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Impact of artisanal drying on the microbiological quality of dried meat sold in N'Djamena, Tchad

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Abstract

Meat is an important source of macronutrients and micronutrients essential for maintaining a healthy body. However, meat processing can sometimes lead to contamination due to poor hygiene. This study aimed to assess the impact of domestic drying on the microbiological quality of dried meats sold in N'Djamena. Microbiological analyses were carried out using standard analytical methods. Data were processed in Excel 2016 and compared using SPSS 17.0 software. A total of 30 samples were collected from April to June 2022 at 5 sites in N'Djamena. Total aerobic mesophilic flora ranged from 5.27×10^5 to 5.18×10^7 CFU/g, while thermotolerant coliforms varied from 2.15×10^3 to 3.75×10^5 CFU/g. *S. aureus* was present in all samples, with loads ranging from 1.82×10^4 to 6.09×10^4 CFU/g. Yeasts and molds ranged from 1.15×10^3 to 5.91×10^4 CFU/g, and *E. coli* from 2.91×10^2 to 6×10^3 CFU/g. The microbiological quality of the samples analyzed showed high levels of unsatisfactory results: 53.30% for total aerobic mesophilic flora, 70% for total coliforms, 26% for thermotolerant coliforms and 60% for *Staphylococcus aureus*. The microbiological results show that artisanal drying methods hurt the quality of dried meat sold in N'Djamena.

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Introduction

Meat is one of the most widely consumed foods in the world and in Sahelian countries. It contains macronutrients (proteins, lipids) and micronutrients that are very important for human nutrition, such as iron, B vitamins: B1, B2, B3, B5, PP, B8, B12, zinc, selenium and phosphorus (Talib *et al.*, 2014; Tom, 2015; Toldra, 2017). Like other animal protein sources, its amino acid composition is very satisfactory, as it contains all the essential amino acids (Loudovic, 2008; Chougui, 2015). Considered a staple food worldwide, global meat consumption reached 323 million tons in the year 2017, consumption per individual was 42.9 Kg worldwide and 32.8 Kg in developing countries (FAO, 2014).

Tchad is one of the Sahelian countries rich in livestock, with an estimated 94 million head of cattle of all breeds (MEPA, 2016). The galloping demographic growth in Tchad and, above all, the flow of refugees from Sudan, the Central African Republic and Nigeria has led to a significant increase in meat consumption, contributing to the creation of numerous jobs and, at the same time, to poverty reduction (Yagdbare, 2014; Deni, 2019).

Numerous meat-drying methods for preserving meat for welding periods have been available worldwide for many years (Apata *et al.*, 2013; Boudechicha, 2014). In Tchad and western Sudan in particular, boneless meat and crushed, fermented bones are dried directly in the sun, producing products that are highly appreciated by consumers. Dried meats are directly consumed or used in cooking, while fermented and dried bones are crushed and used in certain meals in combination with leaves and apricots by vulnerable families (Brigitte *et al.*, 2005; Chougui, 2015).

Meat is an ideal food for the proliferation of germs, as it contains a lot of water and nutrients (El-Hassan *et al.*, 2018; Bersisa *et al.*, 2019). Furthermore, failure to apply good hygiene practices during processing is a factor in contamination by pathogenic germs, responsible for sometimes fatal food poisoning such as typhoid fever and cholera (Tidjani *et al.*, 2014).

Published global estimates of foodborne illness have shown that every year, 1 in 10 people fall ill from eating contaminated food and 420,000 die, including 125,000 children under the age of five (OMS, 2015). In Africa, more than 91 million people fall ill with toxic infections every year, 70% of them from diarrheal diseases, and 137,000 die from them, representing 1/3 of global mortality from foodborne diseases (OMS, 2015). Studies carried out in Tchad on food poisoning have shown that a significant number of people have been consumed by contaminated food. In 2014, out of 2,735 patients consulted in five major hospitals in the capital, 84 toxic infections were confirmed, following ingestion of contaminated food (Tidjani *et al.*, 2014). These figures show the scale of toxic infections in Tchad. However, very little data on the impact of artisanal drying techniques on contamination levels of dried meat in Tchad, as well as the implications for consumer health, have been published. The aim of this study was therefore to assess the microbiological quality of home-cured meat sold in N'Djamena. This study will help to prevent and reduce the risk of consumer contamination.

