SEBHA UNIVERSITY JOURNAL OF PURE & APPLIED SCIENCES VOL.24 NO. 1 2025
DOI: 10.51984/JOPAS.V24I1.3086

مجلة جامعة سبها للعلوم البحتة والتطبيقية
Sebha University Journal of Pure & Applied Sciences
Journal homepage: www.sebhau.edu.ly/journal/jopas

Effects of Traditional and Chemical Ripening Methods on the Physicochemical Properties and Microbial Quality of Banana and Pawpaw Fruits

Oluwapamilerin Fakile*, Okolosi Eviano, Olorunfunmi Solana, Adedokun Mercy, and Oke Ayo.

Department of Home Science and Hospitality Management, College of Agricultural Sciences, Olabisi Onabanjo University, Yewa Campus, Ayetoro, Nigeria.

Keywords:
Traditional ripening.
Chemical Ripening.
Calcium Carbide.
Physicochemical.
Microbial Quality.

ABSTRACT

This study was conducted to evaluate the effects of traditional and chemical ripening methods on the physicochemical properties and microbial quality of banana and pawpaw fruits. The physicochemical properties and microbial load of the fruits were analyzed using standard analytical and microbiological methods. Unripe banana and pawpaw fruits served as control samples. Naturally ripened bananas had the highest protein (4.63%), fat (1.54%), sugar (9.33%), pH (4.47), and vitamin C (6.16 mg/100 g) contents after 72 hours. In contrast, bananas ripened with calcium carbide exhibited the highest moisture (97.55%), ash (3.00%), fiber (1.67%), carbohydrate (55.16%), and titratable acidity (0.20%) at 72 hours. For pawpaw, the sample placed in an airtight bag had the highest moisture (97.21%) and ash (0.50%) content, whereas the blanched sample had the highest fat (0.13%), carbohydrate (13.33%), and pH (7.77) values. Pawpaw ripened with calcium carbide showed the highest protein (0.96%), titratable acidity (1.20%), and vitamin C (0.98 mg/100 g) contents at 72 hours. Microbial analysis revealed that after 72 hours of ripening, bacterial and fungal isolates were present on the fruit surfaces. The identified bacterial isolates included Pseudomonas spp., Citrobacter spp., Staphylococcus aureus, Enterobacter spp., Micrococcus spp., and Escherichia coli. Fungal isolates included Aspergillus flavus, Aspergillus niger, and Fusarium spp. The results indicate that natural ripening methods, such as open-shelf ripening and airtight bag storage, led to a significant increase in nutrient content compared to chemical ripening with calcium carbide.

تأثير الطرق التقليدية والكيميائية للنضج على الخواص الفيزيائية والكيميائية والجودة الميكروبية لثمار الموز والبابايا

أولوباميلرين فاكيليا*، أوكولوسي إيفيانوا، أولورونفونمي سولانا، أديدوكون ميرسيا، وأوكي أيوا.

قسم العلوم المنزلية وإدارة الضيافة، كلية العلوم الزراعية، جامعة أولابيسي أونابانجو، حرم يوا الجامعي، أيتورو، نيجيريا.

الكلمات المفتاحية:
النضج التقليدي.
النضج الكيميائي.
كربيد الكالسيوم.
الجودة الفيزيائية والكيميائية.
الجودة الميكروبية.

الملخص

أجريت هذه الدراسة لتحديد تأثير طرق النضج التقليدية والكيميائية على الخصائص الفيزيائية والكيميائية لثمار الموز والبابايا. تم تحديد الخصائص الفيزيائية والكيميائية والجودة الميكروبية للثمار باستخدام طرق تحليلية قياسية وطرق اختبار ميكروبيولوجية قياسية. تم استخدام ثمار الموز والبابايا غير الناضجة كعينات تحكم. كان للموز الناضج بشكل طبيعي أعلى محتوى من البروتين (4.63٪) والدهون (1.54٪) والسكر (9.33٪) ودرجة الحموضة (4.47) وفيتامين سي (6.16 مجم / 100 جم) عند 72 ساعة. بينما كانت العينات التي تحتوي على كربيد الكالسيوم تحتوي على أعلى محتوى من الرطوبة (97.55٪) والرماد (3.00٪) والألياف (1.67٪) والكربوهيدرات (55.16٪) والحموضة القابلة للقياس (0.20٪) على التوالي عند 72 ساعة. أظهرت الدراسة الميكروبية أن البابايا الموضوعة في أكياس محكمة الغلق كان لها أعلى نسبة رطوبة (97.21٪) ورماد (0.50٪) وعينة مبيضة تحتوي على دهون (0.13٪) وكربوهيدرات (13.33٪) ودرجة حموضة (7.77) بينما كانت العينة التي تحتوي على كربيد الكالسيوم تحتوي على أعلى نسبة بروتين (0.96٪) وحموضة

*Corresponding author.
E-mail addresses: oluwapamilerin.yangomodou@oouagoiwoye.edu.ng.
Article History : Received 25 March 24 - Received in revised form 23 February 25 - Accepted 06 April 25

قابلة للقياس (1.20٪) وفيتامين سي (0.98) على التوالي عند 72 ساعة. أظهرت الدراسة الميكروبية أنه بعد 72 ساعة من وقت النضج تم عزل عزلات البكتيريا والفطريات من أسطح الثمار وتحديدها. تم تحديد العزلات البكتيرية على أنها Pseudomonas spp. و Citrobacter spp. و S. aureus و Enterobacter spp. و Micrococcus spp. و E. coli وعزلات فطرية مثل A. flavus و A. niger و Fusarium spp. وأظهرت الدراسة أن استخدام النضج الطبيعي على الرفوف المفتوحة والأكياس المحكمة الإغلاق (الطرق التقليدية) أدى إلى زيادة كبيرة في العناصر الغذائية للفاكهة مقارنة باستخدام المواد الكيميائية.

1. Introduction

Fruit is the seed-bearing structure of flowering plants. It also includes the fleshy part of the plant, which can be sour, sweet, and edible in its raw form [1].

Ripening is a physiological process that leads to changes in the appearance, flavor, texture, and aroma of fruits [1]. It softens the fruit and increases its sweetness through various sensory, biological, chemical, and physical transformations [1, 2]. Once ripening occurs, it is irreversible. Notable changes during fruit ripening include an increase in sugar and carbohydrate content, the development of flavor compounds, and the formation of phenolic, aromatic, and organic compounds [2].

