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RESEARCH ARTICLE

EVALUATION OF THE HEALTH QUALITY OF PLANTAIN BANANA CHIPS SOLD IN COCODY (ABIDJAN, COTE D'IVOIRE): CASE OF COLIFORMS AND AEROBIC MESOPHILIC GERMS

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Abstract

In Abidjan, the economic capital of Côte d'Ivoire, chips of plantain banana are widely consumed foods. They are generally products of satisfactory quality regarding their cooking temperature in oil (200°C). However, the lack of hygiene during their packaging and display on roadsides can lead to a risk of bacterial contamination that may cause food poisoning. For contributing to the microbiological quality of these chips and guarantying the health of consumers, a search for faecal germs of contamination was carried out on these foods. The study was performed on 30 samples of plantain chips, including 15 ripe and 15 unripe, from 15 sellers randomly chosen in theCocody area. Microbiological standards were used to count the total flora, total coliforms, faecal coliforms and *Escherichia coli* likely to be present in these samples. The pH, moisture content and dry matter content also were measured. The experimentsrevealeda very satisfactory microbiological quality for all the samples of chips except 2 samples of unripe chips related to their very high load of faecal coliforms. The high dry matter rate (97.47 – 97.4%), slight acid pH (5.94 – 5.63) and low acidity rate (0.47 – 0.50 mEq/100g) of these samples facilitated contamination by faecal coliforms following a lack of hygiene of the saleswoman and her working environment. These results encourage the consumption of ripe chips as well as compliance with hygiene measures for reducing the exposure risk to food poisoning.

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Introduction:-

The plantain is a tropical plant native from Southeastern Asia, belonging to the *Musaceae* family. In Côte d'Ivoire, with an estimate annual production of 2.2 million tons, plantain is the third (3rd) food crop after yam and cassava (Anonymous 1, 2015). Plantain makes an essential contribution to food security, job creation, income diversification in rural and urban areas, gross domestic product (GDP) and poverty alleviation (Nyombi, 2020). Thiscrop is

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consumed worldwide, especially in tropical countries. In Côte d'Ivoire, the plantain iswidelyconsumed(FAO, 2018) with an annual proportion of 120 kg per inhabitant (Anonymous 1, 2015). Highly energetic, the plantain is rich in carbohydrates, vitamins, potassium, magnesium and several other nutrients (Oyeyinka, B.O. and Afolayan, 2019). In Côte d'Ivoire, there are various culinary preparations based on plantain:Apkéssi (porridge), foutou (mashed), braised banana, Alloko (frying), nibbling products such as chips (Vitrac and Raoult-Wack, 2002). The most common plantain banana processing product on Côte d'Ivoire'smarkets remains chips (Lassoudière, 2007). Plantain chips are prepared from small pieces of unripe or slightly ripe plantain banana, cut usually in a round shape, 2-4 mm thick and soaked in refined palm oil between 160-170 °C for 2-3 minutes (or more depending on thickness) until they take on a golden color (Anonymous 2, 2015).

Banana chips have several advantages: an easy and inexpensive technology, a product of satisfactory quality due to the cooking temperature in oil (200°C) and a booming market (Tchango et al., 2009). These chips are increasingly consumed in large cities of Côte d'Ivoire, especially in Abidjan through points of sale (supermarkets, bus stations, shops, road tolls, etc.). The chips,produced on an artisanal scale and sold mainly on the streets of Abidjan, particularly in the municipality of Cocody, do not require specific materials. Generally, to storing and selling these chips, plastic bags used are not always of good quality. For bagging, the manufacturer often uses her hands without disposable gloves. In addition, the places of sale are on roadsides where packaged chips are exposed outdoors. As a result, these chips may be at risk of contamination by undesirable microorganisms, some of which can cause Food Toxi-infection.

Numerous scientific studies have been carried out on various aspects of plantain banana (Koffi, 2007, Bomisso et al., 2018; Kwa et Temple, 2019). However, few studies focused on the sanitary quality of plantain chips and their impact on consumer's health. Therefore, total flora and faecal contamination germs such as total and faecal coliforms (*Escherichia coli*) were investigated in plantain banana chips sold in the municipality of Cocody (Abidjan) for identifying a possible health risk for consumers.

This aims of this study was to contribute to a better application of good hygiene practices by street sellers of plantain.

Methodology:-

Material:-

Biological material

The study focused on 30 samples of plantain chips purchased from 15 sellers or producer-sellers in 15 different sites along public roads, distributed in the municipality of Cocody. Of these 30 samples, 15 were prepared from unripe banana and the other 15 from ripe banana (Fig 1).

Analysis methods

Sampling

Cocody is located in the north of Abidjan, with 447,055 inhabitants (Anonymous 3, 2014). A preliminary survey carried out in this area, revealed that the production, sale and supply of ripe or unripe plantain banana chips were very important and lucrative activities due to a great demand and consumption of these appetizers by local populations.

Among about 60 listed sites, 15 production or sale points were randomly selected for this study.Oneach site, a seller or producer alsowas randomly chosen from three to five sellers.

The sampling of the banana chips was carried out on the same day among the 15 sellers or producer-sellers. From each seller, five packets of crisps of approximately 500 g each were randomly purchased according to the stage of ripening (ripe and unripe banana). Each small bag of chips (Fig1) is sold 100 FCFA or 200 FCFA on the shelf. A total of10 packets of chips (5 ripe and 5 unripe) were collected from each vendor and were packaged in numbered blue plastic bags considering the number assigned to the sampling site (Table I).

The samples of ripe banana chips were named A and preceded by the vendor's number relative the number of sampling site. For unripe banana chips, the letter B was assigned. All samples were transported directly to the laboratory.

Before carrying out the physicochemical and microbiological analysis, the five packets (500 g) of each stage of ripeness per salesperson were mixed under aseptic conditions around a Bunsen burner and in a sterile container.

