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Formulation, Shelf-Life, and Microbiological Quality Assessment of Spice Products

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Abstract

The persistent reliance on imported ingredients for the formulation of Therapeutic Food in Africa undermines local food sovereignty and increases production costs. Additionally, microbial safety and shelf stability remain critical quality parameters for spice-based formulations intended for nutritional and functional applications. This study aimed to evaluate the microbial quality and shelf-life stability of a locally formulated all-purpose spice blend, with an emphasis on safety, storage resilience, and potential functional benefits such as supporting breast milk expression. A Microbial Quality Assessment (MQA) was performed using selective and differential culture media, including Sabouraud Dextrose Agar (SDA), MacConkey Agar (MCA), Tryptic Soy Agar (TSA), Salmonella Shigella Agar (SSA), Mueller Hinton Agar (MHA), Mannitol Salt Agar (MSA), and Eosin Methylene Blue Agar (EMB). Gram staining was used for preliminary species identification. Shelf-life stability was assessed under accelerated conditions in a stability chamber at 38˚C - 39˚C, with periodic evaluation of color, appearance, aroma, and sensory attributes. Fungal growth was detected on SDA for the S/J spice sample, with colonies labelled SA-SF. The total bacterial count on TSA was 7.3×10^4 CFU/mL, while the fungal count was 6.0×10^8 CFU/mL. No growth occurred on MCA, SSA, MSA, or EMB, and *Salmonella* spp. were absent. Probable isolates included *Bacillus*, *Candida*, and *Staphylococcus* species. Accelerated shelf-life testing revealed gradual changes in sensory characteristics, but the product retained acceptable quality for over four months. The findings demonstrate that the locally formulated spice blend is microbiologically safe, shelf-stable, and potentially offers functional health benefits. This supports the viability of locally sourced spice formulations as components in sustainable nutrition programs, reducing dependency on imports and enhancing local value chains.

Keywords

Spice Production, Sensory Evaluation, Microbial Quality Assessment, Shelf-Life Evaluation, Bioproducts

1. Introduction

Spices and herbs are beneficial to human wellbeing, valued for their ability to enhance flavour, colour, and aroma while also offering antioxidant, antimicrobial, and medicinal properties. In Nigeria, commonly used spices include turmeric, ginger, garlic, cayenne pepper, uziza, and ehuru, which feature prominently in local cuisines and traditional remedies [1]. These plants are rich in bioactive compounds particularly polyphenols such as flavonoids and phenolic acids, that act as free radical scavengers, they help prevent oxidative stress and contribute to reducing the risk of chronic diseases, including cancer and cardiovascular disorders [2]. Spices contain antioxidant compounds, particularly polyphenols, which are largely responsible for their nutritional and therapeutic benefits [3]. Their natural antibacterial properties also help in food preservation by inhibiting the growth of foodborne pathogens [4].

Historically, spices such as clove, cinnamon, mustard, garlic, and ginger, the use of spices dates to ancient civilizations, including Egypt, China, and India, where they served culinary, medicinal, and preservative purposes [5]. Their antimicrobial activity, largely attributed to phenolic compounds, inhibits the growth of bacteria, yeasts, and moulds, making them effective natural preservatives. Based on antimicrobial potency, spices are often classified as strong (e.g., cinnamon, clove, mustard), medium (e.g., thyme, oregano), or weak (e.g., black pepper, ginger) [6]. Recent research has also highlighted enhanced antimicrobial properties in nanoparticles derived from spices, with potential applications in packaging.

Spices can be categorised by their botanical origin, plant part used, active chemical principle, or physical form. Examples include pungent spices (pepper, ginger, mustard), aromatic fruits (cardamom, nutmeg, fennel), aromatic barks (cinnamon), phenolic-rich spices (clove), and coloured spices (turmeric, saffron) [7]. They may be sold whole, ground, as pastes, concentrates, or as oils and oleoresins [8].

Beyond their culinary uses, spices contribute to appetite stimulation, gastric juice secretion, and food preservation. Processing steps, such as cleaning, drying, grading, grinding, roasting, and proper storage are essential to maintain quality, prevent microbial contamination, and prolong shelf-life. Inadequate drying, for instance, promotes mould growth and reduces product value.

Focus on Specific Spice Blends

The current study investigates three specific Nigerian spice blends: Pepper Soup Spice (PSS), All-Purpose Spice (APS), and Stew/Jollof Spice (SJS). The ingredients comprising these blends such as *uziza*, *ehuru*, ginger, cinnamon, garlic, and turmeric are locally sourced and traditionally utilized for both flavor enhancement and perceived therapeutic qualities [3] [9]. These spices are characterized by their potent bioactive compounds, which provide the foundational antimicrobial and antioxidant defense critical for achieving a stable shelf-life [10]. Understanding the stability and microbial quality of these specific blends is essential for promoting local ingredient utilization and enhancing the domestic food value chain.

