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INFLUENCE OF SELECTED NATURAL SOURCES OF ANTIOXIDANTS ON THE MICROBIAL STATUS AND ORGANOLEPTIC PROPERTIES OF WHOLE EGG POWDER

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ABSTRACT
This study was designed to evaluate the influence of selected natural antioxidant sources (turmeric, ginger, and clove) on the microbial status and organoleptic properties of whole egg powder stored for 90 days. A total of one hundred and twenty (120) eggs were freshly purchased from a reputable farm and allotted into four (4) groups with the same mean weight and size. Each group had three (3) replicates containing 10 eggs per replicate. Eggs in the various treatment groups were treated with: 0g/kg of natural antioxidant, 2.00g/kg of ginger, 2.0g/kg of turmeric and 2.00g/kg of clove, in a completely randomized design (CRD). Fresh whole eggs (yolk and albumen) treated with selected natural sources of antioxidants were homogenized and dehydrated at 65°c for 19 hours using a thermostat oven. The dried eggs were allowed to cool before it was blended, weighed, sieved and packaged using an air-tight container in an aseptic condition. The samples were evaluated over three (3) months in the laboratory for Microbial status (Total aerobics plate count (TAPC), salmonella counts, E. coli counts and yeast/mold counts) and Sensory evaluation was carried out to determine the organoleptic properties (taste, texture, flavour, appearance, colour and aroma). From the result obtained, Clove had the strongest antimicrobial properties with the lowest Total Aerobic Plate Count (TAPC) value (14.33 cfu/g) on Day 1, ginger-treated egg powder recorded the highest score for overall acceptability with a mean of 3.52, ginger enhanced texture and odor with limited antimicrobial effect, and turmeric, with 3.48 value for appearance improved appearance without impacting flavour or texture.

Keywords: Antioxidants, Organoleptic, Sensory, Turmeric, Clove.

INTRODUCTION

Egg is one of the most versatile and near perfect foods in nature. It is rich in protein, amino acids, vitamins and most mineral substances. The yolk and white components are all of high biological value and are readily digested. They are known to supply the best proteins besides milk (Vaclavik and Christian, 2008). Eggs play important culinary roles and are therefore prepared into different dishes. Their functional properties of emulsification, thickening, foaming and moisturizing help contribute desirable characteristics and physical functions in the industrial production of many food products in which they are incorporated (Lechevalier *et al.*, 2020; *Li et al.,* 2021). The increased demand for eggs in the food industry has brought about a transformation in egg production to provide greater security, reduce losses and increase satisfaction to consumers.

Eggs in powder form are lightweight, compact, and non-fragile, providing a near-complete solution to the challenges faced in handling fresh eggs, which simplifies transportation and reduces losses due to breakage (Sharma *et al.,* 2021). Fresh eggs degrade over time, affecting taste and texture, while egg powder retains consistent quality throughout its shelf life. Rehydrating powder eggs yields a product comparable to fresh eggs for various culinary applications (Hedayati *et al.,* 2020). According to McNamara and Thesmar (2005), 4.5 grams of total lipids are present in a commercial egg, of which 4.14 grams are fatty acids, consisting of 1.55 grams of saturated fatty acids, 1.91 grams of monounsaturated fat and 0.68 grams of polyunsaturated fat. These polyunsaturated fatty acids in eggs promote oxidative rancidity. This makes it necessary that lipid oxidation in egg powder be controlled with antioxidants.

Foodborne pathogens are of great concern worldwide and the disease outbreaks occurring due to the consumption of contaminated foods are a serious threat to public health. In order to ensure the safety of food products, several preservatives are employed by the food industry. The addition of synthetic preservatives to foods can have undesirable side effects not only in humans but can also cause changes in the organoleptic and/or nutritional properties of food (Pisoschi *et al.,* 2018). The realization of the adverse side effects of some of the synthetic-based antimicrobials on consumers' health and increasing regulatory restrictions have encouraged scientists to search for natural alternatives. The use of antioxidants from plant sources as natural preservatives has been the interest of several researchers because of the consumer demand for a more acceptable and healthy food supply (Das *et al.,* 2020). Plants, with a rich source of antioxidant and antimicrobial compounds, are the most preferred ones to substitute the synthetic antimicrobials

