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Research Article

INFLUENCE OF BIOACTIVE SPICE EXTRACTS ON THE FUNCTIONAL AND MICROBIAL INTEGRITY OF A TRADITIONAL FERMENTED RICE FOOD

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ABSTRACT

Background:
This study investigates the impact of incorporating natural spices ginger (Zingiber officinale), garlic (Allium sativum), and cloves (Syzygium aromaticum) at concentrations of 1%, 3%, and 5% on the microbial stability, physicochemical properties, nutritional composition, sensory attributes, and safety of Sinasir (Rice pancake), a traditional Nigerian fermented rice cake.
Methods: Over an 8-week storage period, samples were analyzed for microbial load, pH, temperature, titratable acidity, proximate composition (carbohydrates, moisture, fat, ash, protein, and fiber), sensory evaluation, hazard analysis, and antimicrobial sensitivity.
Results: this finding indicated that spice-treated samples, particularly those with 5% clove and garlic, exhibited significantly lower bacterial and coliform counts compared to the control, which reached TNTC by week 4. The 5% clove sample maintained bacterial counts below 3.6×10^5 CFU/g at week 8. pH levels in spiced samples remained acidic (4.2–4.5), while the control increased to 5.8, correlating with spoilage. Moisture content decreased with higher spice concentrations, enhancing shelf stability. The 5% garlic sample showed the highest protein content (9.85%), and the 5% clove sample had the highest ash content (2.41%). Sensory evaluation favored 3% and 5% spice-treated samples. The bacterial isolates include Bacillus cereus, Pseudomonas aeruginosa, Enterobacter aerogenes, and Lactobacillus fermentum. Antimicrobial assays revealed significant inhibition zones against foodborne pathogens, particularly for clove and garlic extracts.
Conclusion: These findings support the use of local spices in improving the safety, quality, and acceptability of traditional fermented foods.

Keywords: Sinasir, Rice pancake, ginger, garlic, cloves, fermented food, microbial load, proximate, analysis, antimicrobial, activity, sensory, quality

INTRODUCTION

Food is more than sustenance; it is memory, culture, and identity. Across the world, fermented foods occupy a unique space at this intersection. They are celebrated not only for their flavors and textures but also for their ability to transform simple ingredients into nutritionally enhanced, microbiologically diverse, and shelf-stable products. From kimchi in Korea to sauerkraut in Germany, injera in Ethiopia, and Sinasir in Northern Nigeria, fermentation embodies both ancient ingenuity and modern relevance [1]. In resource-limited settings, fermented foods remain indispensable, offering affordable nutrition to millions who face food insecurity [2].

Despite their importance, traditional fermented foods are vulnerable. Their production often occurs under informal conditions such as family kitchens, community gatherings, or small-scale roadside vendors where temperature control, hygienic monitoring, and microbial surveillance are difficult to enforce. Consequently, the safety of such foods is frequently compromised by contamination with pathogenic microorganisms. Outbreaks of foodborne illness continue to underscore this vulnerability, raising critical questions about how to preserve the cultural integrity of these foods while ensuring their safety and marketability in a globalized world [3].

One promising solution lies within the same cultural frameworks that gave rise to these foods in the first place: the use of spices. For centuries, communities have incorporated spices not only for flavor but also for preservation. Garlic, ginger, and cloves are ubiquitous in African and Asian cuisines, valued in both kitchens and traditional medicine. Modern science affirms what ancient cultures intuited. These spices harbor bioactive compounds such as allicin in garlic, gingerol in ginger, and eugenol in cloves that confer antimicrobial and antioxidant effects [4]. By integrating these naturally occurring compounds into fermentation processes, it may be possible to mitigate microbial risks while enhancing nutritional and sensory quality.

The case of Sinasir, a rice-based pancake widely consumed in Northern Nigeria, illustrates this challenge and opportunity. Beloved for its soft texture and mild sour flavor, Sinasir is more than a meal; it is a staple of community life, served during festivals, weddings, and family gatherings. Yet its short shelf life and susceptibility to microbial spoilage limit its distribution beyond local markets [5]. Without intervention, its role risks being diminished in an era where food safety standards increasingly dictate global trade and acceptance. By applying locally accessible spice extracts, it may be possible to preserve not only the food but also the cultural continuity it represents.

This endeavor has broader implications. The growing global movement toward “clean label” foods, which refers to products free of synthetic preservatives, demands natural and sustainable solutions [6]. Fermented foods enhanced with bioactive spices align with this demand by bridging traditional knowledge with contemporary food science. Moreover, with climate change threatening food supply chains and antimicrobial resistance rising, the search for natural preservation strategies is more urgent than ever [7].

