHO, 1999). These are
125 products derived exclusively from milk, it being understood that substances necessary for their
126 manufacture may be added, provided they do not replace, in whole or in part, any of the constituents of
127 milk (Rcn, 2009). However, the local dairy products marketed do not always offer a
128 formal health guarantee (Duteurtre *et al.*, 2007).

129 2.2.2. Classification

130 Dairy products are classified into several categories: curdled milk, cheeses, yogurts, and fermented milks
131 (Breiz, 2020). Skimmed curdled milk (*rouaba*) results from the total or partial churning of whole milk after
132 fermentation, or from skimming when it is not churned; it is clearly distinguished from fermented whole milk
133 (*rayib*, or "local yogurt" as a loose term) (Duteurtre & Atteyeh, 2000). Fermented milk is obtained through
134 the action of suitable, viable, active, and abundant microorganisms, resulting in a reduction of pH with
135 or without coagulation (Codex Alimentarius, 2011); yogurt is a specific form of it, fermented exclusively by
136 *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, but not all fermented milks are yogurts
137 (Breiz, 2020).

138 2.3. Microorganisms in milk and dairy products

139 Owing to its composition, milk is a very favorable substrate for the development of microorganisms
140 (Amira, 2022). When these multiply in it, they cause alterations harmful to product quality (degradation of
141 constituents, release of undesirable compounds, defects in taste, odor, or texture) and can impair the

growth of the lactic acid bacteria essential for fermentation. Strict adherence to good manufacturing and hygiene practices is therefore essential to guarantee good-quality food (Carlos, 2020). Indicators of fecal contamination, such as coliforms and *Escherichia coli*, are bioindicators classically used to reveal unclean handling practices (Delcenserie *et al.*, 2002; Tourette, 2002). Contamination can be biological, chemical, or physical in nature; from a microbiological standpoint, the consequences vary greatly depending on whether the germs involved are spoilage organisms (yeasts, molds) or pathogens, the latter representing a greater public health concern (Delcenserie *et al.*, 2002).

2.4. Value of testing for microorganisms in dairy products

Testing for germs of hygienic interest makes it possible to assess the level of contamination of foodstuffs and the nature of their microflora, as part of both official controls and the self-checks carried out by producers (Marnissi *et al.*, 2013; Carlos, 2020). On the pathogenic side, *Listeria monocytogenes* and *Salmonella* spp. are among the germs systematically tested for in raw milk, heat-treated milk, and dairy products (Delcenserie *et al.*, 2002). Nutritionally, contamination by proteolytic or lipolytic germs leads to the denaturation of proteins and vitamins, hence the value of rigorous microbiological assessment in preserving the nutritional qualities of the product (Carlos, 2020).

2.5. Dègué

2.5.1. Definition and origin

In the Bambara language, "dègué" refers to small granules (2 to 3 mm) made from cereal flour (sorghum, millet, fonio) pre-cooked by steaming, as well as to the culinary preparation made of these granules mixed into sweetened yogurt or curdled milk (Cruz *et al.*, 2020). It is also defined as a traditional dish based on millet and fermented milk (Ny, Baba-Moussa *et al.*, 2009). Originating in West Africa, dègué is a Bambara dish (a people of Mali) widely eaten across a region encompassing Senegal, Guinea, Côte d'Ivoire, and the rest of West Africa; it is generally consumed as a snack rather than at the end of a meal.

2.5.2. Sales channels and prices in Chad

In N'Djamena, dègués are sold at the homes of the women who process them, in shops in the various districts, at kiosks, along streets, and through street vending from small coolers. Their shelf life ranges from two to three days when refrigerated (17-18°C); in the absence of electricity, the rise in

temperature accelerates spoilage, which can occur as early as two days for "light" dègués and three days for more "substantial" ones. The product is sold individually, at a price of 250 FCFA for a 33 cl bottle and 500 FCFA for a 75 cl bottle.