Fruits are classified into two categories based on their respiration rate and ripening process: climacteric and non-climacteric. Climacteric fruits produce ethylene during the early stages of ripening, accompanied by an increased respiration rate, whereas non-climacteric fruits do not produce ethylene [3].

Fruits are typically harvested unripe, either at maturity or immaturity, and later ripened using traditional or artificial methods [3]. However, due to their high perishability, they deteriorate rapidly after harvesting. To meet market demands, fruit traders employ various ripening techniques. Traditional ripening methods include storing fruits in heaps of paddy straw, placing them in airtight bags, using underground pits, smoking with burning cow dung, exposing them to kerosene fumes, blanching in warm water, and covering them with coconut leaves or husks for several days [4]. Conversely, artificial ripening methods, commonly used in Nigeria, involve chemicals such as ethephon, ethylene, glycol, ethrel, and calcium carbide. These chemicals accelerate the ripening process by generating acetylene gas in the presence of moisture [4].

However, the use of artificial ripening agents has been associated with serious health risks, including skin burns, irritation, nausea, eye defects, kidney failure, respiratory issues, and gastrointestinal disorders [4]. These health problems arise because traders often apply excessive amounts of ripening chemicals to meet the high demand for fruits.

Despite their high economic value, fruits are highly susceptible to microbial spoilage. It is estimated that approximately **22–26% of harvested fruits** are lost due to microbial contamination during handling [5]. Various microorganisms contribute to fruit spoilage under suitable environmental conditions, leading to significant post-harvest losses. Spoilage alters the taste, smell, texture, and appearance of fruits, rendering them unfit for consumption [2]. Fungi responsible for fruit spoilage produce **pectinases and hemicellulases**, which degrade fruit tissues, while spoilage bacteria colonize fruits and cause lesions [4].

Banana (*Musa* sp.) is an affordable, nutrient-rich fruit with high caloric content. It belongs to the **Musaceae** family and is widely cultivated worldwide [5]. Pawpaw (*Carica papaya*), a member of the **Caricaceae** family, is primarily grown in tropical and subtropical regions, with Nigeria being a major producer [5]. As a climacteric fruit, pawpaw undergoes significant color changes during ripening, transitioning from green to red or orange due to **carotenoid** accumulation [2]. It is rich in nutrients and can be consumed raw as a snack or cooked as a vegetable [2].

Given the widespread use of traditional and artificial ripening methods, it is important to assess their impact on fruit quality. This study investigates the changes in the physicochemical composition of banana and pawpaw during ripening, as well as the isolation and identification of fruit spoilage microorganisms.

2. Materials and Methods

2.1. Collection of Samples

The unripe banana and pawpaw fruits were purchase from farmers in Ijebu-Ode market, Ogun-State, Nigeria. Unripe banana and pawpaw with peel covers and sizes that are uniform were used for the study. Air tight bags and chemicals such as calcium carbide and ethephon were purchased from chemical vendors in Sabo market, Lagos, Nigeria. These samples were placed in clean sterile polythene bags and transported to the laboratory for analysis.

2.2. Preparation of Samples

Unripe, green banana bunch and pawpaw fruits used for the study were washed in sterile distilled water and chlorinated water to remove dirt from the surfaces of the fruits. After cleaning they were left to dry on the air and divided into batches. One bunch of unripe banana containing 12 fingers and 12 unripe pawpaw fruit were all exposed to the same ripening conditions. The unripe fruits were separated into six batches each as A, B, C, D, E and F. Each batch had two fingers of each fruit used for the experiment and all experiment was done in triplicate.

Batch A: unripe banana and pawpaw
Batch B: Naturally ripened on open shelf
Batch C: Ripened in air tight jute bags
Batch D: Blanched in hot water
Batch E: Treated with calcium carbide
Batch F: Treated with ethephon

3. Banana and Pawpaw Ripening Processes

Three ripening processes were used for the traditional method while two ripening processes were used for the chemical method.

3.1. Traditional Ripening Methods

Naturally ripened banana and pawpaw on open shelf

Fresh unripe banana and pawpaw fruits were separately placed on clean sterilized laboratory shelf for 72 h at room temperature and ripening was monitored until all the samples were ripe.

Ripening in air tight jute bags

Fresh unripe banana and pawpaw fruits were separately placed in clean bags. The bags were opened after 72 h and all the samples were ripe.

3.2. Ripening by Blanching in Hot Water

Fresh unripe banana and pawpaw fruits were separately placed in five liters of boiled hot water for 10 mins after which they were removed cleaned, air dried and left on the shelf for 72 h to ripen.

Chemical ripening methods:

3.3. Ripening with Calcium Carbide

Fresh unripe banana and pawpaw fruits were separately placed in a sterilized container and 25 g of calcium carbide lump was placed inside the container in an opposite direction for 72 h.

Ripening with ethephon

Fresh unripe banana and pawpaw fruits were separately placed in a sterilized container and 50 mL of ethephon in a clean plastic cup was placed inside the container in an opposite direction for 72 h.

4. Physicochemical Analysis

The physicochemical parameters determined in the treated banana and pawpaw fruits include moisture, protein, fat, ash crude fibre and carbohydrate. Moisture, ash, fat, protein and crude fibre contents were determined using [6]. Carbohydrate was determined by difference using [7] method. The pH values were determined using the modified method. Vitamin C was determined by the method described by [8].

Total titrable acidity and total sugar was determined using the method described by [2].

5. Microbiological Examination of Spoilage Organisms in the Fruits

5.1. Preparation of Culture Media

Media used for the analysis include MacConkey agar (MA), Nutrient agar (NA), Sabouraud dextrose agar (SDA) and Potato dextrose agar (PDA). Media used were prepared based on the directive given by the manufacturers. The media were weighed separately follows; NA (28 g), SDA (68 g), PDA (39 g) and MA (55 g) and dissolved in 1000 mL of distilled water and autoclaved at 121 ° C for 15 minutes. Media were left to cool and poured into petri-plates to solidify.

5.2. Preparation of sample

One gram of the 72 h naturally ripened banana and pawpaw samples to be tested were separately weighed and put into 90 mL of sterile distilled water for homogenization. Then a ten-fold serial dilution of the homogenates was prepared [21].