In this study, we investigate how spice extracts of garlic, ginger, and clove affect the microbial stability, nutritional composition, and sensory attributes of Sinasir. Beyond the laboratory, the aim is to demonstrate how traditional ethnobotanical practices can be harnessed to address modern food security challenges. By situating local foods within a global scientific framework, this study highlights how indigenous knowledge remains a reservoir of solutions for future food sustainability.

MATERIAL AND METHODS

Sample Collection and Preparation

The core ingredients for Sinasir (rice pancake), namely rice, sugar, yeast, and salt, were purchased from Kurmi Market in Kano, Nigeria. Preparation followed traditional household practices with controlled adjustments to ensure reproducibility. A total of 600 g of rice was used. Out of this, 550 g was soaked in water for 12 hours to initiate partial fermentation, while 50 g was cooked to provide gelatinized starch that improves texture. The soaked and cooked rice were then combined and wet-milled into a batter. Yeast, sugar, and salt were added in standardized quantities, after which the mixture was allowed to ferment for 5 hours. The fermented batter was stirred to incorporate air, reflecting artisanal preparation techniques, and pan-fried to produce Sinasir.

Preparation of Spice Extracts

Ginger (Zingiber officinale), garlic (Allium sativum), and cloves (Syzygium aromaticum) were chosen because of their widespread culinary and medicinal use in Nigeria. After thorough washing, the spices were sliced, shade-dried, and ground into fine powders. Fifty grams of each spice were soaked in 120 ml of distilled water at room temperature for 72 hours to extract bioactive compounds, following the method described by Sah et al. 2020 [8]. The extracts were filtered through Whatman filter paper to remove solid particles and refrigerated at 4°C until use. To evaluate concentration-dependent effects, spice extracts were incorporated into the Sinasir batter at 1 percent, 3 percent, and 5 percent. Prepared pancakes were labeled, refrigerated, and observed over an 8-week storage period.

Microbial Enumeration and Isolation

Microbial stability was evaluated by determining total bacterial counts immediately after production and at weekly intervals during storage. Twenty-five grams of each sample were aseptically homogenized in 225ml of buffered peptone water [9]. Serial dilutions were prepared and plated using the pour-plate technique. One milliliter of each dilution was transferred into sterile Petri dishes and mixed with molten nutrient agar maintained at 45°C. The plates were gently swirled to ensure uniform distribution, solidified, and incubated at 37°C for 24 hours. Plates with 30 to 300 colonies were enumerated, and the results expressed as colony-forming units per gram (CFU/g) [10]. Fungal counts were assessed using the same protocol, except that Potato Dextrose Agar (PDA) was used and plates were incubated at room temperature for 3 to 5 days.

Microbiological Characterization

Standard plate count methods were used to evaluate viable bacteria, coliforms, and fungi at weeks 0, 2, 4, 6, and 8 [11]. Isolates were further characterized using biochemical tests including catalase, citrate, methyl red–Voges Proskauer (MR-VP), indole, and triple sugar iron (TSI). These tests provide insights into the metabolic activities of microorganisms [12].

Physicochemical Analyses

pH Measurement

The acidity of Sinasir was monitored as a marker of fermentation. Three grams of sample were homogenized in 10 ml of distilled water. The slurry was transferred into a beaker, and a calibrated pH meter (Model 501) with a temperature probe was immersed until a stable reading was obtained [13].

Titratable Acidity

Titratable acidity was determined as described by Akpakpan et al [14]. A 3 g sample was homogenized in 10 ml of distilled water, after which five drops of phenolphthalein indicator were added. The mixture was titrated against 0.1 N NaOH until the first permanent pink coloration was observed. Results were expressed as percentage lactic acid equivalents, and ambient temperature (25–28°C) was recorded during analysis.

Proximate Composition

Nutritional quality was determined by proximate analysis of moisture, ash, protein, fat, crude fiber, and carbohydrate contents using standard methods [11].

Sensory Evaluation

To capture consumer perception, sensory evaluation was conducted by a trained panel of 20 members. Samples coded to maintain blinding were evaluated for color, taste, aroma, texture, and overall acceptability using a 9-point hedonic scale [15].

Hazard Analysis

Hazard Analysis and Critical Control Points (HACCP) was applied to identify stages in Sinasir preparation that posed food safety risks. Special attention was given to raw material sourcing, fermentation, and cooking, which were considered critical points for microbial control.

Antimicrobial Sensitivity Testing

The antibacterial activity of spice extracts was tested against selected foodborne pathogens including Escherichia coli, Lactobacillus fermentum, Enterobacter aerogenes, Bacillus cereus, and Pseudomonas spp. Agar well diffusion was used as the assay method. After 24 hours of incubation, inhibition zones were measured in millimeters to quantify antimicrobial effectiveness [16].