Materials and methods

Sample collection and preparation

The biological material consisted of artisanal dried meats collected from five markets in N'Djamena. Samples were collected at random from the marketing sites, coded and transported to the laboratory for microbiological analysis. The surface and deep parts of the dried meats were aseptically collected under a laminar flow hood, using sterile forceps close to the Bunsen burner flame, and packed in clean coolers. A total of 30 samples of 200g dried meats were taken and analyzed.

Microbiological analysis methods

Stock solutions and dilutions were prepared by the international standard ISO 6887-2 (ISO 6887-2, 2017).

Total aerobic mesophilic flora (FAMT) was enumerated on Liofilchem Diagnostic-ITALY PCA agar according to international standard ISO 4833-1 (ISO 4833-1, 2013).

Total coliforms were enumerated according to the international standard ISO 4832 (ISO 4832, 2006) on Levine agar Liofilchem srl Zona Ind.le-Roseto d.Abruzzi (TE)-ITALY Methylene Blue Eosin (EMB).

Thermo-tolerant coliforms and Escherichia Coli colonies were counted according to French standard NF V08-60 (NF V08-60, 2009) on Levine agar Liofilchem srl Zona Ind.le-Roseto d.Abruzzi (TE)-ITALY Methylene Blue Eosin agar (EMB).

Staphylococci (*S. aureus*) were enumerated by the international standard ISO 6888-1 (ISO 6888-1, 2021).

Yeasts and molds were counted on Sabouraud Chloramphenicol agar Liofilchem srl Zona Ind.le-Roseto d.Abruzzi (TE)-ITALY by the international standard ISO 21527-2 (ISO 21527-2, 2008).

Determination of the number of CFU per gram of product

The number (N) of germs per gram of product was calculated according to the international standard ISO 7218 (ISO 7218, 2007) as a weighted average, using the following equation:

$$N = \frac{\sum C}{V.d(n1 + 0{,}1n2)}$$

ΣC: Sum of colonies on all plates of the two successive dilutions

V: inoculum volume

n1 and n2: Number of plates for the 1st and 2nd dilutions respectively

d: Dilution rate of the first box to produce colonies (low dilution)

Interpretation of microbiological results

Microbiological results were interpreted by the European regulation 2073/2005/EC on meat products and their derivatives (CE 2073/2005/CE, 2005). Enumeration results were interpreted according to a 3-class plan, the limits of which are given in Table 1.

Statistical processing

Data were entered into Excel 2007 and analyzed with SPSS 17.0 software to compare the different microbiological means between the different markets in N'Djamena. The difference between means is significant if $p < 0.05$.

Table 1. Criteria for interpreting enumeration results

Appreciations	Criteria	TAMF	TC	FC	S. aureus	Y&M
Satisfactory	m	$\leq 3\times10^6$	$\leq 10^3$	$\leq 10^3$	$\leq 5\times10^2$	$\leq 10^2$
Acceptable	3m	$\leq 9\times10^6$	$\leq 3\times10^3$	$\leq 3\times10^3$	$\leq 15\times10^2$	$\leq 3\times10^2$
Unsatisfactory	M	$> 3\times10^7$	$> 10^4$	$> 10^4$	$> 5\times10^3$	$> 10^3$

(FAO/OMS, 2014; CE 2073/2005/CE, 2005)

Results

Enumeration of microbiological germs in dried meats

For samples from the Central Market, total flora ranged from $1.55x10^5$ to $5x10^6$ CFU/g, with an average of $1.91x10^6$ CFU/g, total coliforms ranged from $6.82x10^3$ to $5x10^4$ CFU/g, with an average of $4.05x10^4$ CFU/g, while thermotolerant coliforms ranged from 10^2 to $9.09x10^3$ CFU/g, with an average of $3.56x10^3$ CFU/g. Staphylococci ranged from $1.23x10^3$ to $3.41x10^4$ CFU/g, with an average of $1.76x10^4$ CFU/g, while yeasts and molds ranged from $1.15x10^3$ to $5.91x10^4$ CFU/g, with an average of $1.56x10^4$ CFU/g (Table 2).