5.3. Isolation of Spoilage Microorganisms

5.3.1. Bacteria

100 mL of dilutions of the homogenates 10^{-2}, 10^{-3} and 10^{-4} for each sample was poured onto the surface of solidified nutrient and MacConkey agar media after which the plates were swirled round, allowed to solidify and incubated at 37 ° C from 24 h to 48 h. After incubation, the viable bacterial colonies were counted [21].

5.3.2. Fungi

[9] Direct plate method for isolation of fungi was used to culture the molds observed on the banana and pawpaw samples. Portions of each fruit samples to be examined was transferred into petri-plates containing solidified SDA using a sterile forcep and each plate was incubated at 28 ° C for 5 days.

5.4. Identification of Spoilage Bacteria Isolated from the Fruits

Standard bacteriological test methods used by [10] were used to identify the isolated bacterial species. Bacteriological tests conducted on the isolates include gram staining, lactose, glucose, catalase, oxidase, citrate and coagulase.

5.5. Identification of Spoilage Fungi Isolated from the Fruits

The different fungal isolates observed on the SDA plates were identified with standard method of identification described by [11]. The morphological and cultural characteristics of each fungus were examined. Parameters examined include colonial growth pattern and morphology of conidial. The identification of the fungi species isolated was performed using lactophenol stain. This was achieved by putting a drop of the stain on a clean slide with a needle, where a small part of the mycelia from the cultures of fungi was removed and placed in a drop of the stain. The mycelium of each fungus was spread on the slide and covered with slip. The slides were mounted and viewed under the light microscope with x40 objective lenses.

5.6. Preparation of Spores of Spoilage Fungi for Identification

[12] Method of preparing fungal suspensions for identification was used. Five day old isolated cultures of *Aspergillus niger*, *Aspergillus flavus* and *Fusarium spp* were separately grown on potato dextrose agar at 35 °C to prepare inoculum suspensions. After growth, the colonies of each fungal strain observed in the plate were covered separately with 0.1 % Tween 20 and 1 mL of distilled added. The conidia of each fungus was collected with sterile swabs and placed into sterile tubes and blended for about 20 minutes. Then the conidium of each sample was examined for hyphae.

5.7. Statistical Analysis

The mean and standard deviation were calculated using Analysis of variance (ANOVA) and Turkey's multiple comparison tests.

6. Results and Discussion

The effect of traditional and chemical methods of ripening on the physicochemical composition of banana and pawpaw is presented in **Table 1** and **2. Figure 1** shows the pictorial representations of banana and pawpaw fruits ripened by traditional and chemical methods. The changes in physicochemical composition of traditionally and chemically ripened banana and pawpaw is presented in **Table 1** and **2**.

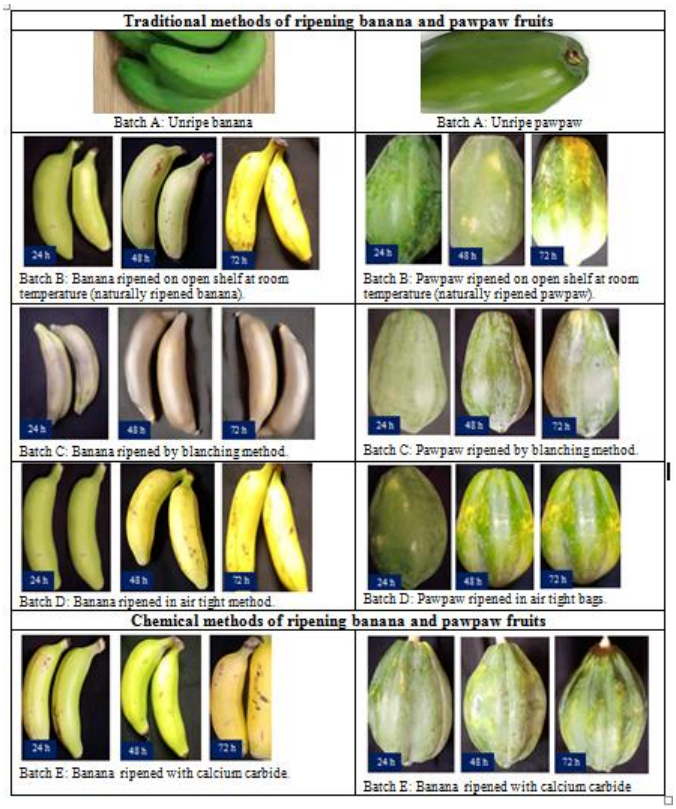

Fig. 1: Pictorial representations of banana and pawpaw fruits ripened by traditional and chemical methods

From tables 1 and 2, naturally ripened banana has the highest protein, fat, sugar, pH and vitamin C contents at 72 h. While the chemically treated samples with calcium carbide had the highest moisture, ash, fiber, carbohydrate and titratable acidity contents respectively at 72 h. There was significant difference between the control sample (unripe banana), the traditionally and chemically treated banana samples during ripening. For pawpaw, the traditionally ripened samples (the pawpaw placed in air tight bags and blanched) had the highest moisture, ash, fat, carbohydrate, sugar and pH contents while the chemically treated samples with calcium carbide had the highest protein, titratable and vitamin C contents respectively at 72 h.

The results obtained showed that the unripe banana and pawpaw which was the control samples had increased moisture contents of 88.35% and 89.00 %. The moisture contents in some traditionally treated samples such as the naturally ripened banana and pawpaw was found to decrease with increase in the ripening days. Values obtained were 70.04 % and 63.21 %. All other samples including banana and pawpaw blanched in hot water, placed in air tight bags, treated with chemicals (ethephon and calcium carbide) had increased moisture contents at 72 h. Blanched banana and pawpaw samples had the highest moisture contents of 98.01 % and 98.22 % followed closely by calcium carbide treated banana (97.55 %) and pawpaw (96.33 %). Results obtained could be due to the interference of hot water and chemicals with the ripening pathway in banana and pawpaw. Similar result was obtained by [3] for banana varieties ripened using different methods and chemical agents [13]. Nuhu *et al*., (2020) and his colleagues also reported increased moisture content in banana fruits ripened with calcium carbide. Moisture content is a determinant of the keeping quality of fruits. Therefore, excess amount of moisture in fruit supports growth of spoilage organisms [3].