Then 10 g of ripe banana chips per vendor were sampled and used for microbiological analysis and 40 g for physicochemical analysis. The same process was applied to the 15 samples of unripe banana chips. In total, 30 samples (500 g) were investigated for physicochemical and microbiological data.

Physicochemical analysis
All the tests relating to the physicochemical parameters were carried out in triplicate.

Measure of pH
The pH was measured using a pH meter (AOAC 981.12, 2000). A mass of 10 g of crushed chips was homogenized in 100 ml of distilled water and filtrated on filter paper (Whatman). The glass electrode of the pH meter (Hanna) previously calibrated with a buffer at pH 7, then pH 4, was soaked in the filtrate under stirring. The pH value was read directly on the display of the pH meter (AOAC 981.12, 2000).

Determination of total titratable acidity
The acidity level was determined by the method described in the AOAC 920.87 standard (1990). It consisted in measuring the total titratable acidity of a product with a standard solution of sodium hydroxide (NAOH) 0.1 N, according to the principle that a base equivalent neutralizes an acid equivalent in the presence of a colored indicator.

Fig 1:- Photographs of the environment of sellers or producers of ripe and unripe chips(Cl. Assanvo J.B., 2022).

Table I:- Sample size for collection of 30 samples of ripe (A) and unripe (B) banana chips.

Township	Location and number of sample collection site	Number assigned to the seller or producer	Number of samples of chips (500 g) per seller and per ripeness state of the banana	Total samples per salesperson
Cocody	Mermoz campus (1)	1	1 BM (A1) 1 BNM (B1)	2
	CPPE Cocody Sud (2)	2	1 BM (A2) 1 BNM (B2)	2
	Saint Jean Church (3)	3	1 BM (A3) 1 BNM (B3)	2
	Crossroads Citelcom (4)	4	1 BM (A4) 1 BNM (B4)	2
	Crossroads The life (5)	5	1 BM (A5) 1 BNM (B5)	2
	Crossroads University FHB entry- police academy (6)	6	1 BM (A6) 1 BNM (B6)	2
	Crossroads Riviera 2-University campus (7)	7	1 BM (A7) 1 BNM (B7)	2
	Crossroads Cocody Riviera 3-Bingerville road (8)	8	1 BM (A8) 1 BNM (B8)	2
	Crossroads BURIDA (9)	9	1 BM (A9) 1 BNM (B9)	2
	Crossroads Duncan-Cocody (10)	10	1 BM (A10) 1 BNM (B10)	2
	Carrefour Echangeur Vallon (11)	11	1 BM (A11) 1 BNM (B11)	2
	Crossroads GuardingVallon (12)	12	1 BM (A12) 1 BNM (B12)	2
	Cocody market Allocodrome (13)	13	1 BM (A13) 1 BNM (B13)	2
	Pharmacy area Las Palmas –	14	1 BM (A14)	2

	Adjin Mosque (14)		1 BNM (B14)	
	Crossroads INSAAC (15)	15	1 BM (A15)	2
			1 BNM (B15)	
Total	15 sampling sites	15 saleswomen	30 (15 A et 15 B)	30 for the 15 saleswomen

BM = Ripe banana (Sample A), BNM= Unripe banana (Sample B)

A mass of sample (10 g) was dissolved in 100 mL of distilled water, in an Erlenmeyer flask. The solution obtained was filtered through filter paper (Whatman No. 4). Then, 10 mL of the filtrate were titrated with a sodium hydroxide solution (0.1 N) in the presence of an indicator until pink color.

The titratable acidity (mEq/100 g) of crushed chip samples was calculated as follows:

$$T.Acidity_{(meq/\,100\,g)} = \frac{N \times V_1 \times 10^4}{m \times V_0}$$

V_0: Volume (mL) of the test portion;
V_1: Volume (mL) of NaOH (0.1 N) poured at equivalence;
m: Mass (g) of the plantain chips sample
N: Normality of NaOH solution

Determination of dry matter content and moisture content
The water content was determined according to the method of the AOAC Method 925.10 standard (2005). Samples were dried in an oven at 105 °C for 4 h, until obtaining a constant weight. The dry matter content was deducted from the water content.

Microbiological analysis
The isolation and counting of germs from plantain banana chips were preceded by main steps as:

Preparation of samples, stock suspension (ISO standard 6887-1: 2017) and decimal dilutions (ISO standard 6887-1: 2017)
A volume of 90 mL of buffered peptone water was added to 10 g of plantain banana chips in a sterile "Stomacher" bag. The bag was tightly closed and put in a stomacher for 30 to 60 seconds to grind and homogenize the chips. After this step, the stock solution (10^{-1}) obtained was diluted with Tryptone salt as diluent.

For this study, the stock suspension at 10^{-1} and dilution 10^{-2} were used for the microbiological analysis based on preliminary tests.

Detection and enumeration of Aerobic Mesophilic Germs (AMG)
The medium used for enumerating mesophilic bacteria was Plate Count Agar (PCA). The inoculation was done with 1 ml of the stock suspension and decimal dilutions performed in the mass in double layer in a sterile Petri dish. Fifteen (15) ml of previously molten medium were then poured. The mixture was homogenized by slight stirring then solidified. After solidification, a second layer of 5 ml of PCA was added. Petri dishes were incubated at 30 °C for 24-72 hours. All the colonies present in dishes containing 30-300 colonies were counted according to the standard method NF ISO 4833-1: 2013. All the tests were carried out in triplicate.