In the Diguel market samples, total flora ranged from $1.18x10^5$ to $5.45x10^6$ CFU/g, with an average of $1.58x10^6$ CFU/g, total coliforms from $0.13x10^2$ to $1.82x10^4$ CFU/g, with an average of $6.88x10^3$ CFU/g, and thermotolerant coliforms from 10^2 to $4.55x10^3$ CFU/g, with an average of $1.67x10^3$ CFU/g. Staphylococci loads ranged from 10^2 to $6.09x10^4$

CFU/g, with an average of $3.22x10^4$ CFU/g, while yeasts and molds ranged from $1.31x10^3$ to $5.91x10^4$ CFU/g, with an average of $2.2x10^4$ CFU/g (Table 2).

In the millet market samples, total flora ranged from $7.59x10^5$ to $9.09x10^6$ CFU/g, with an average of $4.4x10^6$ CFU/g, total coliforms from $1.04x10^3$ to $3.05x10^4$ CFU/g, with an average of $1.48x10^4$ CFU/g, and thermotolerant coliforms from $2.91x10^2$ to $6.00x10^3$ CFU/g, with an average of $3.33x10^3$ CFU/g. Staphylococcus loads ranged from $1.14x10^3$ to $8.64x10^4$ CFU/g, with an average of $3.49x10^4$ CFU/g, while yeasts and molds ranged from $1.21x10^2$ to $1.13x10^4$ CFU/g, with an average of $2.57x10^3$ CFU/g (Table 2).

In samples from the AL-Afia market, total flora ranged from $4.50x10^5$ to $5.09x10^7$ CFU/g, with an average of $1.2x10^7$ CFU/g, total coliforms from $2.15x10^3$ to $3.75x10^5$ CFU/g, with an average of $6.78.10^3$ CFU/g, and thermotolerant coliforms from 10^2 to $2.09x10^3$ CFU/g, with an average of $1.41x10^3$ CFU/g. Staphylococcus loads ranged from 10^2 to $1.50x10^4$ CFU/g, with an average of $5.66x10^3$ CFU/g, while yeasts and molds ranged from $3.81x10^2$ to $5x10^4$ CFU/g, with an average of $1.74x10^4$ CFU/g (Table 2).