2.5.3. Ingredients and preparation

The ingredients used in making dègué include powdered milk, curdled milk or yogurt (plain or vanilla), millet semolina, powdered sugar, vanilla sugar, water, butter, and casta (a starch-based thickener). Preparation involves two main steps: fermentation of the milk (a mixture of powdered milk, lukewarm water, and yogurt, with casta added, then incubated for a maximum of 8 hours in a warm, dry place, otherwise the mixture reverts to a liquid state), and steaming of the millet semolina (25 minutes), which is then cooled and mixed with the butter and the sweetened, vanilla-flavored milk preparation, before being refrigerated and served very cold, sometimes with raisins added (Koussou & Patrice, 2013).

3. Material and methods

3.1. Study site

This descriptive, cross-sectional study with an analytical aim was conducted from October 2022 to March 2023 in five districts of N'Djamena, the capital of Chad, the most populous city. It mainly focused on the microbiological analysis of dègués, carried out at the food microbiology laboratory of the Food Quality Control Center (CECOQDA). Chad is a country with an agro-pastoral vocation where a third of the rural population lives exclusively from livestock farming and agriculture (Pabamé & Frédéric, 2021). The country has a large ruminant herd, with national milk production estimated at 220,000 tonnes per year (Koussou & Patrice, 2013).

Figure 1: Map of study area

3.2. Biological material

The biological material used in the study consisted of dègués produced and marketed locally, in two forms: artisanally produced dègués (unlabeled) and dègués of the DJAMIL commercial brand.

3.3. Survey

A cross-sectional survey was conducted in five districts of N'Djamena among dègué producers, sellers, and consumers, in order to gather sociodemographic information as well as data on manufacturing processes, organoleptic parameters, and the storage and sale conditions of the product. In total, 247 people were surveyed, comprising 15 producers, 13 sellers, and 219 consumers.

3.4. Sampling

Random, systematic sampling covered 60 dègué samples (artisanal and DJAMIL brand) collected from shops in three districts of N'Djamena (5th, 6th, and 7th). The geographic distribution is shown on the map in Figure 1. Sample size was determined using the following statistical method: $p = 1 - (N-n)/N = n/N$; $n = P \times N$.

- n: sample size
- N: estimated population size
- P: probability of the sample being selected

208 With $N = 600$, $P = 10\%$; $n = 600 \times 10\% = 60$.

209 Strict aseptic rules were observed during collection to avoid any contamination and to limit any increase in
210 the initial microbial load. The samples were then transported to the laboratory in a cooler for analysis.

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3.5. Microbiological analyses

Microbiological analyses covered the enumeration of total mesophilic aerobic flora (ISO 4833, 2003) on PCA medium (Oxoid CM 0463), yeasts and molds (NF ISO 21527-2, 2008) on Sabouraud Dextrose Agar (Oxoid CM 0041) supplemented with chloramphenicol (0.05 g/l), total and thermotolerant coliforms (NF ISO 4832, V 08-015, 2006 and V08-060, 2009) on VRBG and TBX media (Oxoid CM 0107), *Bacillus cereus* on MYP medium, *Staphylococcus aureus* (NF EN ISO 6888-1/A1, 2004) on Baird-Parker agar (Oxoid CM 0275) supplemented with egg yolk and potassium tellurite, and *Salmonella* spp. on XLD and Hektoen agars, in accordance with standard NF ISO 6579 (2021). Each sample was analyzed in triplicate.

3.6. Data analyses

Data from the field survey and the microbiological analyses were entered and organized into tables and graphs using Microsoft Word and Excel 2019.

4. Results

4.1. Sociodemographic characteristics of respondents

The survey covered a total of 247 people, including 149 men and 98 women, giving a sex ratio of 0.65. The 3-19 age group was the most represented (58.3%), followed by the 20-30 age group (29.2%). In terms of education level, nearly half of respondents (49.4%) had a primary-school level, and the majority (51.0%) were pupils/school children, reflecting the significant weight of young consumers in the sample (Tables II and III).

