**Physicochemical and Microbiological Characterization of Tamarind Pulp (Tamarindus Indica L) Sold in the Markets of Korhogo and Abidjan (Côte d'Ivoire)**


## Abstract

The tamarind tree is a wild species native to northern Côte d'Ivoire, where its fruits are highly valued. While the ecology and botany of this fruit species are well-documented, there is a scarcity of studies on its consumption and health impacts. This study was conducted to assess the nutritional, physicochemical, and microbiological quality of tamarind with the aim of enhancing its value, promoting its cultivation, and ensuring its sustainable management. A total of 400 tamarind samples were collected from markets in Korhogo and Abidjan to determine their physicochemical properties (pH, titratable acidity) as well as their protein, lipid, and fat content. Microbiological analyses were also performed on the collected samples.

The analysis revealed that the pH of all samples ranged between 2.8 ± 0.07 and 3.03 ± 0.02, with the lowest pH values observed in fresh tamarind samples. Titratable acidity values ranged from 2.8 ± 0.09% to 4.3 ± 0.06%. Microbiological analysis of the tamarind showed the absence of Salmonella, E. coli, Staphylococcus aureus, and total coliforms. The average aerobic mesophilic bacteria (AMB) count was $2.1\pm 0.6 \times 10^4$ CFU/g for fermented fruits from Korhogo and $2.4\pm 0.5 \times 10^4$ CFU/g for fermented fruits from Abidjan. The average lactic acid bacteria count was estimated at $5.6\pm 0.3 \times 10^3$ CFU/g for fermented fruits from Korhogo and $3.6\pm 0.4 \times 10^3$ CFU/g for fermented fruits from Abidjan. Yeast and mold counts were $6.3\pm 0.04 \times 10^1$ CFU/g for fermented fruits from Korhogo and $7.2\pm 0.03 \times 10^1$ CFU/g for fermented fruits from Abidjan.

Of the 100 fresh tamarind fruit samples collected in Korhogo, 90% had satisfactory microbiological quality, while 10% had acceptable microbiological quality. Fermented fruits from Abidjan had the highest percentage of unsatisfactory microbiological quality (24.5%). In total, 60.2% of the samples from Abidjan had satisfactory microbiological quality, and 15.3% had acceptable microbiological quality. In total, 4.6% of the fermented tamarind samples from Korhogo had unsatisfactory microbiological quality, which was linked to high AMB levels (≥3.105 CFU/g) in 75.74% of these samples, while 35.26% of the samples had unsatisfactory quality due to yeast and mold presence. For 40.7% of the fermented tamarind samples collected in Abidjan, unsatisfactory microbiological quality was due to high AMB levels (≥3.105 CFU/g), and in 60.3% of the samples, it was due to yeast and mold presence.

**Keywords:** ***Tamarind Fruit, Fermentation, Physicochemical Quality, Microbiological Quality.***

## 1-Introduction

In tropical countries, many wild fruits are consumed by rural populations. These fruits contribute to improving the nutritional quality of diets by providing essential micronutrients, but there is limited information available on these local fruits regarding their annual production and vegetative cycle. According to **Kambire *et al*. (2020)**, some of these fruits, although known to the population, have received less attention due to their organoleptic quality, dietary habits, and especially a lack of awareness of their nutritional and therapeutic value. Among these species is tamarind.

Tamarind is a fruit with multiple uses and is the subject of a thriving international trade (**Bourou *et al*., 2012; Garba *et al*., 2020**). In the West African sub-region, the collection and commercialization of this product constitute a significant source of income for local populations, especially women. Tamarind is widely traded between different countries and is available in all local markets (**Kambire *et al*., 2021**). According to **Samarou *et al*. (2022)**, although tamarind harvesting is a seasonal activity, the income generated contributes between 22% and 55% of total income for traders, helping to improve their living conditions. The socio-economic importance of tamarind justifies the studies dedicated to it **(Garba *et al*., 2019)**. Ethnobotanical studies have shown that all parts of the tamarind tree, from leaves to roots, are used by local populations **(Fandohan *et al*., 2010a; Garba, ARI *et al*., 2019; Samarou *et al*., 2021)**. In Africa, Tamarindus indica is among the most valued woody species for fruit production **(MERF/FAO, 2018)**. The fundamental reasons for its integration are numerous, but the main one is related to its fruits, which are used to make a tangy beverage, to season dishes, and to produce a highly valued fermented product.

Despite being considered underutilized by many experts, tamarind is increasingly attracting research attention. Indeed, recent scientific publications have focused on the properties of tamarind pulp. However, to our knowledge, few studies have been conducted on its microbiological and nutritional quality in Côte d'Ivoire, even though insights into these aspects of tamarind would be useful for its valorization. This work, therefore, aims to contribute to the valorization of tamarind fruit by acquiring scientific data on this product. The study's objective was to determine the nutritional characteristics and evaluate the microbiological quality of

tamarind sold in two cities in Côte d'Ivoire: Korhogo, a production and consumption area for tamarind, and Abidjan, primarily a consumption area for this product.