RESULTS

Microbial Stability of Sinasir During Storage

Spice-treated samples exhibited significantly lower bacterial, coliform, and fungal loads compared to the untreated control (Fig. 1–3). While microbial proliferation increased over time in all samples, higher spice concentrations (particularly 5% garlic and 5% clove) delayed spoilage, with counts remaining within acceptable food safety limits up to week 6. In contrast, control samples exceeded countable microbial loads as early as week 3, underscoring the vulnerability of Sinasir without preservation.

These findings confirm the antimicrobial potential of traditional spices. Garlic's allicin and clove's eugenol showed the strongest inhibition, consistent with earlier reports of their broad-spectrum activity [17]. Ginger, while moderately effective, showed reduced control over extended storage, suggesting its compounds degrade more rapidly.

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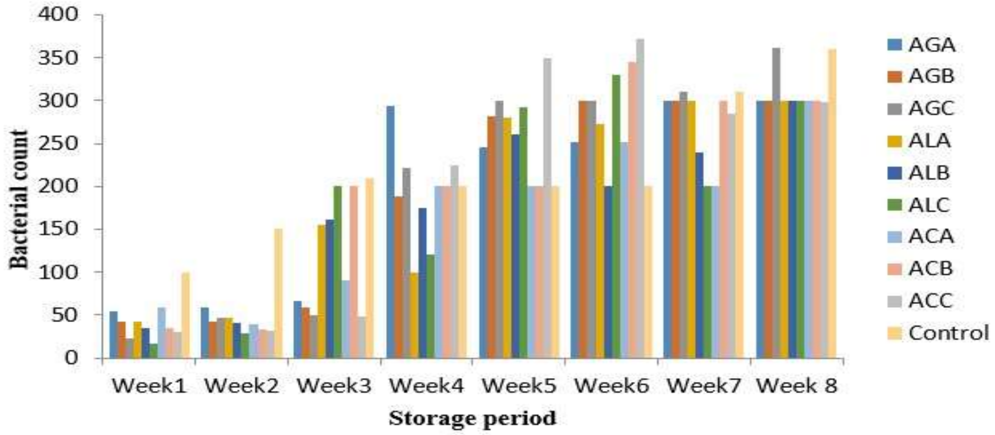

Fig.1. Effect of different spice treatment on bacterial count of Sinasir (Rice pancake) at different concentration.

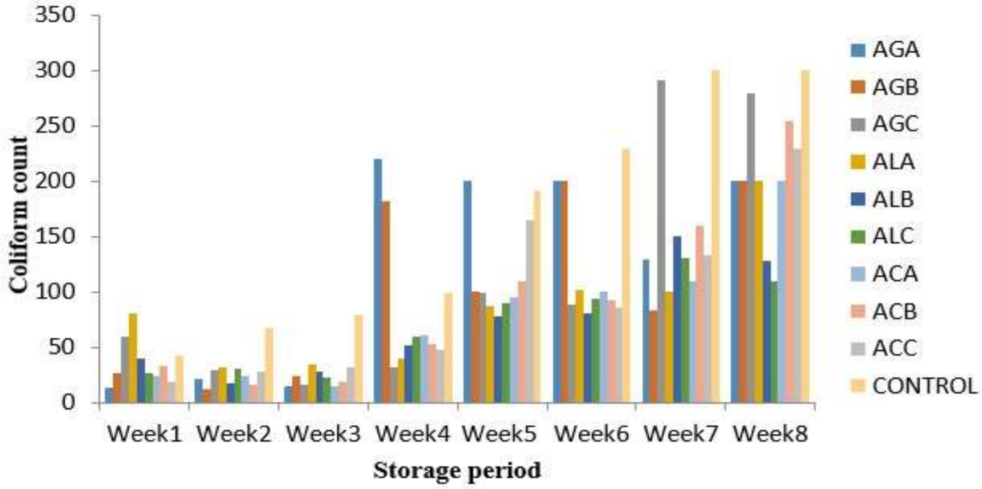

Fig.2. Effect of different spice treatment on coliform count of Sinasir (Rice pancake) at different concentration.