Table II: Distribution of respondents by sex and age group

Table III: Distribution of respondents by education level and profession

Table IV: Distribution of respondents by district (arrondissement)

Table IV shows that the various categories surveyed are more strongly represented in the 7th district (38.05 %).

Table V: Distribution of respondents by level of food hygiene knowledge.

The results in Table V show that nearly a third of respondents (37.24%) have a level of knowledge deemed poor regarding food hygiene, which constitutes a potential risk factor for contamination throughout the *dégué* production, distribution, and consumption chain.

4.2. Distribution of samples analyzed

A total of 60 dègué samples were analyzed, split into two categories: 38 artisanally produced (unlabeled) samples and 22 DJAMIL brand samples, collected from four sampling areas spread across three districts.

Table VI: Number of samples per sampling site

4.3. Microbiological quality of artisanally produced dègués

Table VII presents the results of the microbiological analyses carried out on a representative subset of 16 artisanal dègué samples, expressed in CFU/g and compared to the microbiological criteria adopted for each germ tested. A significant proportion of samples exceeded the thresholds set for total mesophilic aerobic flora (TMAF), total coliforms, Enterobacteriaceae, *Escherichia coli*, and *Bacillus cereus*, with several values far exceeding the upper limit of quantification ($> 1.5 \times 10^5$ to $> 3 \times 10^6$ CFU/g).

Table VII: Results of microbiological analyses of artisanal dègués (CFU/g)

Figure 2: Concentration of germs in artisanal dègués sold in shops

US: unsatisfactory and S: satisfactory

Analysis of the figure 2 shows that artisanal dègués have a higher-than-normal microbial load.

Figure 3: Overall contamination results for artisanal production dègués

US: unsatisfactory, S: satisfactory

The overall assessment of the microbiological quality of artisanal dègués (Figure 3) shows 72% unsatisfactory samples (non-compliant with at least one microbiological criterion) versus 28% satisfactory samples, reflecting a worrying level of contamination in this production sector.

4.4. Microbiological quality of DJAMIL brand dègués

Table VIII presents the results obtained for the DJAMIL brand dègué samples. Unlike the artisanal products, most of the parameters tested were below the microbiological criteria adopted, with the occasional exception of TMAF (samples Ar5A_E1, Ar6D_E1, and Ar6M_E1) and yeasts/molds (samples Ar6M_E1 and Ar7C_E4).

Table VIII: Results of microbiological analyses of DJAMIL dègués (CFU/g)

Figure 4 : Germs concentration in DJAMIL dègués produced and sold in shops

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US: Unsatisfactory and S: Satisfactory

Analysis of figure 4 shows that DJAMIL products have a satisfactory microbial load, except for FAMT and moulds/yeasts.

Figure 5: Overall contamination results for DJAMIL dègués

US: unsatisfactory, S: satisfactory

The overall assessment of DJAMIL brand dègués (Figure 5) shows 19% unsatisfactory samples versus 81% of samples compliant with the microbiological criteria.

Regardless of the type of dègué analyzed (artisanal or DJAMIL), no sample showed the presence of *Salmonella* spp. in 25 g of sample.

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5. Discussion

The results of the microbiological analyses of artisanal and DJAMIL dègués show that the germstested for (TMAF, *E. coli*, *Staphylococcus aureus*, coliforms, *Bacillus cereus*, yeasts/molds, Enterobacteria) largelyexceeded the acceptable standard for eachgerm in dègués from artisanal production, whereasresultswere more variable for the DJAMIL brand. Our resultsexceed the acceptable microbiologicalcriteria for foodstuffs set for each of the above-mentionedgerms (Division de la sécurité alimentaire ([DSA], 2018) ;*Salmonella*strains, on the other hand, were not found in either type of dègué.