Fresh eggs are difficult to transport because of their bulkiness, fragility, and highly perishable nature. Egg in powder form provides a near-complete solution to these problems. Food shelf-life is a very important commodity characteristic for both food producers and consumers and determines, to a certain extent, the commodity value and market acceptability. Maintaining its original nutritional value is not only important as a healthy food for direct consumption, but also a special additive with great potential in its scope of application. Synthetic antioxidants like BHT (butylated hydroxytoluene) and TBHQ (tert-butylhydroquinone) have traditionally been used to mitigate these issues. However, growing health concerns about synthetic additives have driven interest in natural alternatives. Natural sources of antioxidants such as ginger, turmeric, and clove contain bioactive compounds like polyphenols and terpenes, which offer antimicrobial and antioxidative benefits. For instance, clove is rich in eugenol, known for its antimicrobial activity, while turmeric contains curcumin, a compound with potent antioxidative and anti-inflammatory properties. Ginger, known for

its unique spicy flavor, also exhibits antimicrobial effects through compounds like gingerol and shogaol. The integration of natural antioxidants provides a dual benefit of enhancing microbial safety and improving sensory attributes, aligning with consumer preferences for natural and safe food products. This study was therefore designed to determine the influence of selected natural sources of antioxidants (clove, ginger and turmeric) on the microbial status and the sensory properties of egg powder.

MATERIALS AND METHODS

The study was carried out at the Animal Science Laboratory, Kaduna State University, Kafanchan Campus, Kaduna State. Kafanchan is located at latitude 9°59'N, longitude 8°29'E and it is situated at an elevation of 733m above sea level (Gandi *et al*., 2020). A total of 120 eggs were evenly allotted into four treatment groups with three replicates of 10 eggs each and randomly treated with: 0g/kg of natural sources of antioxidant (EP), 2.00g/kg of turmeric (TTEP), 2.00g/kg of ginger (GTEP), and 2.00g/kg of clove (CTEP). Whole eggs and treatments were emptied into a container, homogenized and dehydrated at 65°C for 19 hours. The dry brittle egg was allowed to cool and then packed from the tray into a cleaned dry blender, and blended into powder, sieved and weighed. Egg powder was packaged in airtight plastic containers. All procedures were carried out aseptically.

Egg powder samples were labelled and analyzed over 90 days (Day 1, 45 and 90) at Ahmadu Bello University, Zaria, to determine the microbial status and the following was analyzed: Total Aerobic Plate Counts (TAPC), *Escherichia coli*, Salmonella, and yeast/mold counts. These were conducted at baseline and at intervals during storage to monitor microbial changes. Whole egg powder was reconstituted to scramble eggs and served to twenty-one (21) trained panelists who evaluated the sensory parameters (taste, texture, flavour, aroma, colour and overall acceptability), of the egg. A 5-point Hedonic scale, ranging from 1(very poor) to 5(excellent) was used for scoring each sample by the panelists who were served sensory evaluation forms. Data obtained was subjected to Analysis of Variance (ANOVA) using the general linear model of SAS (2002). Differences in treatment means were separated using the Duncan Multiple Range Test.

RESULTS AND DISCUSSION

The result for the influence of selected natural antioxidant sources (ginger, turmeric and clove powder) on microbial status of whole egg powders is shown in Table 1.

The results from the four (4) samples: 0g/kg of natural antioxidant (EP), Ginger treated Egg Powder (GTEP), Turmeric treated Egg Powder (TTEP) and Clove treated Egg Powder (CTEP), showed that CTEP exhibited the highest antimicrobial activity, represented by the lowest (14.33 cfu/g) Total Aerobic Plate Count (TAPC) value on Day 1. The bioactive components of cloves, especially eugenol, demonstrate a remarkable ability to inhibit microbial growth. The egg powder with 0g/kg of natural antioxidant recorded a comparatively high (53.00 cfu/g) TAPC value, suggesting the importance of incorporating natural antioxidants to reduce microbial contamination in food products. The antimicrobial effectiveness of clove can be attributed to its substantial levels of phenolic compounds, which are recognized for their potent antimicrobial characteristics. In a study by Kossah *et al*., (2020), *eugenol*, the predominant constituent of clove oil, has demonstrated the capacity to compromise microbial cell membranes and hinder enzymatic functions, resulting in cell mortality. This result is consistent with earlier research that emphasized clove's proficiency in markedly decreasing bacterial populations within diverse food matrices. Nasar-Abbas *et al*., (2019) indicated that the extracts obtained from cloves considerably inhibited the growth of pathogenic bacteria, such as *E. coli* and *Salmonella*, hence supporting the notion that clove can be a potential and effective natural preservative. Therefore, the mode of action for eugenol may not be specific to any particular strain of bacteria; it appeared to have a broad-spectrum activity against different pathogens commonly found in foods.