## 2.Materials and Methods

### 2.1 Plant Material

The plant material used in our study consisted of fresh and fermented tamarind collected from various markets in the cities of Abidjan and Korhogo.


**a-Fresh Tamarind Fruits** **b- Fermented Tamarind Fruits**

**Fig 1. Plant material used for the study**

**1: Tamarind Samples Collected for the Study**

### 2.2 Sampling

Les Tamarind samples (both fresh and fermented) were collected from 40 randomly selected producers in various markets in the cities of Korhogo (20 producers) and Abidjan (20 producers), with 10 samples per producer. In each city, 4 markets were chosen, and within each market, 5 vendors were selected. Each sample consisted of 100 to 200 grams of fresh or fermented tamarind from the same batch.

A total of 100 fresh tamarind samples were collected from producers in the village of Lataha (Korhogo), and 300 fermented tamarind samples were collected from vendors in the markets of Korhogo (150 samples) and Abidjan (150 samples). In total, 400 samples were collected.

The fermented samples originated from fresh tamarind fruits that were peeled, soaked in water, formed into balls, and left to ferment for 24 to 72 hours. The samples were collected under market conditions and placed in stomacher bags. All collected samples were stored in a cooler with dry ice and transported to the laboratory for various analyses. Samples were analyzed on the same day of collection. Samples from Korhogo were analyzed at the microbiology laboratory of Peleforo Gon Coulibaly University. Samples from Abidjan were sent to the Antibiotics, Natural Substances, and Microorganism Resistance Surveillance Unit (ASSURMI) at the Pasteur Institute of Côte d'Ivoire.

### 2.3 Preparation of Plant Material

In the laboratory, tamarind fruits were carefully sorted to remove any undesirable material. Using stainless steel knives, the fruit shells were removed. The pulp was then separated from the seeds using a stainless-steel spoon. The resulting pulp was used to prepare the different samples.

### 2.4 Physicochemical Analyses

A 10 g sample of pulp from each tamarind sample was taken to measure the pH. This quantity was then ground and diluted in 50 ml of distilled water, followed by centrifugation at 4000 rpm for ten minutes (AOAC Method, 1990). Five (05) ml of the supernatant was used for pH measurement. The pH was measured by directly immersing the electrode of the pH meter (pH/ORP Meter HI 2211) into the suspension. The pH value was recorded after stabilization on the device's screen. Three trials were conducted for each sample.

#### 2.4.1 Titratable Acidity Determination

The titratable acidity was determined using the method described by **Amoa-Awua *et al*. (2006)**. A 10 g sample of pulp from each tamarind sample was taken, then ground and diluted in 10 ml of distilled water, and finally centrifuged at 4000 rpm for ten minutes. The titration was performed using 5 ml of the supernatant from the mixture with a 0.1 N sodium hydroxide (NaOH) solution, after the addition of two to three drops of 1% phenolphthalein. The endpoint of the titration was indicated by a faint pink coloration, which was compared to a control consisting of the same sample.

#### 2.4.2 Dry Matter Content

The moisture content was determined by drying the sample at 105°C for 24 hours, by **AOAC (1990)** standards. The samples were then cooled in a desiccator and weighed. The weight loss, expressed as a percentage of the initial weight, was used to calculate the moisture content. This provides an estimate of the dry matter content of the tamarind pulp.

### 2.4.3 Ash Content

The ash content was determined according to **AOAC (1990)** standards. A 5 g sample of tamarind pulp was weighed and placed in a pre-dried and weighed porcelain crucible. The crucible and its contents were then heated in a furnace at 550°C for 6 hours. After cooling in a desiccator, the crucible and its contents were weighed again. The weight of the ash was expressed as a percentage of the initial weight of the sample.

## 2.5 Determination of Macronutrient Content

### 2.5.1 Protein Content

Protein content was determined using the Kjeldahl method **(AOAC, 1990)**. One gram of tamarind pulp sample was heated at 400°C for 150 minutes in the presence of a catalyst mixture (selenium + potassium sulfate, $K_2SO_4$) and 20 ml of 95-97% sulfuric acid ($H_2SO_4$). The resulting digest was made up to 60 ml with distilled water. To this volume, 50 ml of 40% sodium hydroxide (NaOH) was added, and the mixture was boiled in a distillation apparatus. The ammonia released was captured in a receiving flask containing 10 ml of an acid-base indicator mixture (4% p/v), using a mixed indicator (methyl red + bromocresol green) at pH 4.4 - 5.8. The titration was carried out using a standard sulfuric acid solution. The percentage of nitrogen was determined using the formula below:

Protein Content (%) = Nitrogen Content (%) ×6.25

This factor is used to convert the nitrogen content into protein content.

$$\mathbf{N\%} = \frac{\mathbf{V\ (H_2SO4)\ x\ N\ (H_2SO_4)\ x\ 14{,}007\ x\ 100}}{\mathbf{100\ x\ PE}} \quad (1)$$

With the following variables:

- V(H2SO4): Volume of sulfuric acid (in ml)

- N(H2SO4): Normality of sulfuric acid used (0.1 N)
- PE: Sample weight (in g)
- N%: Nitrogen content
- 14.007: Atomic mass of nitrogen

The protein content was determined using the following formula:

**Protein Content = Nitrogen Content × 6.25** **(2)**

6.25: Coefficient used to convert nitrogen content to protein content

### 2.5.2 Fat content

Total lipids were extracted according to the **AOAC 1990** method using a Soxhlet extractor. For each sample, 5 g of tamarind pulp were weighed and placed in a WATMAN cartridge. A volume of 200 ml of hexane was added to a previously weighed empty extraction flask. The flask containing hexane (M1) was placed on a heating mantle at 110°C for 8 hours. After the extraction period, the flask was removed from the Soxhlet extractor and placed in an oven at 130°C for 1 hour to ensure complete evaporation of the solvent. Once evaporation was complete, the flask was reweighed (M2). The total lipid content (LT) was determined using the following equation:

:

$$TL\ (\%) = \frac{(M1-M2) \times 100}{5g} \quad (3)$$

Avec where:

M1 is the mass of the flask containing hexane before extraction,

M2 is the mass of the flask after complete evaporation of the solvent,

### 2.5.3 Carbohydrate Content

The total carbohydrate content was determined by the difference method using the formula:

Total Carbohydrates (%)=100%−(Moisture Content (%)+Ash Content (%)+Fat Content (%)+ Protein Content (%)).

## 2.6. Determination of Microbiological Quality

### 2.6.1 Preparation of the Stock Suspension and Decimal Dilutions

For each sample, 10 grams of tamarind pulp were transferred using a sterile spoon into a sterile Stomacher bag, handled near the flame of a Bunsen burner to maintain sterility. A volume of 90 ml of sterile buffered peptone water was added aseptically to the bag. The resulting mixture was manually homogenized to produce a 1/10 dilution of the stock suspension.

A 1 ml aliquot of this stock suspension was then transferred into the first test tube, and the mixture was homogenized to create the $10^{-2}$ dilution. Using the same procedure, subsequent dilutions were prepared sequentially until achieving a $10^{-8}$ dilution. All dilution steps were performed aseptically to prevent contamination.

### 2.6.2 Microbiological Analyses.

The collected samples were assessed for microbiological quality parameters using standard methods. The total mesophilic aerobic flora was enumerated by plating on Plate Count Agar (PCA) and incubating at 30°C for 24-48 hours (NF V08-051). Total coliforms and thermotolerant coliforms were detected using Violet Red Bile Lactose (VRBL) agar, with incubation at 30°C and 44°C, respectively, for 24 hours (NF V08-050).
For the detection of Escherichia coli, Eosin Methylene Blue (EMB) agar was used. A 0.1 ml aliquot of the decimal dilution suspension was spread on the surface of the pre-poured and cooled EMB agar plates. The plates were then incubated at 37°C for 24 hours. Colonies presumptively identified as E. coli on plates with 1 to 150 colonies were counted **(NF ISO 7251)**.

Staphylococcus aureus was detected using Baird Parker agar supplemented with egg yolk, with incubation at 37°C for 24-48 hours **(NF EN ISO 6888-1/A1)**. Yeasts and molds were enumerated on Sabouraud Chloramphenicol agar, incubated at 25°C for 3 to 5 days **(NF V08-059)**. Anaerobic Sulfite-Reducing Bacteria were detected using Tryptone Sulfite Neomycin (TSN) agar, with incubation at 46°C for 20 hours **(NF ISO 15213)**. Lactic acid bacteria were enumerated on Man Rogosa Sharpe (MRS) agar according to the standard (AFNOR NF V08-052).

Finally, Salmonella detection involved pre-enrichment of the stock solution at 37°C for 19 hours. Enrichment was performed on Rappaport Vassiliadis (RV) and Müller-Kauffmann (KM) media, with isolation on Xylose-Lysine-Deoxycholate (XLD) and Hektoen agars **(ISO 6579).**

### 2.7 Statistical Analyses

Statistical analyses of the results were performed using STATISTICA 7.1 software. The normality of the data was assessed using the Shapiro-Wilk test. Subsequently, homogeneity of variances was tested using Levene's test. When variances were equal, one-way analysis of variance (ANOVA) was conducted, followed by Duncan's multiple range test. If variances were not equal, the Kruskal-Wallis test was applied, followed by the Mann-Whitney test. Statistical differences with a probability value less than 0.05 ($p < 0.05$) were considered significant.