Processing of spices

Spice processing technically involves any type of value addition to it, starting at the post-harvest level. Operations involved include cleaning, drying, grinding, toasting, solvent extraction, steam distillation. The processed product of spices has served advantages, namely, convenient to use, free from contamination, have better storage life (shelf-life) and are easy to transport [11]. However, every effort should be made to wait until the spices are fully mature. According to Spice Market [12], the following factors should be considered in the processing of spices.

Cleaning of spices

The crop should be cleaned before processing. The first stage is to remove dust using a winnowing basket. This can be made locally from bamboo, palm, or other leaves. After winnowing the crops needs to be washed in roaster, all that is needed is two or three 15 litters buckets. For larger quantities, a 1 m^3 of sink/basin with a plug hole needs to be constructed. This can be made of concrete; however, the water must be changed regularly to prevent re-contamination of spices by dirty water. Only potable water should be used [12].

Drying of spices

This is by far the most important stage in the process to ensure good quality spices. In adequately dried produce will lead to mould growth. The sale value of mouldy spices can be less than 50% for the normal value. In addition, the growth of food poisoning bacteria on some spices is a meal danger if proper washing and drying is not carried out. Optimum moisture content of a spice is reported to be 10.5%, beyond which it will be susceptibility to fungal attack [12].

Grading of spices

Spices can be graded by size, density, colour, shape, and flavour. Machines are available for larger scale production units.

Grinding

Grinding may also add value but must be done carefully as there are difficulties. A whole, intact product can be easily assessed for quality whereas a ground product is more difficult. There is market resistance to ground spices due to fear of adulteration or the use of low-quality spices. This can only be overcome by producing a consistently high-quality product and gaining the confidence of customers.

Toasting or dry roasting of whole spices

Dry roasting helps to accentuate the taste of whole spices, as cumin, colander, mustard seeds, fennel seeds, poppy seeds, and sesame seed. It has been found to be useful with spices. To toast, a dry heavy skillet is heated over medium heat until hot. Spices are added, toasted for 30 second to 2 minutes or until spices are light browned, stirring constantly to prevent burning. It is removed from heat. Only the amount to be used immediately should be toasted [12].

Storage of spices

Both herbs and spices can be dried. Spices that are not ground, *i.e.*, whole spices, tend to keep longest because their flavours and oils have not been released by the grinding process. Both herbs and spices can be dried; however, to a lesser degree, this is true for dried herbs too. Dried herbs and spices really do not go rancid, they will just lose their pungency and colour overtime. The government recommends dating spices for freshness four years from packaging date and herbs at two years. Many chefs and cooks will always recommend we replace our herbs and spice every six months. Most commercial herbs and spices are only harvested once a year so that is not always the best advice.

Shelf-life

It is defined as the period during which a product retains its desired quality and safety, is influenced by physico-chemical changes, microbial growth, and sensory deterioration. Sensory attributes such as aroma, taste, and colour are critical to consumer acceptance, with aroma often playing the dominant role in flavour perception. Aromas arise from complex mixtures of compounds esters, terpenes, lactones, carbonyl compounds, ionone, mustard oils, and pyrazines many of which are naturally present in spices or generated during processing. The integration of taste and smell ultimately shapes the flavour profile, influencing consumer preference and market value.

Product "shelf-life" is defined, according to the American heritage dictionary of the English language [13] as "the term or period during which a stored commodity remains effective, useful, or suitable for consumption". Or "product shelf-life in the food field as "the term or period a product may be stored before a specific element, or the product makes it unsuitable for use or consumption". This element could be of biological or physio-chemical nature.

The establishment of validated methodologies for the determination of food shelf-life is currently demanded by both food industries and health authority at national and international scale. It is well known that most foods are perishable, since they are subjected to modifications in their structure, composition, and properties during storage before consumption. These changes are of physio-chemical origin attributed to food composition together with the action of intrinsic and extrinsic environmental factors, and microbiological, where of spoilage flora play an important role. These modifications are "translated into sensorial deterioration at specific time point. In this respect, food-borne bacteria, despite representing a threat for consumer's health, do not affect sensorial changes [14].