The protein content of unripe banana and pawpaw was 4.35 % and 0.30 %. A decrease in protein content was observed for traditionally treated banana (blanched in hot water (0.22 %), and samples treated with chemicals such as ethephon (0.69 %) and calcium carbide (0.99 %) at 72 h. However, naturally ripened banana and air tight samples had the highest protein contents of 4.63 % and 4.54 %. In pawpaw samples, higher protein content with increase in storage time was observed in samples treated with ethephon (0.85 %) and calcium carbide (0.96 %) at 72 h. The protein contents obtained in the banana and pawpaw samples were significantly affected by chemical agents

used in ripening. This result correlates with the findings of [8] that studied the effect of calcium carbide on nutritional content of banana and found a decrease in protein content. Decrease in the protein content could be because of the drop in nitrogen content of the banana during the period of storage. The increase in protein content of the chemically treated pawpaw samples agrees with the result of [2] for pawpaw ripened with different chemical agents and [14] who

Table 1: Changes in physicochemical composition of banana during ripening

Storage time(h)	Treatments				
	Traditional			Chemical	
	Banana naturally ripened on open shelf (BNR)	Banana placed in air tight bags (BATB)	Banana blanched in with hot water (BBHW)	Banana treated with ethephon (BTE)	Banana treated with calcium carbide (BTCC)
Moisture % (88.35± 0.32					
24 h	82.32 ± 0.30 [b]	86.66± 0.21 [b]	93.40 ± 0.11 [a]	92.45 ± 0.21 [a]	93.22 ± 0.21 [a]
48 h	79.20 ± 0.27 [c]	88.40± 0.21 [b]	94.45± 0.14 [a]	94.20 ± 0.22 [a]	94.46 ± 0.22 [a]
72 h	70.04 ± 0.35 [c]	90.21± 0.21 [b]	96.21± 0.14 [a]	96.04 ± 0.19 [a]	97.55 ± 0.19 [a]
Crude fat % (1.35± 0.01)					
24 h	1.27± 0.01 [a]	1.20 ± 0.01 [a]	0.19 ± 0.01 [b]	1.20 ± 0.01 [a]	1.24 ± 0.01 [a]
48 h	1.41± 0.02 [a]	1.34 ± 0.02 [a]	0.14± 0.01 [c]	0.76 ± 0.01 [c]	1.17 ± 0.02 [b]
72 h	1.54± 0.01 [a]	1.50 ± 0.01 [a]	0.10± 0.01 [d]	0.42 ± 0.00 [c]	1.14 ± 0.00 [b]
Crude protein % (4.35±0.03)					
24 h	4.30± 0.02 [a]	4.25 ± 0.01 [a]	0.64 ± 0.11 [c]	1.26 ± 0.02 [b]	1.28 ± 0.01 [b]
48 h	4.48± 0.01 [a]	4.40 ± 0.01 [a]	0.41± 0.01 [c]	1.18 ± 0.01 [b]	1.20 ± 0.01 [b]
72 h	4.63± 0.02 [a]	4.54 ± 0.02 [a]	0.22± 0.01 [c]	0.69 ± 0.02 [c]	0.99 ± 0.01 [c]
Ash % (0.50 ± 0.00)					
24 h	0.48± 0.03 [c]	0.47 ± 0.03 [c]	1.98 ± 0.02 [b]	1.99 ± 0.02 [a]	2.02 ± 0.01 [a]
48 h	0.33± 0.01 [b]	0.30 ± 0.01 [b]	2.32± 0.01 [a]	2.76 ± 0.01 [a]	2.40 ± 0.01 [a]
72 h	0.24± 0.01 [c]	0.29 ± 0.01 [c]	2.71± 0.02 [b]	2.88 ± 0.02 [b]	3.00 ± 0.00 [a]
Carbohydrate (45.65 ± 0.19)					
24 h	45.88± 0.03 [b]	43.47 ± 0.04 [b]	50.03 ± 0.09 [a]	52.02 ± 0.12 [a]	52.21 ± 0.15 [a]
48 h	39.42± 0.10 [c]	40.15 ± 0.11 [b]	50.15± 0.09 [a]	52.09 ± 0.12 [a]	54.06 ± 0.15 [a]
72 h	25.21± 0.10 [c]	30.00 ± 0.11 [b]	51.56± 0.09 [a]	53.00 ± 0.13 [a]	55.16 ± 0.12 [a]
Fiber % (0.05 ± 0.00)					
24 h	0.07± 0.01 [b]	0.06± 0.01 [b]	0.08 ± 0.01 [b]	0.09 ± 0.01 [b]	1.04 ± 0.02 [a]
48 h	0.05± 0.02 [c]	0.04 ± 0.02 [c]	0.25± 0.01 [b]	0.18 ± 0.01 [a]	1.09 ± 0.02 [a]
72 h	0.03± 0.01 [b]	0.03 ± 0.00 [b]	1.29± 0.09 [a]	1.34 ± 0.01 [a]	1.67 ± 0.02 [a]
TTA % (0.35 ± 002)					
24 h	0.25 ± 0.01 [a]	0.20± 0.01 [a]	0.28 ± 0.01 [a]	0.29 ± 0.01 [a]	0.29 ± 0.01 [a]
48 h	0.20 ± 0.02 [a]	0.15± 0.01 [a]	0.23± 0.04 [a]	0.20 ± 0.02 [a]	0.25 ± 0.02 [a]
72 h	0.08 ± 0.02 [b]	0.13± 0.02 [a]	0.17± 0.04 [a]	0.19 ± 0.01 [a]	0.20 ± 0.01 [a]
Total Sugar °Bx (4.56 ±0.01)					
24 h	6.68± 0.00 [a]	6.08 ± 0.00 [a]	5.76 ± 0.02 [b]	5.32 ± 0.01 [b]	5.73 ± 0.01 [b]
48 h	8.21± 0.02 [a]	7.89 ± 0.02 [b]	5.85± 0.01 [d]	6.65 ± 0.01 [c]	6.99 ± 0.02 [c]
72 h	9.33± 0.01 [a]	8.99 ± 0.01 [b]	6.10± 0.01 [d]	7.22 ± 0.00 [c]	7.99 ± 0.00 [c]
pH (4.35 ± 0.02)					
24 h	4.40± 0.02 [a]	4.45 ± 0.01 [a]	2.00 ± 0.04 [b]	2.16 ± 0.02 [b]	2.28 ± 0.01 [b]
48 h	4.42± 0.01 [a]	4.58 ± 0.01 [a]	1.41± 0.01 [c]	2.00 ± 0.01 [b]	2.10 ± 0.01 [b]
72 h	4.47± 0.02 [a]	4.64 ± 0.02 [a]	1.09 ± 0.02 [b]	1.67 ± 0.00 [b]	1.88 ± 0.03 [b]
Vitamin C mg/100g (4.60 ± 0.02)					
24 h	4.79± 0.03 [a]	4.32 ± 0.03 [a]	2.98 ± 0.02 [c]	3.70 ± 0.02 [b]	3.73 ± 0.01 [b]
48 h	5.08 ± 0.04 [a]	4.58 ± 0.01 [b]	1.55± 0.01 [d]	2.19 ± 0.02 [c]	2.48 ± 0.01 [c]
72 h	6.16 ± 0.04 [a]	5.78 ± 0.03 [a]	1.07± 0.02 [b]	1.29 ± 0.02 [b]	1.82 ± 0.00 [b]