## 3. Results

### 3.1 Caractéristiques physico-chimiques du tamarin

The results for pH, titratable acidity, and ash content of the different fresh and fermented tamarind samples are presented in Table 1. Analysis of these results reveals that the pH of all samples ranges from 2.8 ± 0.07 (fresh tamarind from Korhogo) to 3.03 ± 0.02 (fermented tamarind from Abidjan), with the lowest pH values found in the fresh tamarind samples. The titratable acidity values for the tamarind samples range between 2.8 ± 0.09% and 4.3 ± 0.06%. According to these results, fresh tamarind samples exhibit the highest acidity, with a titratable acidity of 4.5 ± 0.03%. The titratable acidity for fermented tamarind samples from Korhogo and Abidjan is 4.3 ± 0.06% and 2.8 ± 0.09%, respectively.

**Table 1: Physicochemical Characteristics of Tamarind Fruit**

| | Samples | | |
|---|---|---|---|
| | **Fresh Korhogo samples** | **Fermented Korhogo samples** | **Fermented Abidjan samples** |
| **pH %** | **2,8 ± 0.07 a** | **2,96 ± 0,03b** | **3,03 ±0.02d** |
| **Titratableacidity %** | **4,5 ± 0.03b** | **4,3 ± 0.06 d** | **2,8 ± 0.09c** |

*Note: Values are means ± standard deviations of three measurements (n = 3). Identical letters within a row indicate no significant difference at the 5% level between samples for the given parameter (Duncan's test).*

### 3.2 Macronutrient Content

The protein, lipid, and carbohydrate contents of tamarind fruit are presented in Table 2. The lipid content of fresh tamarind was 0.7 ± 0.03%, while fermented tamarind from Korhogo and Abidjan had lipid contents of 0.65 ± 0.1% and 0.63 ± 0.15%, respectively. Fresh fruits had the highest protein (2.70 ± 0.03%) and carbohydrate (70.6 ± 0.02%) contents. For fermented fruits from Korhogo, the carbohydrate and protein contents were 64.2 ± 0.02% and 2.60 ± 0.03%, respectively. The fermented fruits from Abidjan exhibited the lowest carbohydrate and protein levels, with 63.7 ± 0.1% carbohydrate and 2.57 ± 0.02% protein.



**Table 2: Nutritional Characteristics of Tamarind Fruit**

| | Fresh Korhogo Smaples | Fermented Korhogo Samples | Fermented Abidjan Samples |
|---|---|---|---|
| **Lipids (%)** | **0,7 ±0,03** | **0,65±0,1** | **0,63± 0.15** |
| **Proteins (%)** | **2,70 ±0,03** | **2,60±0,03** | **2,57 ± 0,02** |
| **Carbohydrates ( %)** | **70,6 ± 0,02** | **64,2 ± 0,02** | **63,7± 0,1** |

*Values are the means ± standard deviations of three measurements (n = 3). The same letter on the same row indicates that there is no significant difference between samples for the parameter in question at the 5% significance level (Duncan's test).*

### 3.3. Microbiological Parameters of Different Tamarind Samples

The results of the analysis for total flora, fungal flora, lactic acid bacteria, total coliforms, thermotolerant coliforms, sulfite-reducing anaerobes, staphylococci, and salmonella in the collected tamarind samples are summarized in Table 3. No presence of Salmonella, E. coli, Staphylococcus aureus, or coliforms was detected in any of the tamarind samples. Additionally, the average count of mesophilic aerobic bacteria (MAB) was 2.1± 0.6 x $10^4$ CFU/g for fermented fruits from Korhogo and 2.4± 0.5 x $10^4$ CFU/g for fermented fruits from Abidjan. The average microbial load of lactic acid bacteria was estimated at 5.6± 0.3 x $10^3$ CFU/g for fermented fruits from Korhogo and 3.6± 0.4 x $10^3$ CFU/g for fermented fruits from Abidjan. As for yeast and mold counts, they were 6.3± 0.04 x $10^1$ CFU/g for fermented fruits from Korhogo and 7.2± 0.03 x $10^1$ CFU/g for fermented fruits from Abidjan. Fresh fruits showed no microbial flora.