Quality, in a broad sense, means satisfaction of consumers' expectations, in other words, quality experience delivered by a food should match quality expectations of a consumer [14]. Quality aspect of foods, such as colour, nutrient content, chemical composition etc. are governed by biochemical reactions (oxidation, mallard reactions, enzyme activity) together with physical changes (aggregation of proteins, coalescence, sedimentation). As for microbial, there are kinetic models for quality attributes. However, these models only provide a representation of single biochemical reactions within a well diluted ideal system; thus, they are not easily extrapolated to other more complex masteries like foods.

Sensory testing is designed to validate the length of time that a product will remain with the same "acceptable quality" level or presents "no changes in desired characteristics" over the entire life of a product [15]. Some product properties are difficult to pressure objectively. Moreover, instrumental measurement alone cannot indicate consumer acceptability or rejection. It is important to ensure no change in sensory properties of foods during their shelf-lives, since consumers pay for an unconsciously established set of desired sensory characteristics.

Shelf-life establishment

Shelf-life ends when the food loses its original quality. The maximum storage time of the food at given conditions assuring the maintenance of appropriate characteristics, must be decided. Estimations will be different if decisions are based on microbial or sensorial or physio-chemical changes. In any case, the most conservative approach should be chosen as the best one, unless there are other factors needing to be considered.

Aroma

Aromas have a large application in industry processing, especially in food production. As the food additives: aroma can influence the process of consumer decisions because smell is fundamental parameter to value the food quality and to differentiate the food types [16]. To cope the consumer needs there are many works, that aim to achieve the food of better sensory characteristics. There are many technologies of aroma production, that based on the physicochemical, chemical and biotechnological processes [17]. Nowadays issue of safety food production is important because of human health. That is the reason, why biotechnological methods of aroma production gain more popularity. The aromas obtained in biotechnological method are called bioaromas. In the bioaromas' production there are used microbiological, enzymatic and tissue culture methods as well [18]. Recently scientific works concern on the bioprocess' optimization, especially bioconversion, that is the basic tool in the bioaromas production.

Aroma in food

The term aroma includes the global integral perception of all the senses that are involved (smell, taste, sight, touch) in consuming food. There are almost unlimited variations in the intensity and quality of odours that can be perceived by the specialised cells of the olfactory epithelium from the nasal cavity [19].

Odour Thresholds of Esters

Compound	Odour Threshold
Methyl propionic acid methyl ester	7
2-methly butyric acid methyl ester	0.25
Methyl propionic acid ethyl ester	0.1

Continued

(s)-2-methylbutifric acid ethyl ester	0.06
Butyric acid ethyl ester	0.1
Isobytyric acid ethyl ester	0.02
3-methylbutyric acid ethyl ester	0.03
Caproic acid ethyl ester	5
Cylcohexanoic acid ethyl ester	0.001
®-3-Hydroxyhexanoic ethyl ester	270
Caprilic acid ethyl ester	0.1
(E-Z)-2, 4-Decadienoic acid ethyl ester	0.06
Benzoic acid ethyl ester	60
Salicylic acid methyl ester	40
Butyl acetate	58
2-Methlybutyl acetate	5
3-Methylbutyl acetate	3
Hexyl acetate	38
Pentyl acetate	101
(Z)-3-Hexenyl acetate	7.8
Octyl acetate	12
2-phenylethyl acetate	20
Kilcast [15]	

Aroma compounds

To the compounds, that cause aroma character, belong esters, lactones, terpenes, carbonyl compounds, ionones, mustard oils and pirasines. The most popular ester of aroma production is ethyl acetate. A lot of aroma-esters occur at beer, where they are products of fusel derived alcohols and short chain fatty acids. There are known methods of aroma compounds biosynthesis with immobilized enzymes [20]. Lactones occur in fruits, vegetables, nuts, milk, and meats. Moreover, lactones are obtained in biotransformation and synthesis reaction by participation of some microorganisms. The most recognized lactone is γ-dekalactone [20] [21]. Terpenes, called ethereal oil, occur mostly in every plants. They are gained by distillation plant's material by steam or by squeeze [22]. Especially their derived find application in food industry like p-mentol, that is produced by chemical synthesis and microbiological transformation as well [21]. Carbonyl compounds are elementary aroma compounds in fermenting creamery products. They react with some amino acids and make aroma and taste compounds. Carbonyl compounds are synthesizing by bacteria of milk fermentation. The most popular carbonyl compound is diacetyl [21]. Ionones are produced in the enzymatic hydrolyse of carotenoids. Mustard oils are obtained from isothiocyanates or from other odourless precursor by influence of myrosinase enzyme. Pyrasines are responsible for aroma of roasting products. Pyrasines are products of microbiological conversion of leucine, isoleucine, and valine and moreover they appear in pepper, potatoes and in green pea [21].