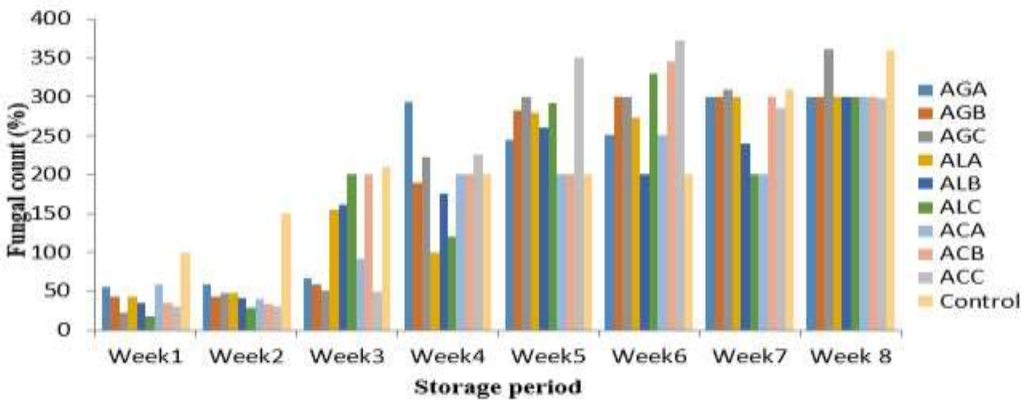

Fig.3. Effect of different spice treatment on Fungal count of Sinasir (Rice pancake) at different concentration

Physicochemical Properties

Changes in pH, titratable acidity, and temperature reflected microbial activity and preservation effects. Spice-treated samples maintained greater stability compared to the control. Notably, clove-treated samples exhibited the least pH fluctuation across storage, highlighting its capacity to moderate fermentation dynamics (Fig. 4–6).

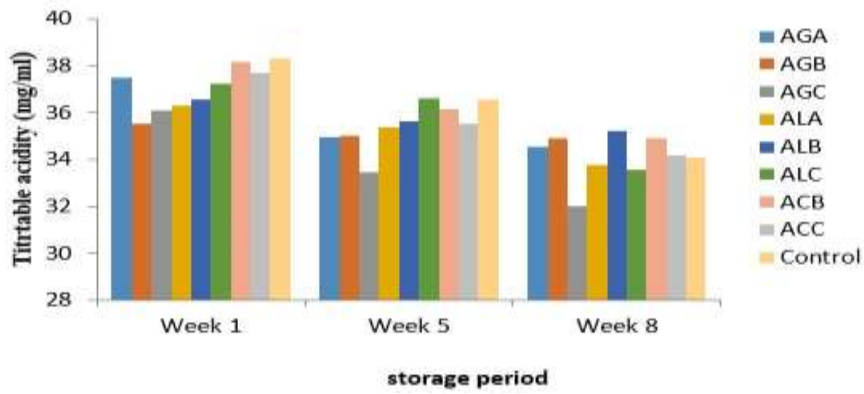

Fig.4. Effects of various treatments on the Titratable acidity of Sinasir (Rice pancake) at different concentration

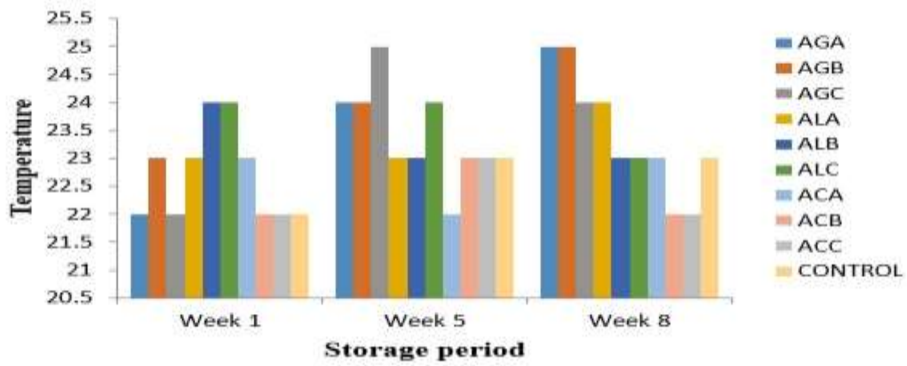

Fig. 5. Effects of various treatments on the Temperature of Sinasir (Rice pancake) samples at different concentration.