**Table 3 : Microbiological Characteristics of Tamarind**

| Microbial Load of Tamarind Pulp (CFU/g) | | | | |
|---|---|---|---|---|
| **Microorganisms** | **Fresh Samples Korhogo** | **Fermented Samples Korhogo** | **Fermented Samples Abidjan** | **Microbiological Criteria** |
| **Mesophilic Aerobic Bacteria (MAB)** | **-** | **2,1± 0,6 .$10^4$** | **2,4± 0,5 1.$0^4$** | **≤ 3.$10^5$** |
| **Lactic Acid Bacteria** | **-** | **5,6± 0,3 .$10^3$** | **3.57± 0.4.$10^3$** | |

| | | | | |
|---|---|---|---|---|
| **Yeasts/Molds** | **-** | **6,3±0,0410[1]** | **7,2± 0,03.10[1]** | **< $10^2$** |
| ***E.coli*** | **-** | **-** | **-** | |
| ***S.aureus*** | **-** | **-** | **-** | **≤ $10^2$** |
| ***Salmonella*** | **-** | **-** | **-** | **Absent in 25 g** |
| **Total Coliforms** | | | | **≤ $10^3$** |
| **Thermotolerant Coliforms (TC)** | **-** | **-** | **-** | **≤ 10** |
| **Sulfite-Reducing Anaerobes (SRA)** | **-** | **-** | **-** | **± ≤ 30** |

MAB: Mesophilic Aerobic Bacteria

TC: Total Coliforms

TTC: Thermotolerant Coliforms

SRA: Sulfite-Reducing Anaerobes

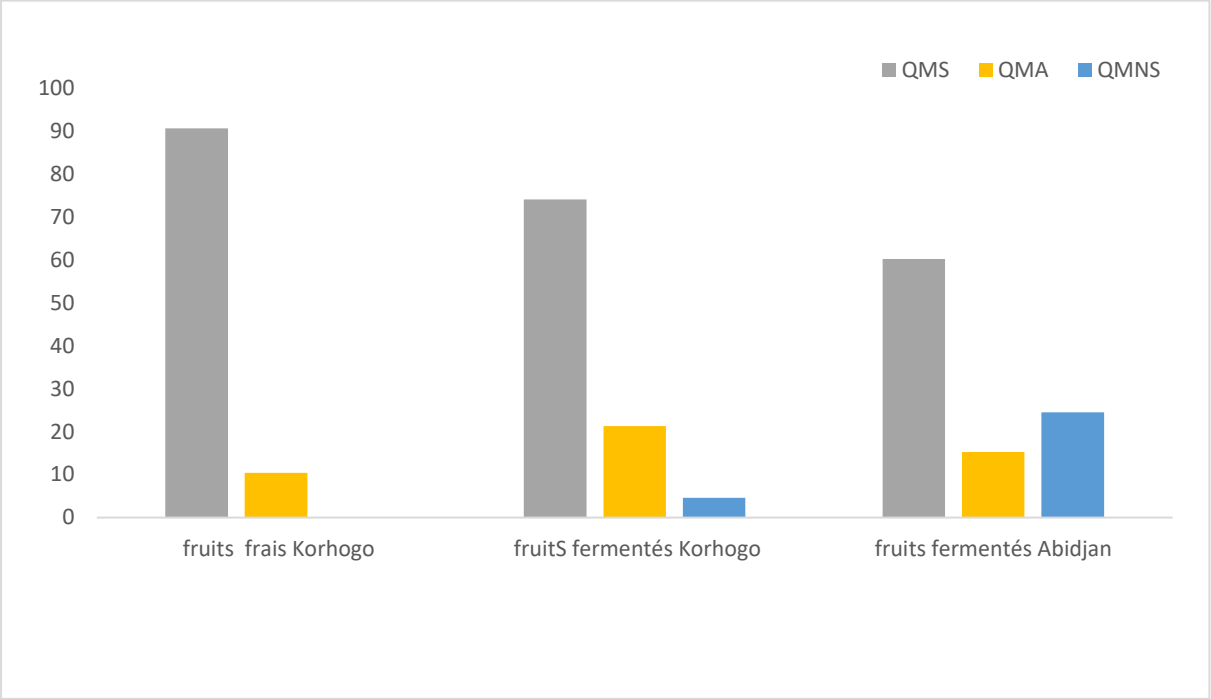
-: Absence



### 3.4 Microbiological Quality of Tamarind Samples

Based on the microorganisms found and/or counted in the tamarind samples, their microbiological quality was assessed. The percentages of samples classified as having satisfactory microbiological quality (SMQ), acceptable microbiological quality (AMQ), and unsatisfactory microbiological quality (UMQ) are shown in Figure 2. Among the 100 fresh tamarind samples collected in Korhogo, 90% had satisfactory microbiological quality, while 10% had acceptable microbiological quality. Of the 150 fermented tamarind samples collected in Korhogo, 74.1% had satisfactory microbiological quality, 21.3% had acceptable microbiological quality, and 4.6% had unsatisfactory microbiological quality. Fermented fruits from Abidjan had the highest percentage of unsatisfactory microbiological quality (24.5%).

Overall, 60.2% of the samples from Abidjan had satisfactory microbiological quality, and 15.3% had acceptable microbiological quality.