Searching and counting Total and faecal (or thermotolerant) coliforms
Lactose Bile Crystal Violet Neutral Red Agar (VRBL Agar) was used for coliform enumeration. The inoculation was done with 1 ml of the stock suspension and decimal dilutions in the mass in double layer in sterile Petri dish. Then, VRBL agar (15 ml) was added to the Petri dish. The stock suspension or dilution was mixed with the culture medium by rotating movements and brought to 45 °C. After solidification, 5 ml of VRBL medium was added again to the Petri dish which was incubated at 30 °C for total coliforms and 44 °C for faecal or thermotolerant coliforms for 24 hours. Colonies appeared purplish red, round with a diameter of 0.5 mm. All the colonies present in dishes containing 15-150 colonies were counted according to the method of standard NF ISO 4832: 2006. All the tests were carried out in triplicate.

Detection and enumeration of *Escherichia coli* on Tryptone-bile-glucuronate (TBX)
One (1) ml of the stock suspension and dilutions was inoculated in the mass on a single layer in sterile Petri dishes. Then, 20 ml of tryptone bile glucuronate was added to Petri dishes. The bacterial dilution was mixed with the agar by rotating movements and the whole was brought to 45 °C. After incubation at 44 °C for 24 hours, all the colonies appearing blue were counted according to the standard method NF ISO 16649-2: July 2001. All the tests were performed in triplicate.

Presumptive identification of *Escherichia coli*
This analysis was carried out on 5 suspect strains grown on VRBL medium, to confirm the presence of *Escherichia coli*. These suspect strains were subcultured on nutritive agar and incubated at 37 °C for 24 hours. They were subjected to series of tests for confirmation (Mackenzie and Kliger Hajna tests)

Mackenzie test (ISO 7251 (ISO, 2005) standard)
A bacterial suspension was prepared in distilled water from the colonies on nutritive agar. From a positive culture at 30-37 °C, two tubes were inoculated: a tube with indole-free peptone water and a tube of BLBVB (brilliant green lactose bile broth) containing a bell jar. Both tubes were incubated at 44 °C for 24 hours. The production of indole on peptone water indicated the presence of *E. coli* in the food examined. On the other hand, a positive result on BLBVB (brilliant green lactose bile broth) indicated the presence of thermotolerant coliforms, including *E. coli*.

Medium Kliger Hajna (NF V08-301 June 1983)
The Kliger Hajna test was performed on 5 suspect faecal coliform colonies, still isolated on nutritive agar for 24 hours- culture at 37 °C. A bacterial suspension was inoculated either by tight streaks on the slope or by central puncture in the pellet using a Pasteur pipette. The culture was incubated at 37 °C for 24 hours, screw cap.

Method for interpreting the results of the microbiological analysis
The results of the microbiological study were interpreted based on the criteria established by French standards. These assessment criteria are defined by the ministerial decree of April 3, 2006 and published in the Official Journal of April 27, 2006 (Anonymous 4, 2006). Article 6 of this decree relates to the microbiological criteria for interpretation of the microbiological analysis of pastries and pastry creams. These criteria were retained with the advice of LANADA's expertise for the interpretation of the microbiological results on plantain banana chips. They are listed in Tables II and III.

Table II:- Microbiological criteria for ripe and unripe plantain chips.

AMG (CFU/g)	TC (CFU/g)	FC (CFU/g)	*E. coli* (CFU/g)
$m = 3.\ 10^5$	$m = 10^2$	m = 1	Absence

AMG= Aerobic Mesophilic Germs; TC= Total Coliforms; FC = Faecal Coliforms;
E. coli = Escherichia coli

Table III:- Standards for microbiological quality of ripe and unripe plantain banana chips.

Microbiological quality	Germs			
	AMG (CFU/g)	Total Coliforms (CFU/g)	Faecal coliforms (CFU/g)	*Escherichia coli*
Very Satisfactory (VSMQ)	$D < 3 \times 10^5$	$D < 10^2$	D < 1	Absence
Satisfactory (SMQ)	$D < 9 \times 10^5$	$D < 3 \times 10^2$	D < 3	
Acceptable (AMQ)	$9 \times 10^5 < D < 3 \times 10^6$	$3 \times 10^2 < D < 10^3$	3 < D < 10	
Unsatisfactory (USMQ)	$D > 3 \times 10^6$	$D > 10^3$	D > 10	
corrupt food	$1.5 \times 10^8 < D < 3 \times 10^8$	$5 \times 10^4 < D < 5 \times 10^5$	$5 \times 10^2 < D < 10^3$	Presence

Very Satisfactory Microbiological Quality (VSMQ)

Acceptable Microbiological Quality (AMQ)

Unsatisfactory Microbiological quality (USMQ)

The interpretation of the results was carried out according to a plan with five classes of contamination according to the microbiological reference criteria m(m is the minimum load of microorganisms):
- when the counts obtained are lower than the criteria (m), the product is of very satisfactory microbiological quality (VSMQ).
- when the counts obtained are less than or equal to 3-fold the critera (3 m), the product is of satisfactory microbiological quality (SMQ).
- when the counts obtained are between 3-fold (3 m) and 10-fold the criteria (10 m), the product is of acceptable microbiological quality (AQM).
- when the counts obtained are greater than 10-fold the criteria (10 m), the product is of unsatisfactory microbiological quality (USMQ).
- when there is presence of *Escherichia coli* in 1 g of sample, the product is corrupted. Similarly, when the counts are between 500 and 1000 -fold the criteria (between 500 m and 1000 m), the product is corrupted.

M is the limit of acceptability, beyond which the results are no longer considered satisfactory, unless the product being considered toxic.
M = 10 m during the count carried out in a solid medium.
The reading and interpretation of the Kliger Hajna test was done according to Table IV.

Statistical analysis
The analysis was carried out using R studio software version 4.0.2 for physicochemical parameters and counts of microorganisms. For the variables measured (pH, dry matter, moisture, aerobic mesophilic germs, total coliforms, faecal coliforms and *Escherichia coli*), means, standard deviations, maximum, minimum, were calculated. A mean comparison using the software and one-way ANOVA (ripeness state of plantain) were performed. The dependent variables (responses) considered were the various biochemical parameters (pH, titratable acidity, dry matter, humidity).