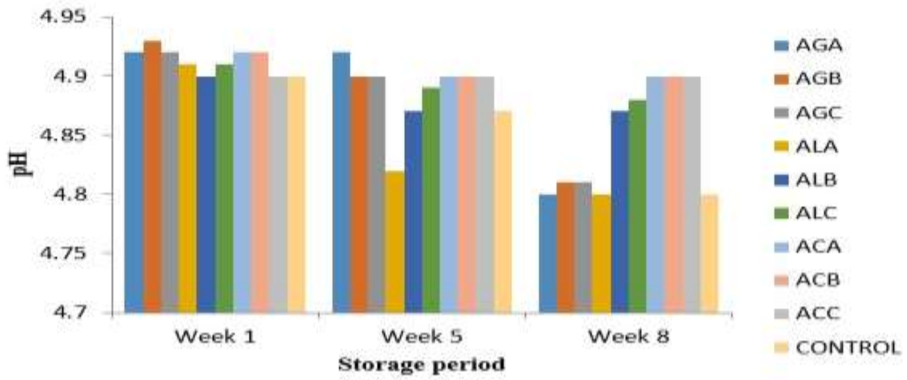

Fig.6. Effects of various treatments on the pH of Sinasir (Rice pancake) at different concentration

Nutrient Composition

Proximate analysis revealed gradual declines in protein, fiber, fat, and carbohydrates during storage (Fig. 7–12). However, garlic and clove at higher concentrations mitigated these losses, likely due to antioxidant activity that slowed degradation. Moisture levels also declined steadily, with spice-treated samples showing more controlled reduction, preserving textural integrity.

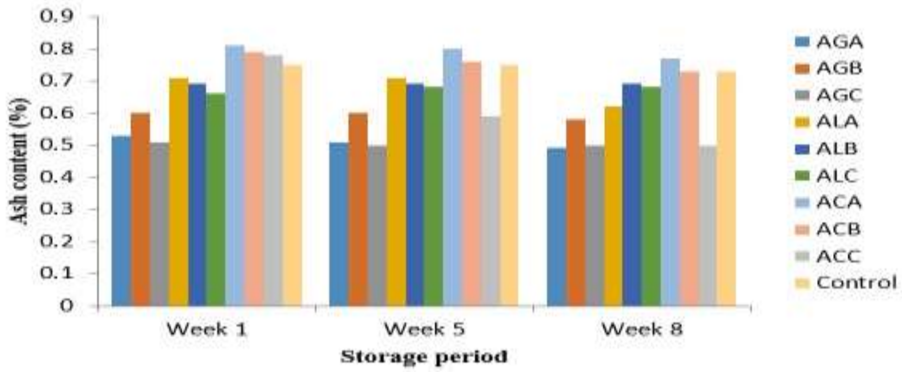

Fig.7. Effects of various treatments on the Ash content of Sinasir (Rice pancake) samples at different concentration.

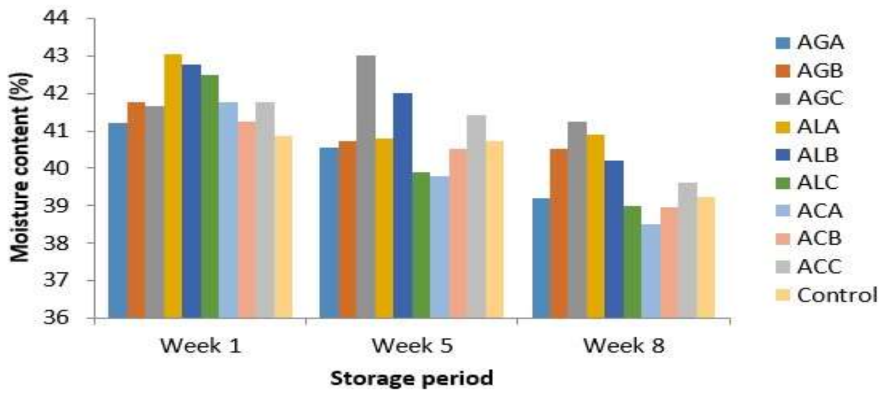

Fig.8. Effects of various treatments on the Moisture content of Sinasir (Rice pancake) at different concentration.

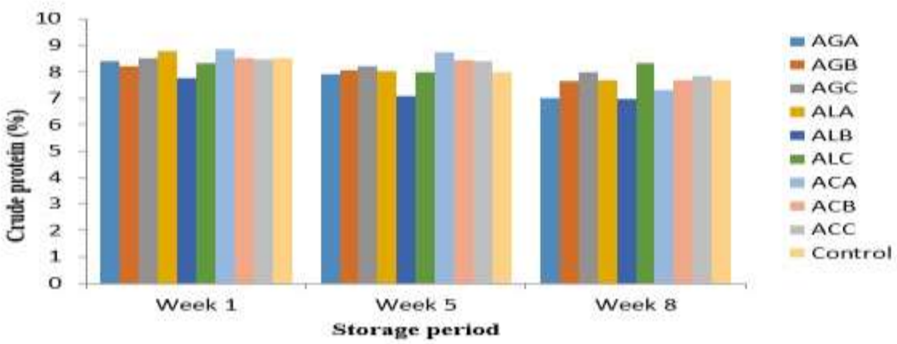

Fig.9. Effects of various treatments on the Crude protein of Sinasir (Rice pancake) at different concentration.