SMQ: Satisfactory Microbiological Quality

AMQ: Acceptable Microbiological Quality

UMQ: Unsatisfactory Microbiological Quality

**Figure 2: Microbiological Quality of Different Tamarind Samples Collected**

### 3.5 Microorganisms Responsible for Unsatisfactory Microbiological Quality of Analyzed Samples

The various microbial flora responsible for unsatisfactory microbiological quality were identified for each type of sample, and the results of this analysis are detailed in Figure 3. In total, 4.6% of the fermented tamarind samples collected in Korhogo had unsatisfactory microbiological quality, with 75.74% of these cases attributed to high mesophilic aerobic bacteria (MAB) counts (≥3 x $10^5$ CFU/g) and 35.26% due to yeasts and molds. For 40.7% of the fermented tamarind samples collected in Abidjan, unsatisfactory microbiological quality was due to MAB (≥3 x $10^5$ CFU/g), while 60.3% was attributed to yeasts and molds.

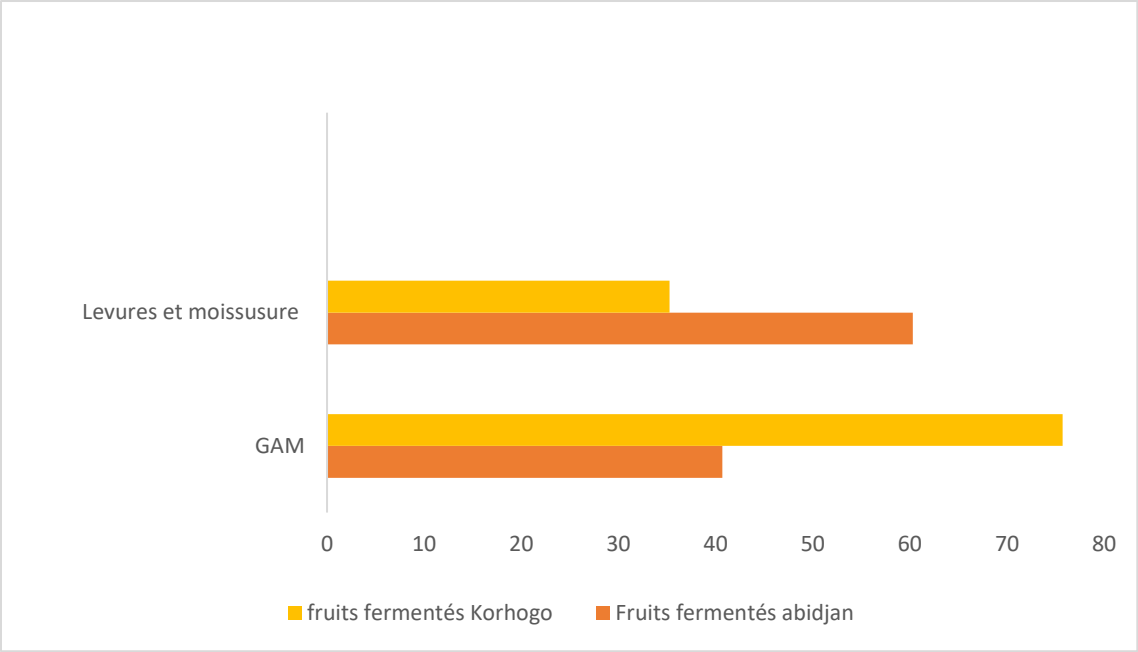



**Figure 3: Percentage of Tamarind Samples with Unsatisfactory Microbiological Quality Based on Responsible Microorganisms**



## 4. Discussion

This study aimed to evaluate the nutritional, physicochemical, and microbiological quality of tamarind. Tamarind pulp was characterized by very high acidity, with titratable acidity values ranging from 2.8 ± 0.09% to 4.3 ± 0.06%. These values correspond to low pH levels (3.03 ± 0.028 and 3.03 ± 0.028). According to **Akpo (2022)**, low food pH is associated with high titratable acidity. These results are not surprising, as it has been noted that tamarind pulp's

acidity does not diminish with maturation, indicating that the high tartaric acid content (98% of organic acids) in tamarind pulp is not utilized during fruit development **(Grollier *et al*., 1998).** Meanwhile, the amount of reducing sugars increases, giving the fruit a sweeter taste. Hence, tamarind is known as both one of the most acidic and sweet fruits **(Grollier *et al*., 1998)**. In this study, the pH of tamarind samples ranged from 2.66 ± 0.05 (fresh fruits from Korhogo) to 3.03 ± 0.028 (fermented fruits from Abidjan). The low pH values obtained indicate that Tamarindus indica pulp is acidic and capable of resisting microbial activity, particularly that of pathogenic microorganisms. This suggests that the fruit could be stored for extended periods. Indeed, studies by **Gbago Onivigui *et al*. (2014)** have indicated that a pH between 2.5 and 5.5 prevents microbial growth and implies long-term preservation of fresh fruits. The pH recorded for tamarind pulp aligns with these values, suggesting that no additional acidifying agents would be needed during tamarind processing to prevent the growth of pathogenic or spoilage microorganisms.