Ginger-treated egg powder showed more antioxidant activity, it simultaneously had the highest (17.00 cfu/g) initial load of *E. coli* on Day 1. The result proves that ginger could be less effective in preventing the growth of *E. coli* in the early stages as compared to clove. This might be because the antimicrobial properties of the bioactive compounds in ginger, particularly gingerol and shogaol, may become less effective against certain strains of bacteria at lower concentrations. Studies conducted by Pandey *et al*., (2014) showed that although ginger has a wide range of antimicrobial activity, the effectiveness of ginger changed considerably depending on the type of bacterial strain and test conditions employed. In addition, Pandey *et al*., (2014) also indicated that ginger extracts exhibited higher activity against Gram-positive bacteria than against Gram-negative bacteria such as *E. coli*, thus suggesting that environmental factors or interactions with the matrix may influence ginger's antimicrobial activity in food systems. The lack of detectable *Salmonella* counts throughout all treatment groups by day 90 was significant, indicating successful microbial management over the study's duration. The result was consistent with existing literature, which indicated that both turmeric and ginger exhibit considerable antibacterial properties against Salmonella species (Dehghan *et al*., 2023). It showed that these spices can inhibit the growth of *Salmonella*, but their efficacy can differ based on extraction methods and the concentrations used. As demonstrated in a study carried out by Al-Hilali *et al*., (2020), turmeric extracts showed higher antibacterial activity against *Salmonella Typhimurium*, where the average inhibition zone was 15 mm compared to 10 mm for ginger under similar conditions. This confirms the suspicion that while both spices have potential as natural preservatives, turmeric may have better efficacy against certain pathogens when used at proper levels. The yeast and mold counts had statistically similar results as those of *E. coli*, with ginger having the highest (8.33 cfu/g) count at day one, and clove had significantly lower (1.67 cfu/g) counts. This result agreed with the study of Burt *et al*., (2019), which reported that clove displays strong antifungal activity due to its active components, thus being effective agents in preventing the growth of yeasts and molds in food products. Moreover, Yadav *et al*., (2016) showed that several spice extracts, such as clove and ginger, strongly inhibited yeast and mold growth in bread products, therefore justifying their use as natural preservatives in food systems.

Influence of Selected Natural Antioxidant Sources on the Sensory Properties of Egg Powder

The result for the influence of selected natural antioxidant sources (ginger, turmeric and clove powder) on sensory properties of whole egg powders are shown in Table 2.

The obtained result from the four (4) samples: 0g/kg of natural antioxidant (EP), Ginger treated Egg Powder (GTEP), Turmeric treated Egg Powder (TTEP) and Clove treated Egg Powder (CTEP), showed that ginger treated egg powder recorded the highest score for overall acceptability with a mean of 3.52, hence

showing a positive influence on sensory attributes of the egg powder. The result agreed with the existing literature that emphasizes ginger as being able to enhance both flavor and aroma of food products (Nutakor *et al*., 2020). The texture score for ginger was also relatively high (3.57), suggesting that it not only brings flavor but also an overall positive mouth-feel effect, thus making it a favorable constituent within whole egg powder formulations. Its bioactive compounds, including gingerol and shogaol, are important to creating the typical spiciness and aroma, as stated in a study by Lee (2017). The aroma of ginger has been able to activate the olfactory receptors, thereby imparting warmth and a lot of depth without overpowering other components of flavor (Shiratori *et al.,* 2018; Abdulkarim *et al*., 2017). Its enhanced sensory qualities make ginger a very potent natural antioxidant and flavoring agent in food products.

Clove treated egg powder had the lowest (1.86) overall acceptability score. The strong flavor profile of clove powder, characterized by its intense aroma, largely due to eugenol, may be unsuitable in this particular use. The scores for taste (1.71) and flavor (1.81) imply that the strong flavor of clove may dominate the sensory characteristics of the product, possibly making it unattractive to consumers who prefer a more balanced tasting experience. The result agreed with the study done by Haro-Gonzalez *et al*., (2021), which suggested that the strong characteristic odor of clove may significantly affect the overall aroma profile of food products. Clove itself is acknowledged to have strong antimicrobial activity due to its high eugenol content (Ghorab *et al*., 2020), but its strong flavor may be a limiting factor in its application in some food uses. The distinctive spicy-sweet flavor profile of clove is able to interact with the inherent flavor of egg powder, potentially resulting in a sensory effect that some consumers found objectionable (Romaniw 2020). This proves the importance of considering consumer preferences when selecting spices for food applications.