Values are means ± standard deviation of triplicate determinations. Means bearing the same alphabet superscripts within the same row are significantly different ($p<0.05$).

Table 2: Changes in physicochemical composition of pawpaw during ripening

Storage time(h)	Treatments				
	Traditional			Chemical	
	Pawpaw naturally ripened on open shelf (PNR)	Pawpaw placed in air tight bags (PAB))	Pawpaw blanched in with hot water (PBHW)	Pawpaw treated with ethephon (PTE)	Pawpaw treated with calcium carbide (PTCC)
Moisture % (89.00± 0.32					
24 h	91.43 ± 0.20[b]	93.66± 0.21[b]	95.56 ± 0.28[a]	94.67 ± 0.28[a]	94.12 ± 0.28[a]
48 h	71.65 ± 0.15[c]	94.40± 0.27[b]	96.44± 0.16[a]	93.66 ± 0.22[a]	95.34 ± 0.27[a]
72 h	63.21 ± 0.15[c]	97.21± 0.21[b]	98.22± 0.16[a]	95.32 ± 0.17[b]	96.33 ± 0.16[b]
Crude fat % (0.23± 0.01)					
24 h	0.25± 0.01[a]	0.22 ± 0.01[a]	0.08 ± 0.01[c]	0.17 ± 0.02[b]	0.17 ± 0.02[b]
48 h	0.15± 0.01[a]	0.19± 0.02[a]	0.05± 0.03[c]	0.12 ± 0.01[b]	0.13 ± 0.02[b]
72 h	0.12± 0.01[a]	0.13 ± 0.01[a]	0.03± 0.02[d]	0.07 ± 0.01[c]	0.08 ± 0.01[b]
Crude protein % (0.30±0.00)					
24 h	0.35± 0.02[b]	0.35 ± 0.02[b]	0.21 ± 0.11[c]	0.40 ± 0.02[a]	0.42 ± 0.02[a]
48 h	0.46± 0.01[b]	0.40 ± 0.01[b]	0.17± 0.02[c]	0.53 ± 0.03[a]	0.54 ± 0.02[a]
72 h	0.63± 0.02[a]	0.55 ± 0.02[a]	0.06± 0.02[c]	0.85 ± 0.03[c]	0.96 ± 0.02[c]
Ash % (0.30 ± 0.00)					
24 h	0.37± 0.03[a]	0.35 ± 0.03[a]	0.27± 0.02[b]	0.31 ± 0.02[a]	0.35 ± 0.01[a]
48 h	0.41± 0.02[a]	0.37 ± 0.01[b]	0.21± 0.03[a]	0.25± 0.03[a]	0.30 ± 0.02[b]
72 h	0.50± 0.02[a]	0.48 ± 0.01[b]	0.14± 0.02[d]	0.20 ± 0.02[c]	0.23 ± 0.02[c]
Carbohydrate (11.76 ± 0.10)					
24 h	11.83± 0.02[b]	11.89 ± 0.06[b]	12.06 ± 0.09[a]	10.02 ± 0.12[c]	10.06 ± 0.11[c]
48 h	12.31± 0.11[b]	12.66 ± 0.11[b]	13.22± 0.09[a]	8.44 ± 0.13[d]	9.02± 0.12[c]
72 h	13.33± 0.11[b]	13.65 ± 0.11[b]	14.26± 0.09[a]	6.06 ± 0.12[d]	7.14 ± 0.12[c]
Fiber % (0.30 ± 0.01)					
24 h	0.30± 0.01[b]	0.32± 0.01[b]	0.39± 0.02[b]	0.35 ± 0.02[b]	0.38 ± 0.01[a]
48 h	0.26± 0.02[c]	0.26 ± 0.02[c]	0.79± 0.01[a]	0.54 ± 0.03[b]	0.75 ± 0.01[a]
72 h	0.14± 0.01[c]	0.20 ± 0.01[c]	0.32± 0.05[a]	0.73 ± 0.04[b]	0.87 ± 0.01[b]
TTA % (0.32 ± 002)					
24 h	0.20 ± 0.02[a]	0.20± 0.01[a]	0.26 ± 0.02[a]	0.25 ± 0.01[a]	0.25 ± 0.00[a]
48 h	0.14 ± 0.02[a]	0.18± 0.03[a]	0.18± 0.03[a]	0.72 ± 0.02[a]	0.70 ± 0.02[a]
72 h	0.10 ± 0.01[b]	0.13± 0.02[a]	0.16± 0.02[a]	1.15 ± 0.02[a]	1. 20± 0.02[a]
Total Sugar °Bx (7.60 ±0.01)					
24 h	13.43± 0.00[a]	14.07 ± 0.00[a]	6.75 ± 0.02[c]	8.02 ± 0.01[b]	8.65 ± 0.01[b]
48 h	14.23± 0.02[a]	14.99 ± 0.02[a]	6.32± 0.01[c]	8.15 ± 0.01[b]	8.76 ± 0.02[b]
72 h	15.24± 0.01[b]	16.33 ± 0.01[a]	7.18± 0.01[d]	8.62 ± 0.00[d]	9.19 ± 0.00[c]
pH (6.14 ± 0.03)					
24 h	6.50± 0.02[a]	6.91 ± 0.01[a]	3.30 ± 0.04[b]	5.18 ± 0.02[b]	5.24 ± 0.01[b]
48 h	6.42± 0.01[a]	6.94 ± 0.01[a]	2.53± 0.01[c]	5.00 ± 0.01[b]	5.30 ± 0.01[b]
72 h	7.22± 0.02[a]	7.77 ± 0.02[a]	2.00 ± 0.02[b]	4.47 ± 0.00[b]	4.99 ± 0.03[b]
Vitamin C mg/100g (0.03 ± 0.01)					
24 h	0.18± 0.03[a]	0.18 ± 0.03[a]	0.02 ± 0.02[c]	0.42 ± 0.01[b]	0.47 ± 0.02[b]
48 h	0.23 ± 0.02[a]	0.67 ± 0.02[b]	0.01± 0.00[d]	0.54 ± 0.01[c]	0.63 ± 0.03[c]
72 h	0.57 ± 0.02[a]	0.86 ± 0.03[a]	0.01± 0.00[b]	0.88 ± 0.02[b]	0.98 ± 0.03[b]