A classification of the means obtained was carried out using the Student-Newman-Keul multiple comparison tests with the relative risk assessed at the threshold $\alpha = 5\%$.

Table IV:- Reading and interpretation of the Kligler Hajna test

Tube aera	Character sought	Observation	Interpretation	Conclusion
Base (Anaerobiosis)	Glucose	yellow base	Base Acidification	Fermentative use of Glucose. Glucose (+) bacteria
		Base color unchanged	No acidification	No use of Glucose Glucose (-) bacterie
Slope (Aerobiosis)	Lactose	Red slope	No acidification	No use of Lactose. Lactose (-) bacteria
		Yelow slope3	Slope Acidification	Use of Lactose Lactose (+) bacteria
Base or junction slope base	Gas production	Presence of bubbles	Gas Production	Production of gas by fermenting lactose Gas (+) bacteria
		No bubbles	No gas production	Gas (-) bacteria
	H_2S production	Presence of a black precipitate	Reduction of sodium thiosulfate to H_2S: black precipitate with iron III	H_2S (+) bacteria
		Absence of a black precipitate	No reduction of sodium thiosulfate to H_2S	H_2S (-) bacteria

Results:-

Physicochemical parameters of chip samples
The physicochemical characteristics (moisture content, dry matter content, titratable acidity and pH) of the 30 samples of ripe and unripe plantain banana chips are presented in Fig 2 to 5; Tables V and VI.

On average, the 30 samples of ripe and unripe plantain chips showed a very low moisture content (3.06 ± 1.01 %).

Considering the chip seller factor (or sale or production site), the average humidity rate of the 30 samples studied ranged from 0.87 ± 0.12% (seller 14) to 5.67 ± 0.23% (saleswoman 11), (Fig 2).

Based on the ripeness state of plantain, the average moisture content of ripe banana chips (V15A) was 3.40 ± 1.01% while that of unripe banana (V15B) was 2.71 ± 0.93% (Table V). Although the average moisture content of ripe chips was higher than that of unripe chips, the difference remained non-significant ($p > 0.05$, Table VI).

For dry matter, whatever the selling factor or the state of maturity of the plantain banana, the rate of dry matter evolved inversely proportional to that of the moisture rate (Fig 3 and Table V). On average for the state of maturity factor, the dry matter rate for the 15 samples of ripe banana chips (V15A) was 96.59 ± 1.03% (minimum = 94.02%, maximum =98,04%) while that of 15 samples of unripe banana chips (V15B) gave a mean of 97.28 ± 0.93% (minimum = 95.2%, maximum =99.2%).

The hydrogen potential (pH) of the 30 studied samples ranged from 5.16 (seller 11) to 6.04 (seller 1). All samples had a pH greater than 5 and therefore were not very acidic with a pH mean of 5.7 ± 0.27 (Fig 4). Nevertheless, based on the pH scale, the ripe plantain banana chips (5.52 ± 0.26) were significantly more acidic than unripe banana chips (5.88 ± 0.12). The level of titratable acidity (mEq/100 g) of the 30 samples varied from 0.38 mEq/100g DM (unripe chip from vendor 1) to 2 mEq/100g DM (ripe chip sample from vendor 11) with a mean of 1.03 ± 0.51 mEq/100g (Fig 5, Table V). The ripe plantain banana chips (1.44 ± 0.29 mEq/100g) had a significantly higher titratable acidity than that of unripe banana chips (0.62 ± 0.3 mEq/100g; $p<0.05$); (Tables V and VI).

Microbiological quality of 30 samples of chips

The isolation of microorganisms on specific medium (VRBL, TBX) revealed the presence of total coliforms on five samples (V1B, V4B, V7B, V10B and V15B) and faecal coliforms only on samples V10B and V15B. On the other hand, a total absence of *Escherichia coli* was recorded in all the samples of plantain chips.

The enumeration of the microflora carried out on the 30 samples of banana chips indicated that the load of total flora (or AMG); (Table VII) ranged from 0.18×10^2 to 2.7×10^2 CFU/g. Furthermore, the presence of total and thermotolerant (faecal) coliforms was only observed on samples of unripe plantain banana chips (Table VII).

The results of the Mackenzie and Kliger Hajna tests (Table VIII) confirmed the absence of *Escherichia coli* on the 5 suspected strains studied. Indeed, the absence of indole production on peptone water and the negative result obtained on BLBV broth showed the absence of thermotolerant coliforms and especially of *E. coli* on the samples of chips investigated.

Except samples V10B (chips from vendor 10) and V15B (chips from vendor 15) which showed an unsatisfactory microbiological quality (high load of faecal or thermotolerant coliforms), all the other samples of ripe and unripe plantain banana chips were of very satisfactory microbiological quality (Tables II, III, VIII and IX).

Discussion:-

This work was carried out to assess the microbiological risk associated with the consumption of chips sold in the municipality of Cocody. Chips are foods that had very low water content. Indeed, the average moisture content of the 30 samples of chips analysed was 3.06 ± 1.01%. Also, the water content of all chips samples was less than 5 %. According to Demasse et al. (2007)andGuillaumin (1988), plantain chips have low water content, between 1 and 10 %. This very low moisture can be explained by the cooking temperature that is around 200 °C (Anonymous 2, 2015). This temperature may not favour the multiplication of microorganisms and spores.Water is both a vector of germs and an essential element for life (Anonymous 5, 2016).