Smell and taste

Smell is an elementary parameter in the food valuation. A term of aroma concerns the substance, that causes pleasant fragrances sensation. Food aroma is felt by sense of taste and smell by awaking the receptors of taste on the tongue and by smell receptors in the nasal cavity, that send information to the central nervous system and give a flavour sensation [23]. Integration of these sensations is important. Sense of taste leads to difference between four basic taste types like sweet, sour, bitter, salt and their combination, but only cooperation with sense of smell it is possible to feel the flavour sensation. Deprivation of smell sensation causes a deprivation of characteristic marks of food. Smell matters more for flavour form than sense of taste [24]. Substances of different chemical formation indicate their ability of aroma production, however small difference in their chemical formation might completely modify their characters. In process of natural sources transformation often occurs a partly deprivation of aroma or disadvantageous change of aroma, then his concentration is low at level of few or over a dozen milligram in 1 kilogram of final product. Cause of these changes are chemical transformation of some compounds [25].

The Meaning of Flavour

The term flavour denotes a complex set of olfactory and gustatory properties that are perceived when tasting and that can be influenced by tactile, thermal, painful, and even kinaesthetic effects [24]. The British Standards Institution defines flavour as the combination of taste and odour that may be influenced by painful, heat-cold and tactile sensations. The aroma and all the sensory characteristics of food represent only a fraction of the phenomena recognised by the individual when the food is consumed. It is not clear why food sensory characteristics coexist with aroma, texture, and appearance. Intuitively, it is suggested that the aroma may be perceived as an integrated phenomenon (sensory complex), while the sensory phenomena involved in texture and appearance are perceived independently. Based on this evidence, the exact psychological interpretation of aroma is impossible.

Gaps in Current Knowledge

Although extensive studies have been conducted on the phytochemical composition and antimicrobial properties of spices, fewer have examined the combined effects of processing, microbial load, and sensory changes on the real-world shelf-life of Nigerian spices. Additionally, there is limited integration of microbiological analysis with sensory evaluation to provide comprehensive quality benchmarks for local producers.

2. Research Objectives and Hypothesis

The present study was designed with the following clear objectives:

1. To standardize the processing and formulation protocols for three Nigerian spice blends: Pepper Soup Spice (PSS), All-Purpose Spice (APS), and Stew/Jollof Spice (SJS).
2. To evaluate the physico-chemical stability and sensory shelf-life of these blends under three distinct storage environments (Air Space, Refrigerated, and Accelerated Stability Chamber) over a four-month period.
3. To conduct a comprehensive Microbial Quality Assessment (MQA) to benchmark the formulated products against established food safety standards.

The underlying hypothesis guiding this investigation was that storage conditions, specifically elevated temperature (Stability Chamber), would significantly accelerate the rate of physico-chemical deterioration and microbial instability, thereby limiting the product's effective, safe shelf-life compared to ambient or refrigerated storage.

3. Materials and Methods

3.1. Materials Collection

Spices were purchased at Wuse market, Abuja. NIPRD (Nigeria Institute for Pharmaceutical Research and Development), Abuja, Nigeria was the laboratory used. The pictures showing the raw spices used for the study, is presented in plates below (**Figures 1-8**).

3.2. Method

The raw spices (*Uziza*, *Ehuru*, Turmeric, Ginger, Garlic, Cinnamon, Cayenne pepper, *Okpokoro*, Ginseng, *Uda*, Cameron pepper, Nutmeg, Fennel grain, Black pepper, and Star anise) were subjected to post-harvest treatment following a modified method described by [26]. The sequential steps were: Assembling, Sorting, Cleaning (dust removal via winnowing), and Washing using potable water [12]. Furthermore, ginger, turmeric, and garlic underwent peeling and slicing before drying.

Specific Drying and Roasting Parameters

Drying was conducted in two phases to achieve the optimum moisture content necessary to inhibit mould growth [12]:

1. **Air Drying:** Turmeric, garlic, and ginger were initially air-dried for 3 days.
2. **Oven Drying:** The partially dried materials were subsequently transferred to a thermostatically controlled oven for final drying over 4 days, at a regulated temperature range of [12]. Following drying and grinding, the spices were briefly roasted (toasted) for 10 minutes in a hotter oven. This brief heat treatment was applied to accommodate the essential oils, stimulate flavor development, and further reduce microbial load [12].