Values are means ± standard deviation of triplicate determinations. Means bearing the same alphabet superscripts within the same row are significantly different ($p<0.05$).

reported increased protein content in three types of fruits ripened with calcium carbide.

The fat content of unripe banana and pawpaw was 1.35 % and 0.23 %. The fat content in banana increased with increase in storage time in naturally ripened banana (1.54 %) and banana placed in air tight bags (1.50 %) while the chemically treated samples had decreased fat contents at 72 h storage. For pawpaw both the traditionally and chemically treated samples had decreased fat contents at 72 h. Significant differences were observed in the increasing and decreasing trend of fat contents. This result correlates with the findings of [8] that studied the effect of calcium carbide on the nutritional content of banana and reported that the fat content of the banana samples decreased during ripening. The ash content of unripe banana and pawpaw was 0.50 % and 0.30 %. The ash content in banana decreased with increase in storage time in naturally ripened banana (0.24 %) and banana placed in air tight bags (0.29 %) while samples treated with chemicals had increased ash contents at 72 h. For pawpaw, naturally ripened and air tight bag samples had increased ash contents of 0.50 % and 0.48 % while chemically treated samples had decreased ash contents. The ash content of the chemically ripened banana samples was significantly different from the traditionally ripened samples. The presence of increased ash contents in the traditionally treated pawpaw samples and chemically treated banana samples is an indication that they could serve as good sources of minerals. Similar result was obtained by [3] for banana varieties ripened using different methods and [2] for pawpaw ripened with different chemical agents. The carbohydrate content of unripe banana and pawpaw was 45.65 % and 11.56 %. The carbohydrate content in banana decreased with increase in storage time in naturally ripened banana (25.21 %) and banana placed in air tight bags (30.00 %). Banana blanched in hot water, treated with ethephon and calcium carbide had increased carbohydrate contents of 51.56 %, 55.16 % and 53.00 % at 72 h. Pawpaw samples treated traditionally had increased carbohydrate contents compared to the chemically treated samples at 72 h. Naturally ripened and air tight bag pawpaw samples had 13.33 % and 13.65 % carbohydrate contents while the blanched pawpaw sample had higher increased value (14.26 %) at 72 h. The increasing and decreasing trend in carbohydrate content of the chemically treated banana and pawpaw samples indicated significant differences between them and the traditionally treated samples during storage. This can be attributed to the increase in respiration rate caused by acetylene production. Results obtained shows that the naturally ripened pawpaw and chemical treated banana samples can provide energy to human body. This result agrees with that of [15] who investigated the effect of carbide on fruits and that of [5] who found that naturally ripened fruits had higher nutrients than artificially ripened fruits. The fiber content of unripe banana and pawpaw was 0.05 % and 0.30 %. The fiber content in banana decreased with increase in storage time in some of the traditionally ripened samples. Naturally ripened banana (0.03 %) and banana placed in air tight bags (0.03 %). Banana blanched in hot water, treated

with chemicals (ethephon and calcium carbide) had increased fibre contents of 1.29 %, 1.34 % and 1.67 % at 72 h of storage. The fibre content of banana samples treated with chemicals was significantly higher during storage. For pawpaw samples, the chemically treated samples had the highest fibre contents while the traditionally treated samples had lowest fibre contents. The presence of fibre in traditional and chemical banana and pawpaw samples is an indication that they are good sources of fibre which can help prevent constipation. Similar result was obtained by [3] for banana varieties ripened using different methods and that of [2] for pawpaw ripened with different chemical agents. The total titrable acidity content of unripe banana and pawpaw was 0.35 % and 0.32 %. The titrable content in banana decreased with increase in storage time in traditionally treated samples especially the naturally ripened banana (0.08 %) and banana placed in air tight bags (0.13 %). Banana blanched in hot water and treated with chemicals (ethephon and calcium carbide) also had decreased values of 0.17 %, 0.19 % and 0.20 % at 72 h of storage. No significant differences were observed between the traditionally and the chemically treated banana samples. Titrable acidity content of the traditionally and chemically ripened pawpaw was moderately different from each other. Ripening was observed to decrease the titrable acidity of pawpaw samples. This result agrees with that of [16] who investigated the effect of ripening agents on banana varieties. The sugar content of unripe banana and pawpaw was 4.56 % and 7.60 %. The sugar content in banana increased with increase in storage time in traditionally treated banana samples. Naturally ripened banana and banana placed in air tight bags had 9.33 % and 8.99 % sugar contents. Banana blanched in hot water, treated with ethepenom and calcium carbide chemicals also had increased values of 6.10 %, 7.22 % and 7.99 % at 72 h of storage. Banana samples that were traditionally ripened had higher sugar contents during storage and were significantly different from those that were chemically treated. Sugar content of traditionally treated pawpaw was significantly higher than the chemically treated samples. Pawpaw placed in air tight bags had the highest sugar content (16.33 %) followed by naturally ripened pawpaw with 15.24 % at 72 h. This result agrees with that of 16] who investigated the effect of ripening agents on banana varieties. The pH content of unripe banana and pawpaw was 4.35 % and 6.14 %. The pH content in banana increased with increase in storage time in naturally ripened banana (4.47 %) and banana placed in air tight bags (4.64 %). However, banana blanched in hot water, and samples treated with ethepenom and calcium carbide chemicals had decreased values of 1.09 %, 1.67 % and 1.88 % at 72 h of storage. The pH content of the traditionally treated banana samples was significantly higher than that of chemically treated samples during storage. Traditionally treated pawpaw samples had the highest pH contents compared to the chemically treated samples. Pawpaw placed in air tight bags had the highest pH content (7.77 %) followed by naturally ripened pawpaw with 7.22 % at 72 h. This result is in line with that of [17] who reported the effects of ripening agents on banana nutritional composition and [18] who reported the effect of calcium carbide on mango fruit. The vitamin C content of unripe banana and pawpaw was 4.60 % and 0.03 %. The vitamin C content in banana increased with increase in storage time in naturally ripened banana (6.16 %) and banana placed in air tight bags (5.78 %). But banana blanched in hot water, treated with ethepenom and calcium carbide had decreased values of 1.07 %, 1.29 % and 1.82 % at 72 h of storage. Pawpaw samples that were chemically treated with ethephon and calcium carbide had the highest vitamin C contents compared to the traditionally treated sample (air tight bags) with 0.86 % at 72 h. Significant differences were observed in both the traditionally and chemically treated banana and pawpaw samples during storage. This result tallies with those of [3], [19] for banana varieties ripened using different methods and [2] for pawpaw ripened with different chemical agents.