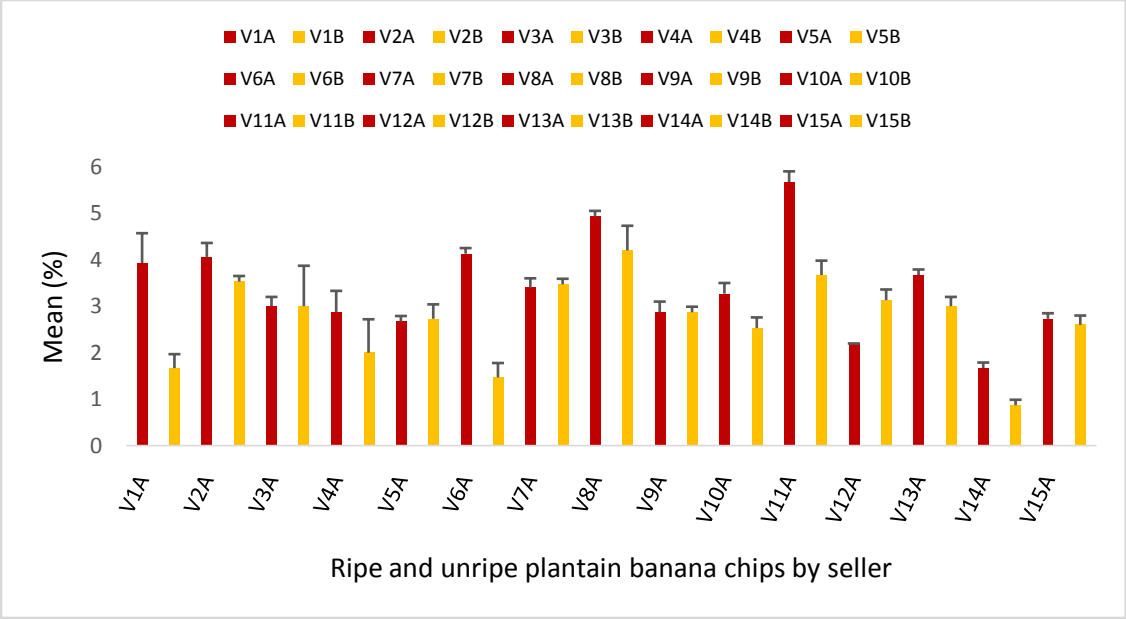

Fig 2:- Moisture content (%) of ripe and unripe plantain banana chips by seller.

V1A= Vendor 1 ripe plantain chip sample, V1B= Vendor 1 unripe plantain chip sample, V2A= Vendor 2 ripe plantain chip sample, V2B= Vendor 2 unripe plantain chip sample, vendor 2, V3A= mature plantain chip sample from vendor 3, V3B= unripe plantain chip sample from vendor 3, V4A= ripe plantain chip sample from vendor 4, V4B= banana chip sample unripe plantain from vendor 4, V5A= ripe plantain chip sample from vendor 5, V5B= unripe plantain chip sample from vendor 5, V6A= ripe plantain chip sample from vendor 6, V6B= unripe plantain chip sample from seller 6,……., V15A= ripe plantain banana chip sample from seller 15, V15B= unripe plantain banana chip sample from seller 15

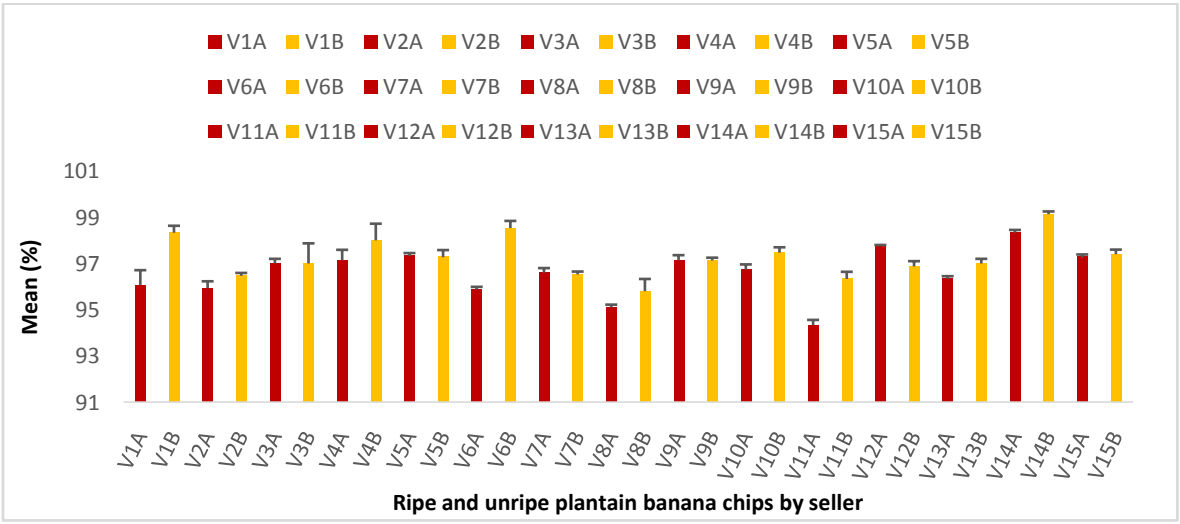

Fig3:- Dry matter content (%) of ripe and unripe plantain banana chips per seller.