Total mesophilicaerobic flora (TMAF) exceeded a concentration of 5×10^4 CFU/g in 87.50% of artisanallyproduced dègué samples, versus 75% for DJAMIL dègués. Theseresultscorroboratethose of a studyconducted in Chad on the physicochemical and hygienicquality of bush milk and local dairyproductssold in N'Djamena'smilk bars, whichlikewiseclassified the samples as unsatisfactory for TMAF (Grimaud *et al.*, 2007; Koussou & Patrice, 2013). The same observations have been reported in Algeria (Hamiroune *et al.*, 2016) and in Benin (Carlos, 2020). The presence of TMAF in dègué reflects the overallhygienicquality of the production chain; the poorhygiene conditions observed in the handling of bottles, processing, and equipment use wereevidently not sufficientlycontrolled.

Coliforms, absent from DJAMIL dègué, reflect the application of certain hygienerules by thisproducer. Althoughsomehygiene conditions have been improved, othersremainuncontrolled, as shown by artisanal dègué, in whichcoliformsweredetected at a frequency of 93.75% above 10^2 CFU/g. The presence of coliforms in the samplesindicates a source of environmentalcontamination ; the presence of dogs and other carnivores in the environmentaroundcows can, in particular, constitute a source of contamination of utensils. Similar observations have been reported by studiesconducted in Algeria and Cameroon (Maïworé *et al.*, 2018).

Staphylococcus aureus is a bacteriumcommonlyfound in humans and animals. Staphylococci are heat-resistant and are not destroyed by cooking;theirpresence in foodrepresents a risk to humanhealth, as certain strains of *S. aureus* produceenterotoxinswhose ingestion causes food-borne toxi-infection (Brisaboise *et al.*, 1997). This bacteriumwasidentified at a concentration above 10^2 CFU/g in 81.25% of samples, contamination generallyresultingfromfood handling by carriers of the bacterium, or fromalready-contaminatedmilk. This resultis consistent with a study on the prevalence of

enterotoxigenic *Staphylococcus aureus* in dègué sold in three municipalities of Abidjan, Côte d'Ivoire (Ny, Yao *et al.*, 2009). It is nonetheless higher than the 70% reported by Maïworé *et al.* (2015), but remains lower than the 90% abnormal presence noted in a study conducted in Burkina Faso in 2018 (Millogo *et al.*, 2018).

Escherichia coli is a normal commensal of the human and animal gut, accounting for about 80% of the aerobic intestinal flora; it is found in very large numbers in feces, from where it spreads into the environment (soil, water). Its presence in food always indicates fecal contamination, whether direct contamination or, for heat-treated products, post-treatment contamination linked to processing equipment or personnel. *E. coli* was detected in artisanal dègué in 87.50% of cases, at values above the 10 CFU/g limit recommended by the food safety division (DSA, 2018), which is consistent with the findings of a study conducted in Burkina Faso (Millogo *et al.*, 2018).

Bacillus cereus is naturally found in soil; its presence in processed foods results from contamination of raw materials (for example the cereals used to make dègué) as well as from the resistance of its spores to heat treatments and manufacturing processes. During cooling, these spores can germinate, allowing *Bacillus cereus* to multiply in the food and produce toxins there (Anses, 2021). Our study revealed the presence of *Bacillus cereus* in 81.25% of artisanally produced dègués, exceeding the standard limit of 10² CFU/g, whereas no *Bacillus cereus* was detected in DJAMIL dègué, reflecting a better choice of raw materials in its processing.

Yeasts and molds were found, respectively, in 68.75% of non-compliant samples for artisanal production (versus 31.25% compliant) and in 50% of non-compliant samples for DJAMIL dègué (versus 50% compliant). These results may reflect non-compliance with hygiene rules within processing households, notably poor hygiene of the utensils used during milking and a poorly controlled production environment. Our results corroborate those of Maïworé *et al.* (2018).