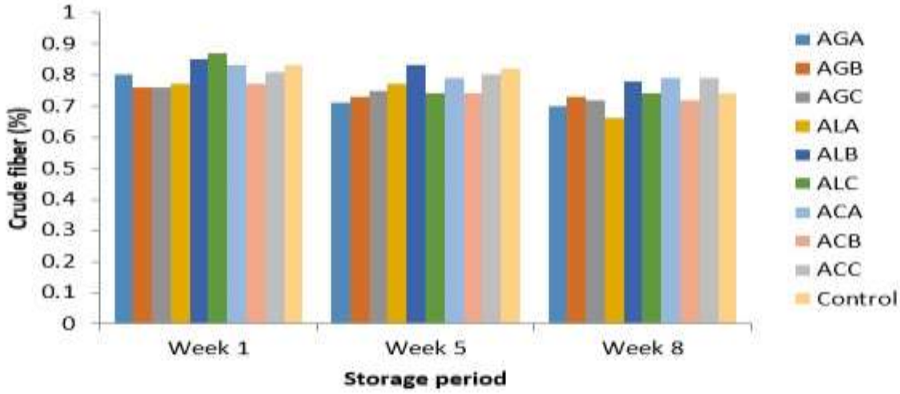

Fig.10. Effects of various treatments on the Crude fiber of Sinasir (Rice pancake) at different concentration

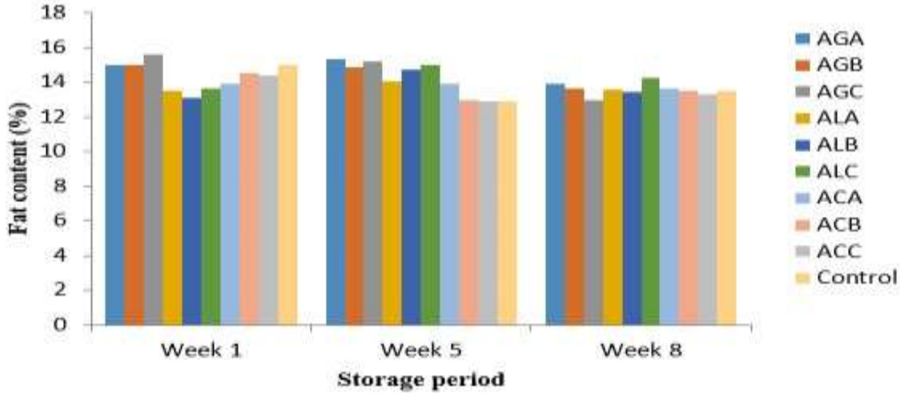

Fig.11. Effects of various treatments on the Fat content of Sinasir (Rice pancake) at different concentration.

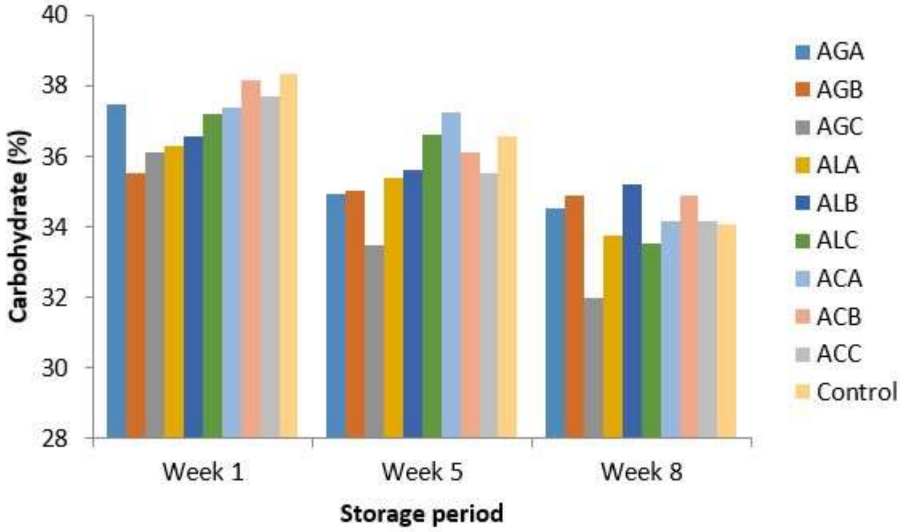

Fig.12. Effects of various treatments on the Carbohydrates of Sinasir (Rice pancake) at different concentration.