V1A= Vendor 1 ripe plantain chip sample, V1B= Vendor 1 unripe plantain chip sample, V2A= Vendor 2 ripe plantain chip sample, V2B= Vendor 2 unripe plantain chip sample, vendor 2, V3A= mature plantain chip sample from vendor 3, V3B= unripe plantain chip sample from vendor 3, V4A= ripe plantain chip sample from vendor 4, V4B= banana chip sample unripe plantain from vendor 4, V5A= ripe plantain chip sample from vendor 5, V5B= unripe plantain chip sample from vendor 5, V6A= ripe plantain chip sample from vendor 6, V6B= unripe plantain chip sample from seller 6,……., V15A= ripe plantain banana chip sample from seller 15, V15B= unripe plantain banana chip sample from seller 15

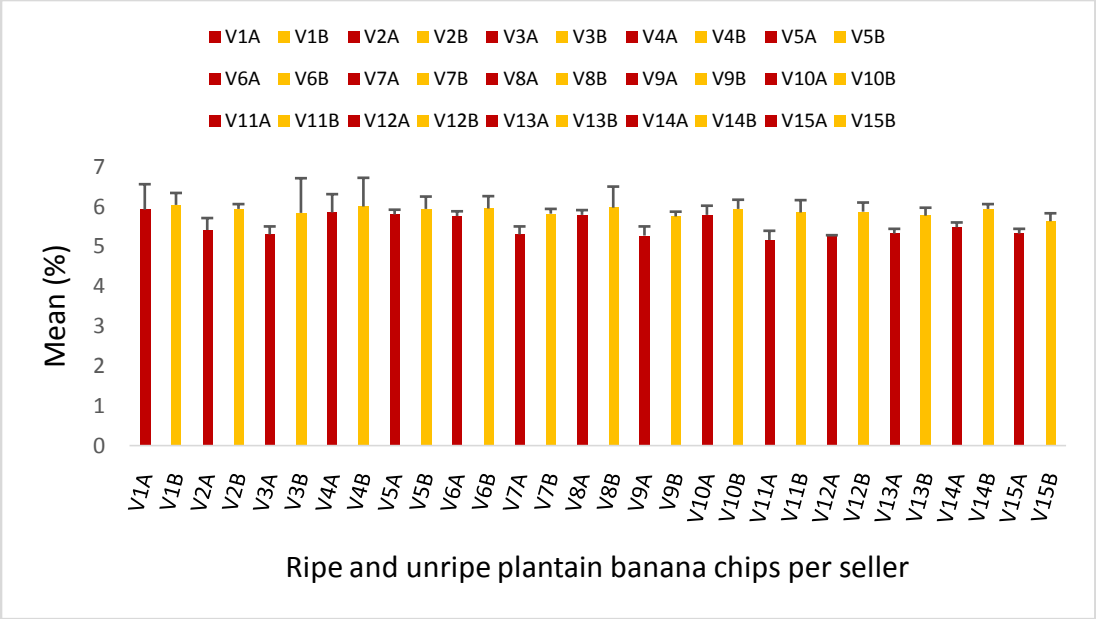

Fig 4:- pH of ripe and unripe plantain banana chips per seller.

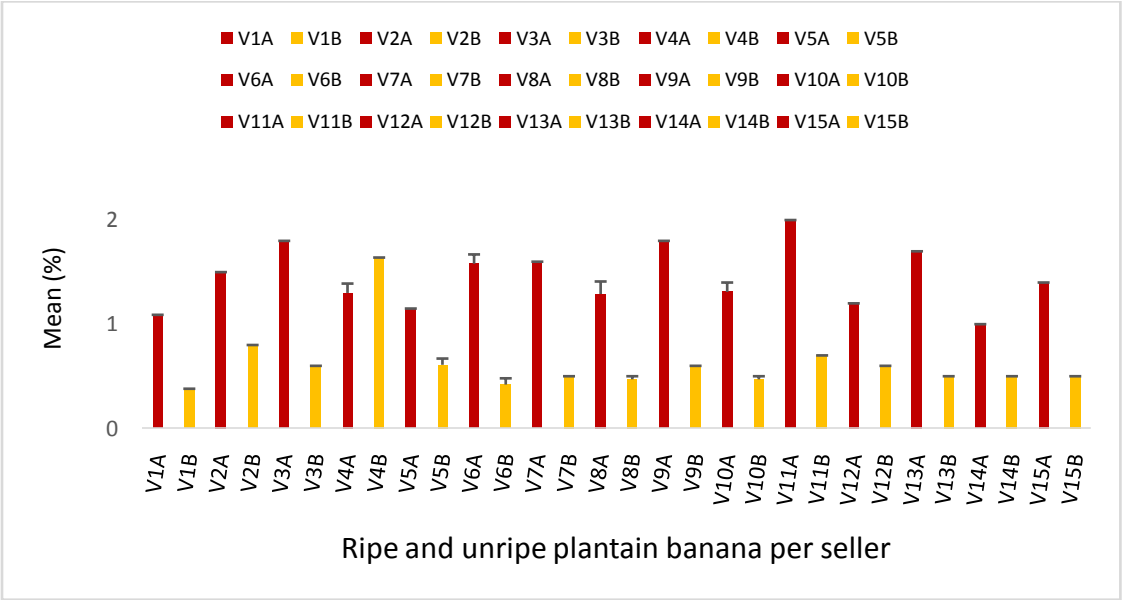

Fig 5:- Acidity titratable mean of plantain banana chips.

Table V:- Physicochemical parameters of 30 ripe and unripe plantain banana chips samples.

Chips						
Parameters	Maturity State					
	Ripe			Unripe		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
pH	5.52 ± 0.26	6.02	5.16	5.88 ± 0.12	6.1	5.58
Titratable Acidity	1.44 ± 0.29	2	1	0.62 ± 0.30	1.64	0.38
Dry matter	96.59 ± 1.03	98.4	94.2	97.28 ± 0.93	99.2	95.2
Humidity	3.40 ± 1.03	5.8	1.6	2.72 ± 0.93	4.8	0.8

Table VI:- Comparison of physicochemical parameters means of 30 ripe and unripe plantain banana chips.

Plantain banana chips	Parameters			
	Moisture (%)	Dry matter (%)	Titratable acidity	pH
Maturity				
Ripes	3.40 **a**	96.59 **a**	1.44 **a**	5.52 **b**
Unripes	2.72 **a**	97.28 **a**	0.62 **b**	5.88 **a**
Moyenne	3.06	96.94	1.03	5.7
Pr> F	0.185	0.210	0.0267	0.0424

The means followed by the same letters in a column are not significantly different at the threshold of 5 p.c. F= Fisher's coefficient

Table VII:- Loads of AMG and Coliforms in ripe and unripe plantain banana chips samples.