Finally, in light of our results, no presence of *Salmonella* spp. was noted in the samples analyzed, regardless of the type of dègué. This result is consistent with that obtained by Carlos (2020) in Benin, as well as with that of a study conducted in Algeria on the bacteriological quality of raw cow's milk, which reports the same conclusions (Sara & Lakhdar, 2021).

Taken together, these results confirm a clear contrast between the artisanal sector, marked by widespread microbial contamination and high non-compliance rates (72%), and the DJAMIL sector,

whose more controlled manufacturing practices (choice of raw materials, equipment hygiene, packaging) translate into a markedly lower non-compliance rate (19%). This finding is consistent with the survey's sociodemographic data, which reveal a mixed level of food hygiene knowledge among a significant proportion of producers, sellers, and consumers (37.24% rated as having poor knowledge), as well as the profile of *dègué* consumers, who are mostly children and young people in school (58.3% aged 3-19; 51.0% pupils/school children) — a population particularly vulnerable to food-borne toxicoinfections. These elements, combined with the precarious storage conditions mentioned above (frequent breaks in the cold chain, short shelf lives), point to a set of risk factors that should be addressed as a priority in the artisanal sector.

6. Conclusion

This study aimed to assess the microbiological quality of *dègués* produced and sold in the municipality of N'Djamena. It revealed significant microbial contamination of artisanally produced *dègués*, with 72% of samples non-compliant with the microbiological criteria adopted, compared with only 19% for DJAMIL brand *dègués*, whose more standardized manufacturing process appears to better control contamination risks. Total mesophilic aerobic flora, coliforms, Enterobacteriaceae, *Escherichia coli*, and *Bacillus cereus* are the parameters most frequently out of standard in the artisanal sector, reflecting shortcomings in good hygiene practices during milk collection, processing, packaging, and storage of the product. The absence of *Salmonella* spp. in all samples is, however, a reassuring finding.

In light of these findings, it appears necessary to strengthen the awareness and training of *dègué* producers and sellers in good food hygiene practices, to improve the cold chain throughout the distribution circuit, to encourage the labeling and traceability of artisanal products, and to establish regular health monitoring of this sector, given the importance of its consumption by children and young people in N'Djamena. Further studies, covering a larger number of samples and including testing for other pathogens (notably *Listeria monocytogenes*), would help to better characterize the health risks associated with the consumption of *dègué* in Chad.

Disclosure (artificial intelligence)

The authors certify that they have no conflicts of interest/competing interests. The authors hereby declare that no generative AI technologies such as large language models (ChatGPT, COPILOT, etc.) and text-to-image generators were used in the writing or revision of this manuscript.

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368 **Conflicts of interest**

369 The authors declared that no conflict of interest exists.

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Table I: Chemical composition of milk from different ruminants (in g/l)

Species	Water	Dry matter	Total protein	Casein	Lipids	Lactose	Total minerals	Calcium	Phosphorus
Cow	900	130	30-35	27-30	35-40	45-50	8-10	1.25	0.95
Goat	900	140	35-40	30-35	40-45	40-45	8-10	1.35	1
Sheep	860	190	55-60	45-50	70-75	45-50	10-12	1.9	1.5

Table II: Distribution of respondents by sex and age group

Sociodemographic variables	Producers	Sellers	Consumers	Total	Percentage (%)
Sex					
Male	05	11	133	149	60,32
Female	10	02	86	98	39,67
Total	15	13	219	247	
Age [years]					
[3 - 19]	01	03	140	144	58,29
[20 - 30]	09	06	57	72	29,15
[31 - 45]	05	04	22	31	12,55
Total	15	13	219	247	

Table III: Distribution of respondents by education level and profession

Sociodemographic variables	Producers	Sellers	Consumers	Total	Percentage (%)
Education level					
Higher	01	02	24	27	10,93
Secondary	06	04	69	79	31,98
Primary	03	00	119	122	49,39
No schooling	05	07	07	19	07,69
Total	15	13	219	247	
Profession					
Civil servants	01	00	14	15	06,07
Students	02	03	49	54	21,86
Schoolchildren	00	00	126	126	51,01
Unemployed	05	06	17	28	11,33
Housewives	07	04	13	24	09,71
Total	15	13	219	247	