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Sensory Evaluation

Sensory scores (taste, aroma, texture, color, and overall acceptability) favored spice-treated samples, with garlic- and clove-enriched Sinasir ranking highest in taste and aroma (Fig. 13). Importantly, spices did not diminish visual appeal or textural qualities, suggesting they can enhance both shelf-life and consumer acceptance.

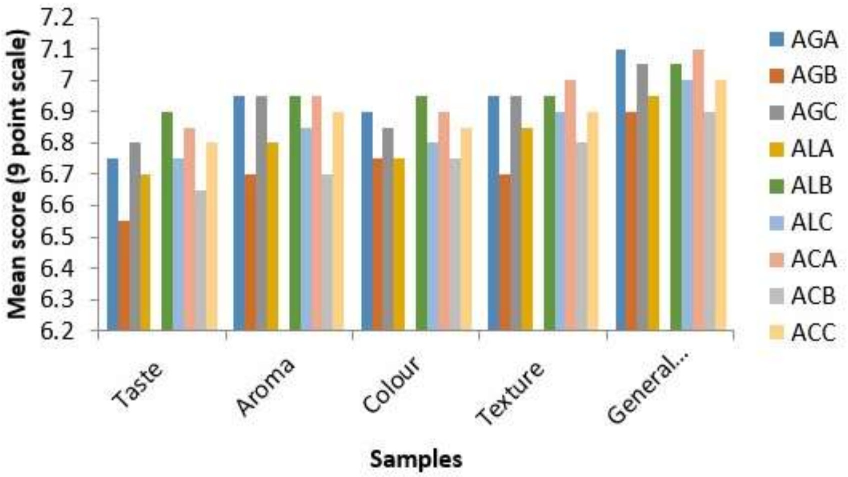

Fig.13. Mean sensory scores of Sinasir (Rice pancake) at different concentration

Hazard Analysis

HACCP evaluation identified soaking and cooling as critical points of microbial risk. However, frying effectively eliminated detectable microbial loads (Fig. 14). The reappearance of microbes after cooling highlights the importance of hygienic handling post-cooking. Spices provided additional microbial suppression, but strict handling practices remain indispensable.

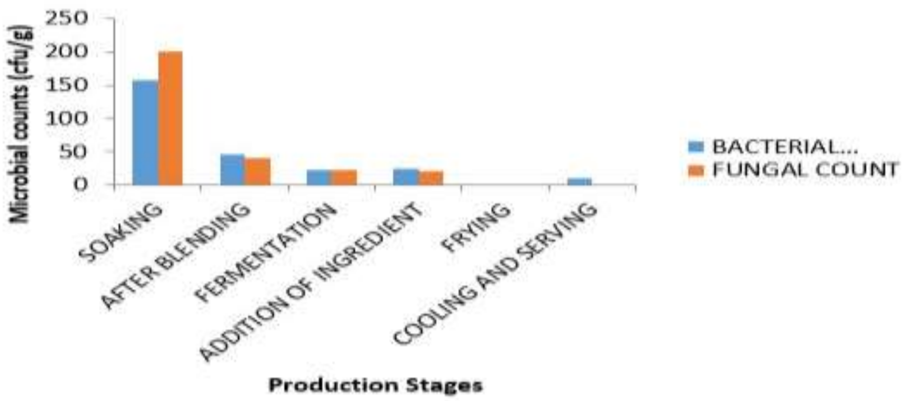

Fig.14. Microbial load at different stages of Sinasir (Rice pancake) product

Antimicrobial Sensitivity

Aqueous spice extracts displayed concentration-dependent antibacterial activity (Tables 2–4). Garlic was the most potent, producing inhibition zones up to 17.3 mm against Enterobacter aerogenes. Ginger demonstrated moderate activity, while clove showed limited efficacy in aqueous form, reflecting eugenol's low solubility in water. These results reinforce the importance of extraction method optimization for maximizing antimicrobial potential.

Table 1: Results of Antibacterial Effect of Aqueous Extract of Allium sativum on the test organisms

Conc. Mg/ml	*Pseudomonas Aeruginosa*	*Bacillus Cereus*	*Lactobacillus fermentum*	*Enterobacter Aerogenes*
0.2	2.9mm	4.2mm	4.9mm	3.5mm
0.4	5mm	5.1mm	7.5mm	6.8mm
0.6	13mm	10.2mm	6.4mm	4.3mm
0.8	9mm	7.1mm	8.2mm	11.9mm
1.0	16mm	12.8mm	10.8mm	17.3mm

Table 2: Results of Antibacterial Effect of Aqueous Extract of Syzgium aromaticum on the test organisms