Chips samples	AMG (CFU/g)	Total coliforms (CFU/g)	Faecal coliforms (CFU/g)	Escherichia coli (CFU/g)
V1A	0.23×10^2	0	0	0
V1B	0.59×10^2	0.05×10^2	0	0
V2A	3.40×10^2	0	0	0
V2B	19×10^2	0	0	0
V3A	0.86×10^2	0	0	0
V3B	19×10^2	0	0	0
V4A	0.32×10^2	0	0	0
V4B	1.90×10^2	0.05×10^2	0	0
V5A	1.40×10^2	0	0	0
V5B	3.50×10^2	0	0	0
V6A	1.10×10^2	0	0	0
V6B	1.20×10^2	0	0	0
V7A	2.90×10^2	0	0	0
V7B	1.60×10^2	0.23×10^2	0	0
V8A	0.18×10^1	0	0	0
V8B	1.5×10^3	0	0	0
V9A	0.9×10^1	0	0	0
V9B	1.200 x 103	0	0	0
V10A	4.5×10^2	0	0	0
V10B	2.7×10^3	1.50×10^2	1.40×10^2	0
V11A	3.50×10^2	0	0	0
V11B	9.16×10^2	0	0	0
V12A	1.5×10^1	0	0	0
V12B	3.24×10^2	0	0	0
V13A	5.4×10^1	0	0	0
V13B	2.57×10^2	0	0	0
V14A	0.6×10^1	0	0	0
V14B	2.8×10^1	0	0	0
V15A	2.75×10^2	0	0	0
V15B	1.78×10^3	1.20×10^2	1.10×10^2	0

A = ripe plantain chip sample and B = unripe plantain chip sample ; V1A= Vendor 1 ripe plantain chip sample, V1B= Vendor 1 unripe plantain chip sample, V2A= Vendor 2 ripe plantain chip sample, V2B= Vendor 2 unripe plantain chip sample, vendor 2, V3A= mature plantain chip sample from vendor 3, V3B= unripe plantain chip sample from vendor 3, V4A= ripe plantain chip sample from vendor 4, V4B= banana chip sample unripe plantain from vendor 4, V5A= ripe plantain chip sample from vendor 5, V5B= unripe plantain chip sample from vendor 5, V6A= ripe plantain chip sample from vendor 6, V6B= unripe plantain chip sample from vendor 6,……., V15A= ripe plantain chip sample from vendor 15, V15B= unripe plantain chip sample from vendor 15

Zone of the tube	Character sought	Observation	Interpretation	Conclusion
Base (Anaerobiosis)	Glucose	Unchanged colour	Absence of acidification	Glucose bacteria(-)
Slope (Aerobiosis)	Lactose	Red slope	Absence of acidification	Lactose bacteria (-)
Base or socket slope junction	Gas production	Presence bubbles	Gas production	Gas bacteria (+)
	Production of H_2S	Absence of a black precipitate	No reduction of sodium thiosulfate to H_2S	H_2S bacteria (-)

Table VIII:-Results and interpretation of the Kligler Hajna test after analysis.

Table IX:- Microbiological quality of samples of ripe and unripe banana chips per seller.

SAMPLES	MAG (CFU /g) / m = $3x10^5$	Total Coliforms (CFU/g) / m = 100	Faecal Coliforms (CFU/g) / m = 1	*Escherichia coli* (CFU/g) / Absence	MICROBIOLOGY QUALITY
V1A	C < m	C < m	C <m	Absence	VSMQ
V1B	C < m	C < m	C < m	Absence	VSMQ
V2A	C < m	C < m	C < m	Absence	VSMQ
V2B	C < m	C < m	C < m	Absence	VSMQ
V3A	C < m	C < m	C < m	Absence	VSMQ
V3B	C < m	C < m	C < m	Absence	VSMQ
V4A	C < m	C < m	C < m	Absence	VSMQ
V4B	C < m	C < m	C < m	Absence	VSMQ
V5A	C< m	C < m	C < m	Absence	VSMQ
V5B	C < m	C < m	C < m	Absence	VSMQ
V6A	C < m	C < m	C < m	Absence	VSMQ
V6B	C < m	C < m	C < m	Absence	VSMQ
V7A	C < m	C < m	C < m	Absence	VSMQ
V7B	C < m	C < m	C < m	Absence	VSMQ
V8A	C < m	C < m	C < m	Absence	VSMQ
V8B	C < m	C < m	C < m	Absence	VSMQ
V9A	C < m	C < m	C < m	Absence	VSMQ
V9B	C < m	C < m	C < m	Absence	VSMQ
V10A	C < m	C < m	C < m	Absence	VSMQ
V10B	**C < m**	**C < 3m**	**C > 10m**	**Absence**	**USMQ**
V11A	C < m	C < m	C < m	Absence	VSMQ
V11B	C < m	C < m	C < m	Absence	VSMQ
V12A	C < m	C < m	C < m	Absence	VSMQ
V12B	C < m	C < m	C < m	Absence	VSMQ
V13A	C < m	C < m	C < m	Absence	VSMQ
V13B	C < m	C < m	C < m	Absence	VSMQ
V14A	C < m	C < m	C < m	Absence	VSMQ
V14B	C < m	C < m	C < m	Absence	VSMQ
V15A	C < m	C < m	C < m	Absence	VSMQ
V15B	**C < m**	**C < 3 m**	**C > 10m**	**Absence**	**USMQ**

Samples A : unripe banana chips ; Sample B : ripe banana chips ; C= counts; TC: Total coliforms; FC: Faecal coliforms; MAG : Mesophilic Aerobic Germs; *E.coli*: *Escherichia coli*; VSMQ: very satisfactory microbiological quality; USMQ: unsatisfactory microbiological quality; CFU: Colony forming unit, m = microbiological criterion

Water is fundamental for the multiplication of germs and the germination of spores. According to Manikantanet al. (2014), this low humidity associated with a water activity less than or equal to 0.4 generally assigned to plantain chips, allows storage at room temperature and preservation of the organoleptic qualities of the chips for several months.