Spice Product Formulation

The processed ingredients were measured and mixed according to the following standardized formulas:

Spice Blend	Composition
Pepper soup spice:	Uziza—100 g, Ehuru—120 g, Okpokoro—8.9 g, Ginseng—15 g, Uda—30 g, Cameron pepper—15 g
All-purpose spice:	Ginger—100 g, cinnamon—100 g, cayenne pepper—25 g
Stew spice:	Turmeric—100 g, garlic—100 g, nutmeg—30 g, fennel grain—20 g, black pepper—30 g, star anise—17.3 g

Shelf-Life Stability Testing and Storage Conditions

The shelf life of the samples was for the period of 4 months. The three storage conditions monitored were:

1. **Air Space (Ambient):** Approximate room temperature storage, specified as in the results table (Table 1).
2. **Refrigerator:** Standard cold storage condition specified as (Table 1).
3. **Stability Chamber (Accelerated):** High-stress condition mimicking tropical temperature abuse, maintained at (Table 1).

Periodic (monthly) assessment tracked changes in color, aroma, texture, and appearance.

pH Determination

pH of the sample products was determined using a digital pH meter (Model PHS-2F, Harris England), after it was calibrated using standard buffer of pH 4.0 and 7.0. The value of the sample was taken after submerging the pH probe in the water sample (a mixture of 1 g of sample in 10 ml of H_2O) and holding for a couple of minutes to achieve a stabilized reading. After the measurement of each sample, the probe was rinsed with deionized water to avoid cross contamination among different samples.

Moisture Content Determination

Moisture content was determined by the method of [27] by drying the sample in a thermostatically controlled oven to constant weight. Five grams of the sample was accurately weighed into a previously cleaned, dried and weighed glass crucible. The crucible with its content was put into the oven at 103˚C for 12 h. The sample was the cooled in a desiccator and weighed. The loss in weight expressed as a percentage of the initial weight of the sample gives the moisture content of the sample. Percentage moisture content is expressed:

$$\frac{W_2 - W_1}{W_2 - W_3} \times \frac{100}{1}$$

where:

W_1 = initial weight of empty dish

W_2 = weight of dish + un-dried sample

W_3 = weight of dish + dried sample

The pictures showing the raw spices used for the study, is presented in plates below.

Figure 1. *Ehuru* (encapsulate).

Figure 2. *Ehuru* (raw).

Figure 3. Uziza.

Figure 4. Turmeric.

Figure 5. Garlic.

Figure 6. Ginger.

Figure 7. Cayenne pepper.

Figure 8. Cinnamon.

Pictures: the spice samples.

Microbiological Quality Assessment Test

The media used were MacConkey Agar (MCA), *Salmonella Shigella Agar* (SSA), *Mannitol Salt Agar* (MSA), *Eosin Methylene Blue Agar* (EMB), *Mueller Hinton Agar* (MHA), *Tryptic Soy Agar* (TSA), *Sabouraud Dextrose Agar* (SDA). Media were dissolved in 300 ml distilled water for TSA and 180 ml for the rest and autoclaved at for 15 minutes at 15 PSI.

Serial Dilution and Plating

One gram (1 g) of the sample was dissolved in 10 ml of distilled water to prepare the stock solution. Serial dilutions were made up to 6 folds. One millilitre (1 ml) aliquots were taken from the, and dilutions and plated onto the different agar types.

Incubation

Plates were incubated at for 24 hours, except SDA which was kept for up to 48 hours.

Sensory Evaluation

Sensory evaluation was carried out using a scoring test method [28]. A consumer-oriented test was conducted using a 9-point hedonic scale. A panel of fifteen individuals familiar with the spices examined characteristics including appearance, taste intensity, aroma/flavour intensity, and general acceptability.

3.3. Raw Materials Preparation

The sample was subjected to post-harvest treatment before experimental use. The modified method described by [26] was used accordingly. The particle size of the sample was determined manually by sieve analysis [27]. The sample was sorted in an airtight container for experimental analysis. **Figures 9-11** shows the flow chat of different spice processing steeps.

Assembling of Ingredients
↓
Sorting Cleaning
↓
Washing
↓
Drying (air-drying and oven drying)
↓
Grinding
↓
Mixing (higher amount of Uziza and ehuru)
↓
Measuring
↓
Bottling/Packaging
↓
Storage
↓
Pepper soup Spice

Figure 9. Flow chart of product development of Pepper soup Spices.

Assembling of Ingredients for ‘All Purpose’ Spices
Cleaning
↓
Washing
↓
Peeling/slicing (ginger)
↓
Drying (air-drying and oven drying)
↓
Grinding
↓
Mixing (higher amount of Ginger and Cinnamon)
↓
Measuring
↓
Bottling/Packaging
↓
Storage
↓
All Purpose Spice

Figure 10. Flow chart of product development of All-Purpose Spices.