Table 2. Microorganisms counted in dried meat from different markets

Market	Sample	TAMF	TC	FC	Staph	Y&M
Central market	C1	$4.55x10^5$	$4.55x10^4$	$9.09x10^3$	$3.41x10^4$	$1.36x10^3$
	C2	$1.64x10^6$	$4.55x10^4$	$5.45x10^3$	$2.00x10^4$	$5.91x10^4$
	C3	$3.55x10^6$	$6.82x10^3$	$1.00x10^2$	$1.23x10^3$	$5.91x10^3$
	C4	$5.00x10^6$	$5.45x10^4$	$4.00x10^3$	$1.73x10^4$	$1.36x10^4$
	C5	$6.45x10^5$	$5.00x10^4$	$1.36x10^3$	$1.41x10^3$	$1.26x10^4$
	C6	$1.55x10^5$	$4.09x10^4$	$1.36x10^3$	$3.18x10^4$	$1.15x10^3$
	Mean	$1.91x10^6$	$4.05x10^4$	$3.56x10^3$	$1.76x10^4$	$1.56x10^4$
Diguel market	D1	$2.50x10^5$	$4.55x10^3$	$1.00x10^2$	$1.82x10^4$	$1.40x10^3$
	D2	$3.64x10^5$	$9.90x10^3$	$1.00x10^2$	$6.09x10^4$	$1.37x10^3$
	D3	$1.18x10^5$	$4.55x10^3$	$4.55x10^3$	$3.05x10^4$	$1.28x10^4$
	D4	$3.09x10^6$	$0.13x10^2$	$1.00x10^2$	$1.00x10^2$	$5.31x10^3$
	D5	$2.09x10^5$	$1.82x10^4$	$4.55x10^3$	$5.77x10^4$	$5.20x10^4$
	D6	$5.45x10^6$	$4.09x10^3$	$6.36x10^2$	$2.59x10^4$	$5.91x10^4$
	Mean	$1.58x10^6$	$6.88x10^3$	$1.67x10^3$	$3.22x10^4$	$2.2x10^4$
Millet market	M1	$2.05x10^6$	$1.73x10^4$	$9.09x10^2$	$8.64x10^4$	$1.73x10^3$
	M2	$2.41x10^6$	$1.77x10^4$	$6.00x10^3$	$4.23x10^4$	$1.13x10^4$
	M3	$9.09x10^6$	$3.05x10^4$	$4.86x10^3$	$2.73x10^4$	$1.21x10^2$
	M4	$1.09x10^6$	$1.09x10^4$	$3.68x10^3$	$5.09x10^4$	$2.00x10^2$
	M5	$7.59x10^5$	$1.04x10^3$	$2.91x10^2$	$1.14x10^3$	$1.01x10^3$
	M6	$7.68x10^6$	$1.16x10^4$	$4.23x10^3$	$1.55x10^3$	$1.08x10^3$
	Mean	$4.4x10^6$	$1.48x10^4$	$3.33x10^3$	$3.49x10^4$	$2.57x10^3$
AL-Afia market	A1	$5.09x10^6$	$3.37x10^4$	$2.09x10^3$	$1.50x10^4$	$0.91x10^4$
	A2	$5.09x10^6$	$2.15x10^3$	$1.00x10^2$	$1.14x10^4$	$5.00x10^4$
	A3	$5.09x10^7$	$3.73x10^5$	$2.09x10^3$	$1.36x10^3$	$5.32x10^2$
	A4	$5.09x10^6$	$3.14x10^5$	$2.09x10^3$	$5.91x10^3$	$4.16x10^4$
	A5	$5.09x10^6$	$3.75x10^5$	$2.00x10^3$	$1.82x10^2$	$3.81x10^2$
	A6	$4.50x10^5$	$3.73x10^3$	$1.00x10^2$	$1.00x10^2$	$2.68x10^3$
	Mean	$1.2x10^7$	$6.78x10^3$	$1.41x10^3$	$5.66x10^3$	$1.74x10^4$
Farcha market	F1	$4.09x10^6$	$4.09x10^4$	$0.01x10^2$	$1.45x10^3$	$1.00x10^3$
	F2	$1.55x10^6$	$0.04x10^2$	$1.00x10^2$	$4.55x10^3$	$1.25x10^3$
	F3	$5.18x10^7$	$0.06x10^2$	$1.00x10^2$	$1.50x10^4$	$1.18x10^4$
	F4	$5.27x10^5$	$0.1x10^3$	$1.00x10^2$	$2.10x10^2$	$1.00x10^3$
	F5	$5.45x10^5$	$0.09x10^2$	$1.00x10^2$	$1.36x10^4$	$1.15x10^3$
	F6	$1.05x10^6$	$0.10x10^3$	$1.00x10^2$	$1.00x10^2$	$0.58x10^2$
	Mean	$9.93x10^6$	$6.85x10^3$	$0.84x10^2$	$5.82x10^3$	$2.71x10^3$
p-value	-	0.406	0.406	0.406	0.406	0.406

TAMF: Total Aerobic Mesophilic Flora; TC: Total Coliforms; FC: Fecal Coliforms; Staph: Staphylococci; Y&M: Yeasts and Molds; C1, D1, … : Samples

In the Farcha market samples, total flora ranged from 5.27x10^{5} to 5.18x10^{7} CFU/g, with an average of 9.93x10^{6} CFU/g, total coliforms from 0.04x10^{2} to 4.09x10^{4} CFU/g, with an average of 6.85x10^{3} CFU/g, and thermotolerant coliforms from 0.01x10^{2} to 10^{2} CFU/g, with an average of 0.84x10^{2} CFU/g. As for staphylococci, loads ranged from 10^{2} to 1.50x10^{4} CFU/g with an average of 5.82x10^{3} CFU/g, while yeasts and molds were between 0.58x10^{2} and 1.18x10^{4} CFU/g with an average of 2.71x10^{3} CFU/g (Table 2). Statistical analysis revealed no significant difference between the averages obtained.

Microbiological quality assessment of dried meat

The results of the microbiological quality assessment showed that 56.67% of samples were fully satisfactory about total aerobic mesophilic flora, while 6.67% of samples were unsatisfactory (Fig. 1). Regarding staphylococci, the evaluation showed that only 16.67% of samples were fully satisfactory, while 60% of samples were unsatisfactory, with loads above the acceptable limit. The results also showed that 43.33% of samples were unsatisfactory about coliforms. However, no sample had a load above the acceptable limit for thermotolerant coliforms. As for yeasts and molds, the results showed that the majority of samples were above the acceptable limit, with 76.67% of samples unsatisfactory and only 3.33% satisfactory.