After 72 h of storage time the mean count of bacterlal isolates associated from the naturally ripened banana and pawpaw fruits are presented in **Table 3**. Microorganisms were found on the entire surface of the naturally ripened banana and pawpaw samples. Result showed that banana samples had the highest count of spoilage bacteria on its surfaces. The standard plate result in **Table 4** showed the different colonial forms of spoilage bacterial isolates isolated from both fruits. **Table 5** showed the characteristics of the spoilage bacterial species isolated from banana and pawpaw after 72 h. Table 6 showed the characteristics of fungal species identified in the banana and pawpaw fruits.

Table 3: Total viable plate count of bacterial species isolated from the naturally ripened banana and pawpaw fruits after 72 h.

Sample number	Mean count of Bacterial isolates/mL	
	Pawpaw	Banana
1	35	43
2	58	63
3	62	60
4	40	45
5	50	61
Mean count	**49**	**54.5**

Table 4: Standard plate count of colonial forms of spoilage bacterial pathogens isolated from the naturally ripened banana and pawpaw fruits after 72 h.

	Codes of isolated spoilage bacterial pathogens											
	Banana (*Musa* sp.)						Pawpaw (					
Sample number	A	B	C	D	E	F	A	B	C	D	E	F
1	20	30	15	23	10	10	19	28	12	31	12	12
2	15	24	10	20	6	12	21	30	10	22	9	9
3	21	16	10	24	12	11	14	15	11	18	5	8
4	18	17	12	18	8	9	19	10	11	14	7	12
5	10	11	6	23	2	8	22	18	21	10	3	10
Mean count	**16.8**	**19.6**	**10.6**	**21.6**	**7.6**	**10**	**19**	**20.2**	**13**	**19**	**7.2**	**10.2**

Table 5: Morphological and Biochemical Characteristics of the spoilage bacterial species isolated from naturally ripened banana and pawpaw after 72 h.

S/N	Morphology of bacterial species	Gram reactions	Lactose	Glucose	Catalase	Citrate	Oxidase	Coagulase	Suspected foodborne patogens
1	Rod shape *bacilli*	Gram negetive	-	+		+	+	Not detected	*Pseudomonas spp.*
2	Rod shape *bacilli*	Gram negetive	+	+	+	-	-	Not detected	*Escherichia coli*
3	Cocci shape	Gram positive	-	+	+	-	-	Not detected	*Micrococcus spp*
4	Cocci shape	Gram positive	-	+	+	+	-	+	*Stphylococcus aureus*
5	Rod shape *bacilli*	Gram negetive	+	+	+	+	-	Not detected	*Citrobacter spp*
6	Rod shape *bacilli*	Gram Negetive	-	-	+	+	-	Not detected	*Enterobacter spp*

Key:
A= *Pseudomonas spp*
B = *Escherichia coli*
C= *Micrococcus spp*
D= *Staphylococcus spp*
E= *Citrobacter spp*
F= *Enterobacter spp*

Table 6: Identification and Characteristics of spoilage Fungi isolated from naturally ripened banana and pawpaw after 72 h

S/N	Morphology appearance of fungi	Microscopic examination with lactophenol stain	Identified fungi
1	Front view appears as black colouration and reverse view as cream in colour	Aseptate hyphae with pigments	*Aspergillus flavus*
2	Appears smooth and shining with front and reverse view coloured pink	Aseptate hyphae with conidia at the tips	*Fusarium spp*
3	Colonies have yellow or white mycelim that are loose and turns dark brown rapidly and later to black after the development of conidia	Observed vesicles were brown and light in colour.The vesicles had phialides growing along its periphery.	*Aspergillus niger*

Microbiological result obtained in this study showed that three main

fungal species namely *A. flavus*, *A. niger* and *Fusarium* spp. were found in the banana and pawpaw fruits. Among the organisms isolated, *A. niger* is the most pathogenic strain. Generally, during storage of fruits, fungi isolated from them are often considered as toxigenic strains. The isolates of bacteria identified in this study include *Pseudomonas spp., Citrobacter spp., S. aureus, Enterobacter spp., Micrococcus spp. and E. coli.* This result agrees with the findings of [20] who reported similar fungal isolates in banana and sweet oranges.

7. Conclusion

The use of chemicals such as calcium the use of chemical ripening agents such as calcium carbide and ethephon leads to a reduction in the essential nutritional content of fruits. For instance, bananas ripened with calcium carbide exhibited decreased fat, protein, sugar, and vitamin C content, while showing an increase in moisture, carbohydrate, fiber, and ash levels.

In pawpaw, samples placed in airtight bags had the highest moisture, ash, fat, carbohydrate, sugar, and pH levels. However, samples ripened using calcium carbide had the highest protein, titratable acidity, and vitamin C content at 72 hours.

The isolation and identification of spoilage bacteria and fungi from the fruit samples indicate that they are highly susceptible to microbial deterioration after harvesting if not properly stored.

Overall, this study demonstrates that the use of chemical ripening agents results in a significant loss of essential nutrients in fruits. Therefore, traditional ripening methods, such as ripening in airtight bags or open shelves, are recommended to preserve fruit quality and nutritional value.