One objective of this study was to evaluate some nutrients in tamarind. The results revealed various nutrients at different levels. The protein content of the evaluated fruits ranged from 2.70 ± 0.03% to 2.57 ± 0.02%. These relatively low levels might be due to protein degradation during fruit maturation **(Goswami & Borthakur, 1996)**. Most fruits typically contain less protein than tamarind pulp. Common fruits like papaya (0.5%) and passion fruit (2.6%) **(Rodrigues et al., 2001; Besco et al., 2007)** have lower protein levels than tamarind. Due to its low protein content, tamarind is not an excellent protein source. However, the proteins in tamarind can contribute effectively to dietary needs. The lipid content in tamarind pulp ranged from 0.7 ± 0.03% to 0.63 ± 0.15%, reflecting its low fat content.

Microbiological analyses showed that tamarind pulp contains yeasts, molds, and mesophilic aerobic bacteria. Their presence in the pulp may be attributed to environmental conditions during food production or fruit maturity, as ripe fruits promote the growth of yeasts and molds and also undergo fermentation. Lactobacilli and yeasts and molds were identified as the main microorganisms involved in fermentation. Lactic acid bacteria are generally present in low numbers and mainly belong to the genera Lactobacillus, Leuconostoc, Pediococcus, and Streptococcus **(Beuchat, 1995)**. Nevertheless, these microorganisms are within acceptable limits according to international standards.

The majority of the samples had acceptable microbiological quality. The absence of spoilage microorganisms could be explained by the tamarind fermentation process. Fermentation is a

food preservation method where lactic acid bacteria produce several natural antimicrobial compounds, such as organic acids (lactic, acetic, formic, phenylacetic, caproic), carbon dioxide, hydrogen peroxide, diacetyl, ethanol, and bacteriocins **(Messens & De Vuyst, 2002)**. Organic acid production during fermentation leads to a significant pH reduction, which, combined with antimicrobial compound formation, determines microbial stability and inhibits the growth of pathogenic bacteria and other microorganisms. Additionally, the acidic environment created by lactic acid bacteria favors yeast growth. Thus, the alcohol produced by yeast, the acids produced by bacteria, and the anaerobic conditions induced by fermentation help suppress filamentous fungi and bacteria associated with food spoilage **(Mensah et al., 1991).**

## CONCLUSION

The objective of this study was to characterize the microbiological and physicochemical qualities of tamarind sold in the markets of Korhogo and Abidjan. Tamarind has a low pH, indicating its acidity. Its macronutrient content reveals low levels of carbohydrates, proteins, and lipids. The study results show that the majority of tamarind samples had satisfactory microbiological quality. A small percentage of samples had unsatisfactory microbiological quality, with mesophilic aerobic bacteria and yeasts and molds being responsible for these unsatisfactory results.



## REFERENCES

**1.A.O.A.C. (1990)**. Official methods of analysis, vol 2, 15th ed. Association Official Analytical Chemists, Edition Washington, D.C. 684 p.

**2.AFNOR NF V08-052**

3. Akpo A. F. (2022). Implementation of a method for preserving tomatoes (Solanum lycopersicum) by applying cold and plant extracts with anti-ripening and antifungal effects. Joint thesis in Agronomic Sciences, Chemistry and Food Science and Technology,

specializing in Biochemistry and Food Technology. University of Avignon and Nangui Abrogoua University. 168p.

4. Amoa-Awua WK, Terlabie NN and Sakyi-Dawson E (2006). Screening of 42 Bacillus isolates for ability to ferment soybeans into dawadawa. International Journal of Food Microbiology, 106(3): 343- 347. doi: http://dx.doi.org/10.1016/j.ijfoodmicro.2005.08.016

5. Besco E. Bracioli E., Vertuani S. Ziosi P., Brazzo F., Bruni R., Sacchetti G. & Manfredini S. (2007). The use of photochemiliminescence for the measurement of the integral antioxidant capacity of baobab products. Food Chemistry, 102:1352-1356.

6. Beuchat L.R. Indigenous fermented foods. In: Rehm H.-J., Reed G., Puhler A., Stadler P. (Eds), Biotechnology. Verlag Chemie: Weinheim, 1995, 505-559.

7. Bourou S., 2012. Eco-physiological study of the tamarind tree (Tamarindus indica L.) in an arid tropical environment. Ghent University, 164 p.

8. Eleazu C.O., Okafor P.N., Amajor J.A.F., Ikpeama A. I. & Eleazu K.C. (2011). Chemical composition, antioxidant activity, functional properties and inhibitory action of unripe plantain (M. Paradisiacae) flour. African Journal of Biotechnology, 10: 16948-16952.