The pH of the 30 samples of ripe and unripe plantain chips was slightly acidic with values ranging from 5.16 (ripe chip sample from seller 11) to 6.04 (unripe chip sample from seller 1). These results are similar to those reported by Ngoh Newilah et al. (2011) who indicates that the average pH of green plantain is 5.8. For Alegbeleye et al. (2022) and Bourgeois (1985), pH values of food closer to neutrality are favourable to the growth of certain microorganisms such as coliforms. The minimum growth pH of Escherichia coliis 4.4 and its maximum pH is 9. This may explain the presence of total and faecal coliforms in samples of ripe and unripe plantain banana chips whose carbohydrate content was high. Coliforms ferment sugars with the production of acid and gas (Halkman and Halkman, 2014). The total titratable acidity rate, inversely proportional to the pH, was also very low (on average 1.03 mEq/100g DM). This low rate of acidity is in full agreement with the above statements on the presence of coliforms linked to pH values in the present study. However, ripe chips were significantly (mean= 1.44 mEq/100g) more acidic ($p<0.05$) than unripe plantain banana chips (mean = 0.62 mEq/100g). This acidity may explain the higher load of faecal coliforms in unripe chips than in ripe chips. The microbiological analysis showed that only two unripe banana samples V10B and V15B were contaminated with faecal coliforms with an alarming load above 10 m acceptability threshold (10 CFU/g).

The thirty (30) samples of plantain chips showed loads of aerobic mesophilic germs (AMG) from 0.06×10^2 to 2.7×10^3 CFU/g with a mean load of 5.19×10^2 CFU/g (Table VII). This AMGload was widely inferior to the standard, 3-fold the criteria m (9×10^5 CFU/g with m = 3×10^5 CFU/g) and below the acceptability threshold M (10 m = $3x10^6$ CFU/ g).

According to Anonymous 6 (2006), it is recognized that the aerobic mesophilic count remains the best method for assessing the general microbiological quality of foods, particularly in the consumer sector, for considering all the conditions suffered by the food. The present results are like those of Navarro et al. (2018), with a value of 5.78×10^2 CFU/g for aerobic mesophilic germs during an evaluation of the microbiological quality of plantain banana snacks in Venezuela. This load indicates that the plantain snack product is safe for consumption without harmful damage to the health of the consumers.

Only 5 samples showed the presence of total coliforms. The loads were V1B (5 CFU/g), V4B (5 CFU/g), V7B (23 CFU/g), V10B (150 CFU/g) and V15B (120 CFU/g). The average coliform loads obtained were widely below 3 m (300 CFU/g with m = 100 CFU/g) and the acceptability threshold M = 10 m (1000 CFU/g). These 5 samples were all prepared from unripe plantain bananas which tend to be contaminated more quickly than ripe bananas. For plantain chips, the presence of total coliforms indicates contamination subsequent to treatment with the use of hot oil (Anonymous 6, 2006). These microorganisms may also demonstrate poor cleaning and disinfection of utensils and packaging used when bagging chips.

At the level of faecal coliforms, only two unripe samples V10B and V15B were contaminated with respectively an alarming load of 150 CFU /g and 120 CFU/g above 10 m acceptability threshold (10 CFU/g). The microbiological quality of these two samples was therefore not satisfactory. According to Anonymous 6 (2006), the presence of faecal coliforms indicates a lack of hygiene, lack of disinfection of utensils and poor storage or protection conditions (packaging). However, *Escherichia coli*, which belongs to the faecal coliform group,indicatesfaecal contamination since it is present in the digestive tract of animals and humans. *E. coli* is the only member of the coliform group to be exclusively of faecal origin. The presence of *E. coli* in a ready-to-eat food is therefore a sign of a potential contamination by enteric pathogens of this food and, makes it at risk for human consumption. This bacteria should not be detected in a ready-to-eat food whethera tolerance is allowed as it is related to poor hygienic conditions or insufficient heat treatment. Interestingly, samples of ripe or unripe plantain chips examined were free of *E. coli*. However, with regards to their high faecal coliform load, samples V10B and V15B cannot be recommended for consumption. Similar investigations reported the presence of aerobic mesophilic germs, total coliforms and faecal coliforms in chips (Navarro et al., 2018). Studies of Elmarnissi et al. (2012) and Oluwafemi (2013) reached to same results when working on different street foods (ready meals, snacks and drinks) from some regions of Morocco, Ouagadougou and Nigeria respectively. These authors conclude an unsatisfactory microbiological quality of the samples analysed.

Conclusion:-

The results of the present study have shown that failure to comply with hygiene measures by manufacturers and sellers of plantain banana chips in the municipality of Cocody, as well as the exposure of these food to an unsuitable environment, could favour multiplication of pathogenic microorganisms and harmful faecal contamination for the usual consumer. Overall, the samples of ripe and unripe plantain banana chips showed a very satisfactory microbiological quality.

However, the samples V10B and V15B were of unsatisfactory microbiological quality related to their huge loads of faecal coliforms. The high dry matter content (97.47 – 97.4%) and little acid pH (5.94 – 5.63) may have promoted contamination by faecal coliforms in these samples, probably due to a lack of hygiene at the side of sellers or manufacturers and working environment. Only samples of unripe plantain banana were contaminated, a fact attesting that unripe banana chips would be more susceptible to contamination than ripe banana chips. This result calls the main recommendation as increasing hygiene measures for handlers or sale assistants (hand washing), utensils, rooms and packaging.

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