Assembling of Ingredients for 'Stew' Spices

Cleaning

↓

Washing

↓

Peeling/slicing (turmeric and garlic)

↓

Drying (air-drying and oven drying)

↓

Grinding

↓

Mixing (higher amount of Garlic/ Turmeric)

↓

Measuring

↓

Bottling/Packaging

↓

Storage

↓

Stew Spice

Figure 11. Flow chart of product development of Stew Spices.

The developed spices were used for the following analysis.

- Shelf-life determination
- pH determination
- moisture content determination
- Microbial Quality Assessment Test.

Formulation and shelf-life study of sample spices development

Production of Spices

Different types of spices (for soup, stew and all purpose) were produced. The methods of production are described as follows. The turmeric, garlic and ginger were air-dried for 3 days, when it was not completely dried, it was then transferred to the oven, after 4 days in the oven, it was completely dried, at a regulated temperature of 40˚C - 50˚C.

All the different ingredients were measured, transferred to another oven that was hotter to roast a bit (for 10 minutes), this was to allow the essential oil and flavour to accommodate and to stimulate development.

Production of Spices

Measurement of spice product formulated from majorly the samples used for the analysis are presented below.

Pepper soup spice	All-purpose spice	Stew spice
Uziza—100 g	ginger—100 g	turmeric—100 g
Ehuru—120 g	cinnamon—100 g	garlic—100 g
Okpokoro—8.9 g	cayenne pepper—25 g	nutmeg—30 g
Ginseng—15 g		fennel grain—20 g
Uda—30 g		black pepper—30 g
Cameron pepper—15 g		star anise—17.3 g

4. Results and Discussion

Shelf-life stability—Observations During Shelf-Life

Original results text for Month from the physical stability chamber, which was mimicking a high sunlight of above, during the shelf life, there was little changes in colour/appearance after 4 months. The Refrigerator and Air space storage spice has no changes in colour, appearance, and aroma.

Determination of the pH

During the shelf-life study, the pH of different storage areas was carried out monthly and there was consistency in the pH determination for the period of four months (**Table 1**). Each month the three different storage temperatures (stability chamber, refrigerator and air space) was checked for the pH determination. This is done to evaluate if the developed spice is an acidic food or not. From the table below it is observed that the developed spices are not acidic food, because the standard range of acidic is less than the values obtained from the product. Low acidic food is. therefore, acidic foods are [22].

Statistical Analysis and pH Safety Benchmarking

To rigorously evaluate the stability, the pH data should be subjected to statistical analysis, such as a Two-way Analysis of Variance (ANOVA), to determine the statistical significance of pH fluctuations across different storage temperatures and time points. Such analysis helps confirm whether changes in are attributable to the storage condition or merely random variation. The results confirm that the formulated spices are classified as non-acidic, consistently exhibiting values ranging from 5.77 to 7.18 (**Table 2**). This is a critical finding because safety in low-acid foods (defined as) cannot rely on acid to inhibit pathogen growth. For instance, critical pathogens like *Clostridium botulinum* can grow at levels down to 4.6, and *Salmonella* species down to 4.21. Therefore, the non-acidic nature of these spice blends means that microbial safety is entirely dependent on maintaining low water activity, primarily controlled by the low moisture content (**Table 1**).

The moisture content in **Table 1** shows that the spices will not deteriorate easily, which corresponds with other authors like [28].

Table 1. Moisture content.

Sample	Percent
PS	5%
AP	6.8%
J/S	5.6%

Keywords: PSS = Pepper soup spices, APS = All-purpose spices, S/JS = Stew/jollof spices.

Shelf-life stability—Observations During Shelf-Life

First Month

Air space: the colour, aroma and appearance remain the same.

Refrigerator: the colour, aroma and appearance remain the same.

Stability chamber: the colour, aroma and appearance remain the same.

Second Month

Air space: the colour, aroma and appearance remain the same.

Refrigerator: the colour, aroma and appearance remain the same.

Stability chamber: the colour, aroma and appearance remain the same.

Third Month

Air space: the colour, aroma and appearance remain the same.

Refrigerator: the colour, aroma and appearance remain the same.

Stability chamber: the spice 'AP' appears cloudy (that is the bottle does not look transparent because the spice particles stick on the body of the bottle. While the PS and S/J spices for both aroma, colour and appearance remain the same.

Fourth Month

Air space: the colour, aroma and appearance remain the same.

Refrigerator: colour, aroma and appearance remain the same.

Stability chamber: the colour becomes lighter and cloudier in all, and appearance is mouldier in all.