Table IV: Distribution of respondents by district(arrondissement)

Category of respondents	Producers	Sellers	Consumers	Total	Percentage (%)
Districts					
1 st	02	01	25	28	11,33
5 th	01	01	22	24	09,71
6 th	05	07	43	54	21,86
7 th	07	03	84	94	38,05
9 th	00	01	45	47	19,03
Total	15	13	219	247	

Table V: Distribution of respondents by level of foodhygieneknowledge.

Category of respondents	Producers	Sellers	Consumers	Total	Percentage (%)
Hygieneknowledge					
Bad	06	07	79	92	37,24
Average	04	02	89	95	38,46
Good	05	04	51	60	24,29
Total	15	13	219	247	

Table VI: Number of samples per sampling site

District (Ar) / Samples	5 th (Am-riguébé)	6 th (Dembé)	6 th (Moursal)	7 th (Chagoua)	Total
Artisanal dègués	10	07	15	06	38
Djamil dègués	05	04	08	05	22
Total	15	11	23	11	60

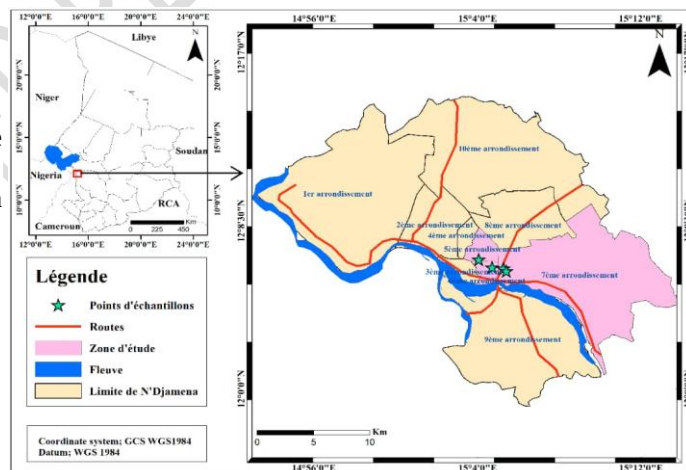
Table VII: Results of microbiological analyses of artisanal dègués (CFU/g)