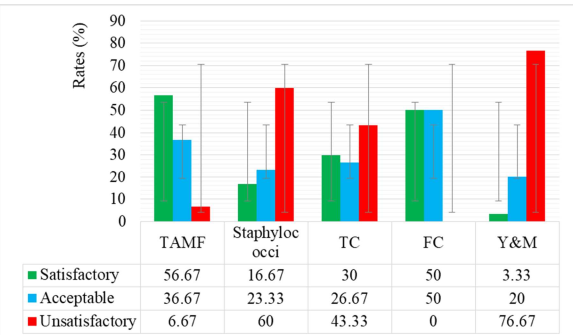

Fig. 1. Microbiological quality by hygiene indicator germs

TAMF: Total Aerobic Mesophilic Flora; TC: Total Coliforms; FC: Fecal Coliforms; Y&M: Yeasts and Molds

Discussion

The total aerobic mesophilic flora values obtained in the present study showed an overall low rate of contamination of the sampled carcasses by pathogenic microbes even though the total aerobic mesophilic flora was abundant. The total aerobic mesophilic flora obtained in this study were close to those reported by Denis *et al.* (2019) with loads that varied from 3.84x10^{6} to 4.10x10^{6} CFU/g as well as those of Ali (2019) with average loads that were 7.38x10^{5} CFU/g in Tchad (Denis, 2011; Ali, 2019). However, the overall values obtained were lower than those reported by Sa'adatu *et al.* (2019) on meat samples from Rabat abattoirs with an average load of 8x10^{9} CFU/g (Sa'adatu *et al.*, 2019). The total aerobic mesophilic flora is an indicator of the microbiological quality of the food, as it reflects the exposure of the sample to any contamination and in general the existence of favorable conditions for the growth of microorganisms (Briki and Mekhermeche, 2017; Temamri and Zadek, 2023). This flora is useful for indicating whether cleaning and disinfection during preparation have been sufficiently carried out. The total aerobic mesophilic flora obtained in the present study is a control indicating poor application of hygiene measures in artisanal meat drying.

Concerning total coliform loads, the averages obtained in this study were higher than those obtained by Tidjani *et al.* (2014) and Deni *et al.* (2019) in Kilishi with loads of 1.98x10^{5} CFU/g and 4.18x10^{6} CFU/g respectively showing thus a negative impact of artisanal drying (Tidjani *et al.*, 2014; Denis, 2011). As for thermotolerant coliforms, the loads obtained in this study were lower than those reported by Ali (2019) with loads ranging from 10^{2} CFU/g to 5.32x10^{5} CFU/g (Ali, 2019). The presence of thermotolerant coliforms in the proportions obtained in the present study could be explained by the unsanitary conditions in which meat is obtained in abattoirs and butcheries, poor slaughtering conditions and poor post-slaughter handling, as well as a lack of hygiene during artisanal drying and packaging (Goueu, 2006). These germs are indicators of fecal contamination of foodstuffs (Khelaifia, 2021; Rayene *et al.*, 2022).

The presence of *Staphylococcus aureus* in all dried meat samples could therefore also reflect post-drying insalubrity, particularly during packaging, distribution, transport and sale (Abdoullahi, 2014; Atchibri *et al.*, 2016; Alba *et al.*, 2023). Slaughtering operations tend to increase by 0.66 germs/g, transport by 5 germs/g and butchering by 5.66 germs/g (Agossa, 2010). Microbiological quality assessment has shown that *S. aureus* contamination levels are quite high and require particular attention, as their presence in food could be a source of nausea, vomiting, diarrhea and even more serious consequences in young children and vulnerable people (Tabet and Tesbia, 2017).

About yeasts and molds, the results showed high loads. These yeast and mold loads were, therefore, higher than the results reported by Abdoullahi *et al.* (2019) with an average load of $9.76x10^4$ CFU/g (Abdoullahi, 2019). The overall microbiological quality assessment also showed a high level of contamination, which could be explained by prolonged exposure to dust and wind. This presence also poses significant risks, as these germs can sometimes lead to food poisoning for consumers (Kouame-Sina, 2013; Koua *et al.*, 2022).

Conclusion

The enumeration results showed presence of total aerobic mesophilic flora, but these were mostly within acceptable limits. Coliform loads were also high. Staphylococci, yeasts and molds also showed high loads. Taken together, the results showed that artisanal drying has a highly negative impact on the microbiological quality of dried meat sold at N'Djamena markets. Awareness-raising measures on good hygiene practices are therefore necessary to control hazards for butchers and meat processors in Tchad.

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