9. Fandohan A, Assogbadjo A, Glèlèlè R, Sinsin B & Van Damme P (2010). Impact of habitat type on the conservation status of tamarind (Tamarindus indica L.) populations in the National Park of Benin. Fruits 65:11–19.

10. Garba A. R. I., Adakal H., Abasse T., Koudouvo K., Karim S., Akourki A., Gbeassor M., Mahamane S., 2019. Ethnobotanical studies of plants used in the treatment of digestive parasitoses of small ruminants (sheep) in the South-West of Niger. IJBCS, 13(3): 1534-1546.

11. Garba A., Amani A., Douma S., Sina A. K. S., Mahamane A., 2020. Structure of Tamarindus indica L. populations in the South-West zone of Niger. IJBCS, 14(1): 126-142.

12. Garba A., Amani A., Laouali A., Mahamane A., 2019. Socioeconomic perceptions and uses of tamarind (Tamarindus indica L.) in Southwestern Niger: Implications for sustainable domestication and conservation. J. Anim. Plant Sci., 40: 6584-6602.

13. Gbago O., Zhang H., Erasto M., Diaby M. and Song Y. (2014). Chemical Composition, Nutritional Properties and Antioxidant Activity of Monkey Apple (Anisophyllea laurina R. Br. Ex Sabine). Journal of Food and Nutrition Research, 2(6): 281-287.

14. Goswami, B. and Borthakur, A 1996. Chemical and biochemical aspects of the development of culinary banana (Musa ABB) 'Kachkal'. Food Chemistry , 55 (2), 169-172.

15. Grollier C., Debien C., Domier M. & Reynes M. (1998). Main characteristics and valorization pathways of tamarind, Fruits, 53(4): 271-280.

16. Kambire O. , Boli ZIA , Yao KM , Ahipo DMP , and Koffi-Nevry R. ( 2020 ) , Microbiological quality of “Soumbala”, a carob (Parkia biglobosa) condiment sold in the markets of Abidjan, Côte d’Ivoire , Journal of Advances in Microbiology . 20 , no. 10, 67 – 74 .

17. Mensah P., Tomkins A.M., Drasar B.S., Harrison T.J. Antimicrobial effect of fermented Ghanaian maize dough. J. Appl. Bacteriol., 1991, 70, 203-210.

18. MERF/FAO. (2018). Non-timber forest products of Togo: inventory of potential, management and valorization. Final report, Project TCP/TOG/3604, Lomé, Togo, p. 97.

19. Messens W., De Vuyst L 2002. Inhibitory substances produced by Lactobacilli isolated from sourdoughs-a review. Int. J. Food Microbiol., 72, 31-43.

20. NF EN ISO 6579. 2002. Microbiology of food – Horizontal method for the detection of Salmonella spp. (Classification index: V08-013).

21. NF EN ISO 6888-1/A1, 2004, “Microbiology of food and feed - Horizontal method for the enumeration of coagulase-positive staphylococci (Staphylococcus aureus and other species)” - Part 1: technique using Baird-Parker agar medium - Amendment 1: inclusion of precision data,.

22. NF ISO 15213. 2003. Microbiology of food and feed - Horizontal method for the enumeration of sulfite-reducing bacteria growing under anaerobic conditions (Classification index: V08-029).

23. NF ISO 7251 (July 2005) Microbiology of food and feed - Horizontal method for the G. R. DEGNON et al. / Int. J. Biol. Chem. Sci. 12(3): 1528-1541, 2018 1541 enumeration of suspected Escherichia coli – Most probable number technique (Classification index: V08-020).

24. NF V08-050,1999, “Food microbiology. Coliform counts by counting the colonies obtained at 30ºC”, Routine method, 1999. NF V08-051, “Food Microbiology. Enumeration of Microorganisms by Counting the Colonies Obtained at 30ºC”, Routine method.

25. NF V08-051, 1999, “Food Microbiology. Enumeration of Microorganisms by Counting the Colonies Obtaine d at 30ºC”, Routine method.

26. Rodrigues R.B., De Menezes H.C., Cabral L.M.C., Dornier M. & Reynes M. (2001). An amazonian fruit with a high potential as natural source of vitamin C: the camu-canu (Myrciaria dubia). Fruits, 56: 345-354.

27. Samarou M, Atakpama W, Kanda M, et al. Tamarindus Indica L. (Fabaceae) in ecological zone I of Togo: use value and vulnerability. Int J Complement Alt Med. 2021;14(6):307–315. DOI: 10.15406/ijcam.2021.14.00577

28. Samarou M., Atakpama W., Atato A., Pessinaba Mamoudou M., Batawila K., Akapagana K., 2022. Socio-economic value of tamarind (Tamarindus indica) in ecological zone I of Togo. RMSAV, 10(2): 272-281.