8. References

[1] Muthal, T., Harini, R., Sunil, C. K. and Chidanand, D. V. (2019). Effect of artificial ripening techniques on physico-chemical properties of banana (*Musa sp*) variety poovan. *Int J Pure App Biosci*, *7*, 482-9. http://dx.doi.org/10.18782/2320-7051.7453.

[2] Orisa, C. A. and Usoroh, C. I. (2020). Effects of accelerated ripening agents on the fruit quality of pawpaw (Carica papaya). ARC *Journal of Nutrition and Growth*, 6(2), 42-49. https://doi.org/10.20431/2455-2550.0602006 .

[3] Roy, M., Hazarika, J., Timung, B. and Basumatary, S. (2023). Effects of Various Indigenous Ripening Methods on Biochemical Characteristics of Banana Cv. Chenichampa. International Journal of Environment and Climate Change, 13(12), 173-177. https://doi.org/10.9734/IJECC/2023/v13i123672.

[4]. Hussain, A., Kausar, T., Siddique, T., Kabir, K., An, Q. U., Rukhsar, F. and Mahdi, A. A. (2024). Physiological and biochemical variations of naturally ripened mango (Mangifera Indica L.) with synthetic calcium carbide and ethylene. Scientific Reports, 14(1), 2121. https://doi.org/10.1038/s41598-024-52483-9.

[5]. Farouq, A. U. and Nwani, E. C. (2022). The Effects of Artificial Ripening (Calcium Carbide) on Pawpaw. American Journal of Food Science and Technology, 10(2), 84-88. https://doi.org/10.12691/ajfst-10-2-4.

[6].Association of Official Analytical Chemist, A.O.A.C. (2019). Official Methods of Analysis of the Association of Official Chemist.

7]. Pearson D. Pearsons Chemical Analysis of Foods. 8th Edn., Churchill Livingston, Edinburgh, 1981, 591.

[8]. Olubiyo, G. T., Obochi, V. U., Edogbanya, P. R. O., Olubiyo, C. K., Iyeh, V. A., Obaje, J. O. and Matthew, E. O. (2022). Evaluation of the Effect of Calcium Carbide as a Ripening Agent on the Nutritional Value and Heavy Metal Content of Banana and Orange. *Nigeria Agricultural Journal*, 53(3), 16-21.

[9]. Oseghale, F. O., Fasina, K. A., Ohifueme, A. and Omoruyi, J. (2020). Biocontrol of Food Spoilage Microorganisms using Leaf extracts from Magnifera indica (Mango) and Psidium guajava (Guava). *Journal of Chemical Society of Nigeria*, 45(4): 712-723.

[10]. Ugwuanyi, R. C., Chibuzor, C. A. and Onah, G. T. Isolation and Identification of Microorganisms Involved in the Spoilage of Pawpaw Fruit (*Carica papaya*) Enugu Metropolis, Nigeria. *Journal of Science and Technology* 4(1): 36-43

[11]. Mailafia, S., Olabode, H. O. K. and Osanupin, R. (2017). Isolation and identification of fungi associated with spoilt fruits vended in Gwagwalada market, Abuja, Nigeria. *Veterinary world*, 10(4), 393. https://doi.org/10.14202/vetworld.2017.393-397

[12]. Al-Garadi, M. A., Qaid, M. M., Alqhtani, A. H., Alhajj, M. S., Al-abdullatif, A. A. and Al Mufarrej, S. I. (2023). In Vitro antimicrobial efficacy assessment of ethanolic and aqueous extracts of cinnamon (*Cinnamomum Verum*) bark against selected microbes. *Brazilian Journal of Poultry Science*, 25(1), 001-016. https://doi.org/10.1590/1806-9061-2022-1682.

[13]. Nuhu, A. M., Rabi, A. and Tukur, H. R. (2020). Proximate and elemental analysis of banana fruits (*Musa spp*) ripened with various concentrations of calcium carbide. *Journal of Chemical Society of Nigeria*, 45(4).

[14]. Adeyemi, M. M., Bawa, M. H. and Muktar, B. (2018). Evaluation of the Effect of Calcium Carbide on Induce Ripening of Banana, Pawpaw and Mango cultivated within Kaduna Metropolis, Nigeria. *Journal of Chemical Society of Nigeria*, 43(2), 108-118.

[15]. Abubakar, F., Eleke, P. N. and Bawa, M. H. (2020). Effect of calcium carbide on concentration of trace elements in fruits grown within kaduna metropolis. *Int. J. Sci. Eng. Appl*, 9(1), 8-11.

[16]. Maduwanthi, S. D. T. and Marapana, R. A. U. J. (2019). Comparative study on aroma volatiles, organic acids, and sugars of Ambul banana (Musa acuminata, AAB) treated with induced ripening agents. *Journal of Food Quality*, 1-9. https://doi.org/10.1155/2019/7653154

[17].Sogo-Temi, C. M., Idowu, O. A. and Idowu, E. (2014). Effect of biological and chemical ripening agents on the nutritional and metal composition of banana (Musa spp). *Journal of Applied Sciences and Environmental Management*, 18(2), 243-246.

[18].Palpandian, P., Shanmugam, H., Rani, E. A. and Prabu, G. T. V. (2019).Determination of fruit quality of calcium carbide induced ripening in mango (*Mangifera indica* L. cv. *Alphonso*) by physiological, biochemical, bio-enzymatic and elemental composition analysis (EDX). *Indian Journal of Biochemistry and Biophysics* (IJBB), 56(3), 205-213.

[19].Tafinta, I. Y., Shehu, K., Abdulganiyyu, H., Rabe, A. M. and Usman, A. (2013). Isolation and identification of fungi associated with the spoilage of sweet orange (Citrus sinensis) fruits in Sokoto State. *Nigerian Journal of Basic and Applied Sciences*, 21(3), 193-196. http://dx.doi.org/10.4314/njbas.v21i3.4.

[20]. Oladipupo, A. R., Akinleye, M. O. and Coker, H. (2022). The use of calcium carbide in fruit ripening: Health risks and arsenic index as a quantitative marker for calcium carbide residue. *Progress in Chemical and Biochemical research*, 5(2), 125-132.

[21].Kifle, D. R., Bacha, K. B., Hora, R. N., & Likasa, L. L. (2024). Evaluation of microbiome and physico-chemical profiles of fresh fruits of *Musa paradisiaca*, *Citrus sinensis* and *Carica papaya* at different ripening stages: Implication to quality and safety management. *Plos one*, *19*(1), e0297574.