Conc. Mg/ml	*Pseudomonas aeruginosa*	*Bacillus Cereus*	*Lactobacillus fermentum*	*Enterobacter Aerogenes*
0.2	NA	NA	NA	NA
0.4	NA	NA	NA	NA
0.6	NA	NA	NA	NA
0.8	0.6mm	NA	NA	NA
1.0	1.5mm	1.1mm	NA	2.0mm

NA-Not detected

Table 3: Results of Antibacterial Effect of Aqueous Extract of Zingiber officinale on the test organisms

Conc. Mg/ml	*Pseudomonas Aeruginosa*	*Bacillus Cereus*	*Lactobacillus fermentum*	*Enterobacter Aerogenes*
0.2	NA	NA	NA	NA
0.4	NA	1.7mm	NA	1.5mm
0.6	3.8mm	3.9mm	3.3mm	2.9mm
0.8	4.5mm	5.00mm	5.1mm	4.0mm
1.0	6.2mm	8.1mm	7.9mm	6.5mm

NA-Not detected

DISCUSSION

The results of this study demonstrate that incorporating spice extracts, particularly garlic and cloves, significantly reduced bacterial, coliform, and fungal loads in Sinasir during storage, while also preserving nutritional and sensory qualities. These findings are in strong agreement with Adeyanju et al. (2022) [18] and Hassan et al. (2020) [19], who emphasized the antimicrobial efficacy of traditional spices in extending the shelf life of African fermented foods. Similarly, the dose-dependent effects of ginger, garlic, and cloves observed here align with reports by Gholami-Shabani et al. (2017) [20] and Gholipour Kanani et al. (2014) [21], who showed that higher spice concentrations delay microbial proliferation more effectively. The persistence of Bacillus cereus and Pseudomonas aeruginosa despite treatment reflects earlier observations by Omotayo et al. (2020) [22] and Yehia et al (2022) [23] that spore-formers and adaptive spoilage organisms often resist natural antimicrobials, suggesting that spices alone may not provide complete inhibition. Nutritional stability, particularly in protein and ash content, corroborates the findings of Bou et al. (2009) [24] and Ozma et al. (2003) [25], who noted that bioactive compounds in garlic and cloves preserve structural integrity and slow nutrient degradation. However, the relatively weaker and inconsistent antimicrobial effect of ginger diverges from studies such as Žitek et al. (2022) [26], where ginger extracts showed stronger inhibition under controlled conditions, indicating that food matrix complexity and storage conditions may influence efficacy.

Collectively, this study both confirms and nuances earlier research by showing that spices enhance the microbial safety and consumer acceptability of traditional foods, but their effectiveness may depend on concentration, food composition, and storage duration [27].

CONCLUSION

This study examined the role of ginger, garlic, and clove extracts in shaping the microbial, nutritional, physicochemical, and sensory characteristics of Sinasir, a traditional Nigerian rice-based pancake that holds deep cultural significance. By integrating these natural spices into the fermentation process, we demonstrated that food safety, nutritional stability, and consumer acceptability can be significantly improved without compromising authenticity.

The findings reveal that garlic and clove, in particular, exhibit strong antimicrobial effects that slowed spoilage and maintained microbial loads within safe limits during extended storage. These spices also helped preserve critical nutrients such as protein and minerals while moderating physicochemical changes in pH and titratable acidity, which are often linked to product deterioration. From a sensory perspective, panelists consistently rated spice-treated samples as acceptable and in some cases even preferable, underscoring the potential of these natural additives to enhance both shelf-life and consumer enjoyment. Importantly, hazard analysis confirmed that the integration of spices into production can mitigate risks at critical control points, offering an added layer of protection in contexts where modern food preservation systems are often inaccessible.

Beyond the laboratory, the implications of these findings are substantial. In Nigeria and across sub-Saharan Africa, where food insecurity and foodborne illnesses remain pressing public health challenges, culturally embedded strategies like the use of indigenous spices represent practical and sustainable solutions. They provide households and small-scale vendors with affordable tools to safeguard traditional foods while aligning with global calls for clean-label, chemical-free preservation. On a broader scale, this work highlights the untapped potential of ethnobotanical knowledge in addressing modern scientific and societal concerns, from antimicrobial resistance to sustainable food systems.

In conclusion, the incorporation of garlic, clove, and ginger into Sinasir production is more than a technical adjustment; it represents a bridge between tradition and innovation. By validating long-standing culinary practices through rigorous scientific analysis, this study contributes to the preservation of cultural heritage while offering a pathway toward safer, more nutritious, and more resilient food systems. Future research should build on these findings by exploring synergistic combinations of spices, optimizing extraction methods, and scaling applications to other fermented foods within and beyond Africa. In doing so, local traditions may inspire global innovations in food safety and sustainability.

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