Germ	TMAF	Total coliforms	Enterobacteria	E. coli	S. aureus	B. cereus	Yeasts/molds	Salmonella spp.
Criteria>Samples	$\leq 5.10^4$	$\leq 10^2$	$\leq 10^2$	≤ 10	$\leq 10^2$	$\leq 10^2$	$\leq 10^3$	Absent /25g
Ar5A_E1	$= 4,9.10^4$	< 10	< 10	< 10	$= 4,6.10^3$	$< 10^2$	$= 4,9.10^4$	Absent
Ar5A_E2	$7,8.10^5$	$2,5.10^4$	$5,4.10^4$	$> 1,5.10^4$	$4,6.10^3$	$> 1,5.10^5$	4.10^2	Absent
Ar5A_E3	$2,5.10^5$	$2,8.10^4$	$4,3.10^4$	$> 1,5.10^4$	$4,6.10^3$	$> 1,5.10^5$	5.10^2	Absent
Ar5A_E4	$3,5.10^4$	$2,8.10^2$	$2,2.10^2$	< 10	$4,6.10^3$	$< 10^2$	$1,2.10^3$	Absent
Ar6D_E1	$9,7.10^5$	$9,5.10^4$	$1,2.10^5$	$> 1,5.10^4$	$4,6.10^3$	$> 1,5.10^5$	6.10^2	Absent
Ar6D_E2	$> 3.10^6$	$1,7.10^4$	$2,1.10^4$	$> 1,5.10^4$	$1,4.10^3$	$> 1,5.10^5$	< 40	Absent
Ar6D_E3	$2,5.10^5$	$> 1,5.10^5$	$> 1,5.10^5$	< 40	$1,4.10^3$	< 40	$3,2.10^3$	Absent
Ar6D_E4	$6,4.10^5$	$8,3.10^4$	$8,3.10^4$	$> 1,5.10^4$	$1,4.10^3$	$> 1,5.10^5$	4.10^2	Absent
Ar6M_E1	$> 3.10^6$	$1,2.10^2$	$> 1,5.10^5$	$> 1,5.10^4$	$1,4.10^3$	$> 1,5.10^5$	$> 1,5.10^5$	Absent
Ar6M_E2	$> 3.10^5$	$3,8.10^3$	$> 1,5.10^5$	4.10^1	$< 10^2$	$> 1,5.10^5$	$> 1,5.10^5$	Absent
Ar6M_E3	$> 3.10^6$	$1,3.10^5$	$> 1,5.10^5$	$> 1,5.10^5$	$4,6.10^3$	$> 1,5.10^5$	$> 1,5.10^5$	Absent
Ar6M_E4	$> 3.10^6$	7.10^1	$> 1,5.10^5$	10^2	$< 10^2$	$> 1,5.10^5$	$> 1,5.10^5$	Absent
Ar7C_E1	$> 3.10^6$	< 10	$> 1,5.10^5$	$3,2.10^3$	$< 10^2$	$> 1,5.10^5$	$> 1,5.10^5$	Absent
Ar7C_E2	$> 3.10^6$	$> 1,5.10^5$	$> 1,5.10^5$	$> 1,5.10^4$	$1,2.10^3$	$> 1,5.10^5$	2.10^3	Absent
Ar7C_E3	$> 3.10^6$	$> 1,5.10^5$	$> 1,5.10^5$	$> 1,5.10^4$	$1,4.10^3$	$> 1,5.10^5$	3.10^3	Absent
Ar7C_E4	$> 3.10^6$	$5,1.10^4$	$> 1,5.10^5$	$> 1,5.10^4$	$< 10^2$	$> 1,5.10^5$	$> 1,5.10^5$	Absent

Table VIII: Results of microbiological analyses of DJAMIL dègués (CFU/g)

Germ	TMAF	Total coliforms	Enterobacteria	E. coli	S. aureus	B. cereus	Yeasts/molds	Salmonella spp.
Criteria>Samples	$\leq 5.10^4$	$\leq 10^2$	$\leq 10^2$	≤ 10	$\leq 10^2$	$\leq 10^2$	$\leq 10^3$	Absent /25g
Ar5A_E1	$> 3.10^6$	< 10	< 10	< 10	$< 10^2$	$1,8.10^3$	$< 10^2$	Absent
Ar6D_E1	$7,6.10^5$	< 10	< 10	< 10	$< 10^2$	$< 10^2$	$< 10^2$	Absent
Ar6M_E1	$> 3.10^6$	< 10	< 10	< 10	$< 10^2$	< 10	$1,5.10^5$	Absent
Ar7C_E1	$1,4.10^4$	< 10	< 10	< 10	$< 10^2$	< 10	$7,5.10^3$	Absent