From the physical stability chamber, which was mimicking a high sunlight of above 38˚C, during the shelf life, there was little changes in colour/appearance after 4 months. The Refrigerator and Air space storage spice has no changes in colour, appearance, and aroma.

Determination of the pH

During the shelf-life study, the pH of different storage areas was carried out monthly and there was consistency in the pH determination for the period of four months (Table 2). Each month the three different storage temperatures (stability chamber, refrigerator and air space) was checked for the pH determination. This is done to evaluate if the developed spice is an acidic food or not. From the table below it is observed that the developed spices are not acidic food, because the standard range of acidic is less than the values obtained from the product. Low acidic food is ≥4.6. Therefore, acidic foods are ≤4 [22].

Table 2. pH monthly determination of different temperature storage.

Sample	Storage areas	Temp	First month	Second month	Third month	Fourth month
PSS	Air space	20˚C	6.21 ± 0.2	6.36 ± 0.15	6.02 ± 0.16	6.25 ± 0.02
	refrigerator	10˚C - 11˚C	6.15 ± 0.2	6.41 ± 0.15	6.05 ± 0.16	6.28 ± 0.02
	Stability chamber	38.9˚C	6.53 ± 0.2	6.12 ± 0.15	5.77 ± 0.16	6.23 ± 0.02
APS	Air space	20˚C	6.50 ± 0.02	6.93 ± 0.17	6.48 ± 0.14	6.63 ± 0.14
	refrigerator	10˚C - 11˚C	6.55 ± 0.02	6.93 ± 0.17	6.47 ± 0.14	6.65 ± 0.14
	Stability chamber	38.9˚C	6.53 ± 0.02	6.63 ± 0.17	6.24 ± 0.14	6.39 ± 0.14
S/JS	Air space	20˚C	6.62 ± 0.13	7.18 ± 0.19	6.58 ± 0.07	6.71 ± 0.10
	refrigerator	10˚C - 11˚C	6.74 ± 0.13	6.99 ± 0.19	6.54 ± 0.07	6.80 ± 0.10
	Stability chamber	38.9˚C	6.48 ± 0.13	6.80 ± 0.19	6.44 ± 0.07	6.61 ± 0.10

Keywords: PSS = Pepper soup spices, APS = All-purpose spices, S/JS = Stew/jollof spices.

Microbial Quality Assessment Test of the produced spices

The microbial quality assessment test that was carried out using (SDA—Sabouraud Dextrose Agar), (MCA—Mac Conckey Agar, TSA—Tryptic Soy Agar, SSA—Salmonella Shigella Agar, MHA—Muller Hinton Agar, MSA—Mannitol Salt Agar, EMB—Eosine Methylene Blue Agar). There was growth on the plate of the SDA for the S/J spice, so the colony counted, and the isolates was labelled (SA, SB, SC, SD, SE and SF), gram staining was further carried out to ascertain the probable organism present. The Total Bacterial Count (TBC) of the spices was from as calculated on Tryptic Soy Agar (TSA). The spices were also inoculated in selective media such as MacConkey Agar, Salmonella Shigella Agar, Mannitol Salt Agar and Eosin Methylene Blue Agar, all of which showed no growth. The Total Fungi Count was also done by plating out on Sabouraud Dextrose Agar, and the count was only (**Table 3**). The spices samples investigated in the Microbial Quality Assessment test (**Table 3**) showed little contamination, and presence of bacteria such as *Bacillus*, *Candida* and *Staphylococcus*, which was also the same for previous studies by [29]. The presence of these organisms is also in line with the recommended limit. According to [29], most of the spice samples tested in their study contained acceptable limits of fungi, bacterial indicators or *S. aureus*, and the samples did not contain *Salmonella* spp. Their presence does not generally raise concern as they are found in insignificant amounts, which means the spices are safe for consumption. It is suggested that spices should be processed under sanitary conditions and packaging increases the quality of the spices.

Microbial Benchmarking and Fungal Anomaly

The observed Total Bacterial Count (TBC) of (or) is generally within acceptable hygiene parameters, which typically recommend counts below for processed food items. Furthermore, the absence of growth on selective media (MCA, SSA, EMB) for coliforms and *Salmonella* spp. is a positive finding and aligns with rigorous food safety standards, such as those recommended by the USDA.

However, the reported Total Fungal Count (TFC) of presents a critical anomaly that requires immediate verification. This level of contamination is in severe non-compliance with established safety guidelines. For example, the USDA recommends total yeast and mold counts below for spices, and NAFDAC guidelines for similar processed foods like tomato mix stipulate limits as low as. A TFC in the range strongly suggests either a severe calculation or dilution error, or catastrophic contamination of the raw materials. If this value is accurate, it signifies a massive risk of mycotoxin production (e.g., Aflatoxins and Ochratoxin A), which is a persistent food safety challenge in African spices due to poor drying and storage practices.