Figure 2: Map of study area



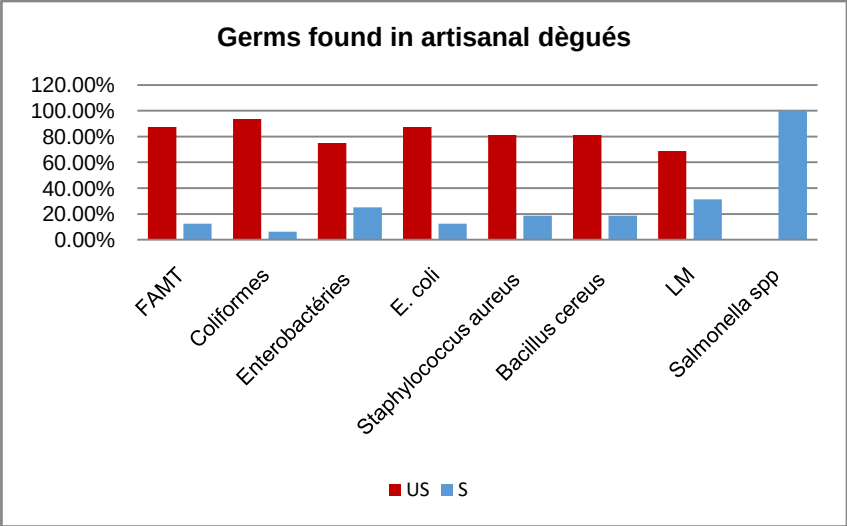


Figure 2: Concentration of germs in artisanal dègués sold in shops
US: unsatisfactory and S: satisfactory

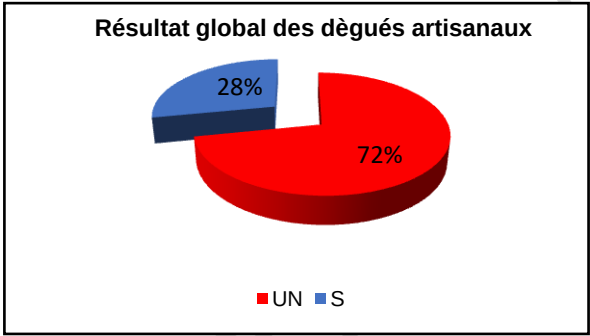


Figure 3: Overall contamination results for artisanal production dègués
US: unsatisfactory, S: satisfactory

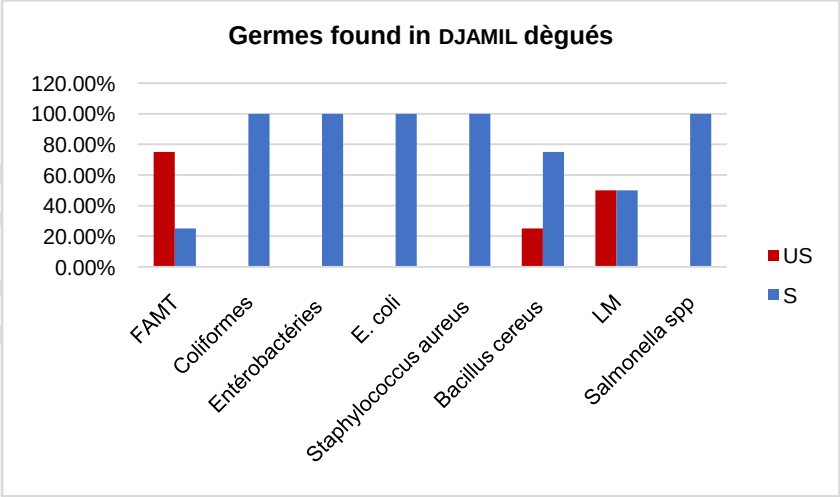


Figure 4 : Germs concentration in DJAMIL dègués produced and sold in shops
US: Unsatisfactory and S: Satisfactory

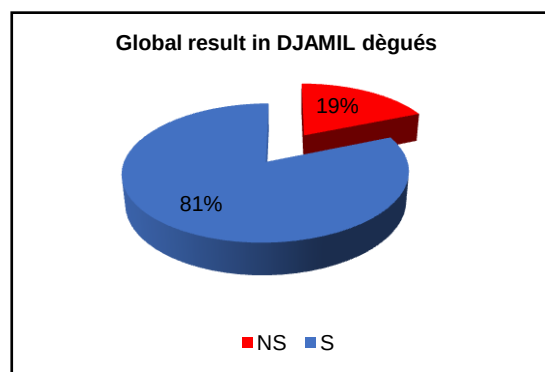


Figure 5: Overall contamination results for DJAMIL dègués
 US: unsatisfactory, S: satisfactory