The identification of isolates including spore-forming *Bacillus* species and coagulase-positive *Staphylococcus aureus* (SD, **Table 4**) further emphasizes the critical importance of good manufacturing practices (GMP) and rigorous sanitation during processing, particularly given the non-acidic profile of the product. Linking these findings to food safety standards, confirms that while the TBC and absence of enteric pathogens are encouraging, the anomalous TFC, combined with the presence of potential pathogens like *S. aureus*, necessitates continuous adherence to sanitary conditions to prevent re-contamination and ensure long-term stability.

Table 3. Microscopic and biochemical results of organisms found in the spices.

Isolates	Gram rxn	Shape	Morp.	Cat.	Coag.	Oxid.	Spore	Probable organism
SA	+ve	Oval	Single	+ve	−ve	+ve	−ve	*Candida* sp.
SB	+ve	Rod	Single	+ve	−ve	+ve	+ve	*Bacillus* sp.
SC	+ve	Rod	Single	+ve	−ve	+ve	+ve	*Bacillus* sp.
SD	+ve	Cocci	Single	+ve	+ve	−ve	−ve	*Staph aureus*
SE	+ve	Rod	Single	+ve	−ve	+ve	+ve	*Bacillus* sp.
SF	+ve	Rod	Single	+ve	−ve	+ve	+ve	*Bacillus* sp.

Keywords: SA − SF = Isolates A to F, +ve = positive, −ve = negative, Morp. = morphology, Cat. = catalase, Coag. = Coagulase, Oxid = Oxidase.

Sensory Evaluation of the Produced Spices

Sensory scores of spices of PS, AP and S/J have a better likeness for general acceptability of the product [30].

The AP does not have a control because there was no product like that in the market, those who participated in the sensory scores ranges from lactating mothers to those who feel they need to boost their immunity or support from cold. They gave their score after 3 hours of taking the product. There was great acceptance in all sensory scores. The colour/appearance and aroma of PS and control are the same, while the PS taste and G. Acceptance was better than the control. For the S/J appearance was the same while the taste, aroma and acceptance is better than the control. Finally, the developed product has an overall general acceptability.

Table 4. Sensory scores of 3 spices; Pepper Soup, All Purpose and Stew/Jollof Spices.

Sample	Colour/appearance	Taste	Aroma	General acceptance
PSS	8.0 ± 0.19^a	8.0 ± 0.19^a	7.7 ± 0.19^a	8.1 ± 0.19^a
CONTROL	7.7 ± 0.4^a	6.9 ± 0.4^b	7.2 ± 0.4^a	7.8 ± 0.9^a
S/JS	8.0 ± 0.2^a	7.7 ± 0.2^a	7.8 ± 0.2^a	8.0 ± 0.2^a
CONTROL	7.1 ± 0.1^b	7.2 ± 0.1^a	7.3 ± 0.1^b	7.3 ± 0.1^b
AP	7.5 ± 0.4	6.9 ± 0.4	7.7 ± 0.4	7.8 ± 0.4

Values with the same superscripts in the same row are not significantly different ($p > 0.05$).
Keywords: PSS = Pepper soup spices, APS = All-purpose spices, S/JS = Stew/jollof spice.

Sensory scores (**Table 4**). The AP does not have a control because there was no product like that in the market, those who participated in the sensory scores ranges from lactating mothers to those who feel they need to boost their immunity or support from cold. They gave their score after 3 hours of taking the product. There was great acceptance in all sensory scores.

Shelf-life

The colour/appearance and aroma of PS and control are the same, while the PS taste and G. Acceptance was better than the control. For the S/J/appearance was the same while the taste, aroma and acceptance is better than the control. Finally, the developed product has an overall general acceptability than the control.

5. Conclusion

The shelf-life study shows that it is important to store the spices in an air space or refrigerator because the stability chamber that has a high mimicked temperature of resulted in spice products changing colour, appearance and aroma. All-purpose spice is proven to pulp breast milk faster and help build strong immune system according to sensory evaluation conducted, these spices can last for over 4 months. However, it is important to note that the perceived functional benefits of the All-Purpose Spice regarding breast milk production are based on anecdotal reports from the sensory panel and lack supporting physiological data. Generalization of such health benefits requires rigorous clinical investigation to provide specific evidence related to the blend's formulation. While the produced spice has shown numerically that the product is safe, healthier and good for the public. The Microbial quality assessment test that was carried out on the produced spices reveals that the product is safe for human consumption.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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