Turmeric was moderate in this study, with an overall acceptability score of 3.10 and had the highest (3.48) rating for appearance. It is suggested that turmeric may not add much to the taste or aroma of the product compared to ginger; it does bring a positive effect on the visual appeal of whole egg powder due to the bright yellow color imparted by curcumin (Onyenwoke *et al*., 2018). The aesthetic improvement that turmeric can provide could be of utmost importance with consumer acceptance, as visual attractiveness is one of the primary determinants of food choice. Turmeric imparts a characteristic spicy and earthy flavor to food products according to various research (Salehi *et al*., 2019). Nevertheless, most studies have indicated that the addition of turmeric does not significantly influence textural properties, such as hardness or cohesiveness, upon incorporation into food matrices like egg powder (Gharibzahedi and Chronakis, 2018; Fatemeh *et al*., 2018).

These spices have different chemical compositions and, therefore, interact differently with food matrices, resulting in different impacts on sensory characteristics. The volatile compounds in ginger enhance the aroma and flavor of the product without dominating its inherent sensory profile (Abdulkarim *et al*., 2017). Clove, on the other hand, is strongly aromatic, which may mask the sensory profile, thus not being appropriate in situations where a balanced flavor is required. As shown in the study, ginger repeatedly indicated positive effects on most of the sensory attributes, but the effectiveness can vary depending on the food matrix it is introduced to.

Table 1: Effects of Some Natural Antioxidant Sources on the Microbial Status of Whole Egg Powder

	Microbial Status							
	TAPC (10^6cfu/g)		**Salmonella counts (10^2cfu/g)**		**E. coli counts (10^2cfu/g)**		**Yeast/Mold counts (10^4cfu/g)**	
Treatment	**DAY 1**	**DAY 90**	**DAY 1**	**DAY 90**	**DAY 1**	**DAY 90**	**DAY 1**	**DAY 90**
EP(Control)	53.00^{c}	0.00^{a}	3.33^{ab}	-	7.33^{a}	-	1.67^{a}	0.00^{a}
GTEP	29.00^{b}	0.00^{a}	4.67^{c}	-	17.00^{c}	-	8.33^{c}	5.67^{c}
TTEP	39.00^{b}	5.67^{c}	4.33^{c}	-	12.00^{b}	-	2.67^{b}	0.00^{a}
CTEP	14.33^{a}	1.67^{b}	2.67^{a}	-	8.33^{a}	-	1.67^{a}	2.67^{b}
SE (±)	1.374	0.333	0.624	-	0.972	-	0.850	0.333

ab: the values marked with different letters vary significantly ($P < 0.05$), EP: 0g/kg of natural antioxidant, GTEP: 2g/kg of ginger, TTEP: 2g/kg of turmeric, CTEP: 2g/kg of clove, TAPC: Total Aerobic Plate Counts

Table 2: Effects of Some Natural Sources Antioxidants on the Sensory Properties of Egg Powder

	Sensory Properties						
Treatment	**Taste**	**Texture**	**Flavour**	**Appearance**	**Colour**	**Aroma**	**Overall Acceptability**
EP(control)	3.24^{a}	3.05^{a}	2.95^{a}	3.33^{a}	3.19^{a}	2.90^{a}	3.43^{a}
GTEP	3.29^{a}	3.57^{a}	3.00^{a}	3.24^{a}	3.62^{a}	3.14^{a}	3.52^{a}
TTEP	2.57^{b}	3.24^{a}	2.86^{a}	3.48^{a}	3.52^{a}	2.95^{a}	3.10^{a}
CTEP	1.71^{c}	2.06^{b}	1.81^{b}	1.72^{b}	1.86^{b}	1.81^{b}	1.86^{b}
SE (±)	0.374	0.333	0.353	0.355	0.342	0.360	0.265

ab: the values marked with different letters across columns vary significantly ($P < 0.05$), EP: 0g/kg of natural antioxidant, GTEP: 2g/kg of ginger, TTEP: 2g/kg of turmeric, CTEP: 2g/kg of clove

Conclusion

The results from the study showed the influence of ginger, turmeric, and clove as natural antioxidants and preservatives to enhance both the microbial stability and sensory characteristics of whole egg powder.

Among the three spices studied, Clove, having the lowest Total Aerobic Plate Count (TAPC) value(14.33 cfu/g) on Day 1, was found to be the most potent antimicrobial agent in terms of reducing microbial counts and maintaining wide-spectrum activity against a variety of pathogens.

Ginger, with the overall acceptability mean of 3.52, was seen to enhance sensory characteristics, particularly texture and odor, rendering it a versatile ingredient in food products; still, its antimicrobial potential against certain bacteria, such as *E. coli*, may not be very strong under all conditions.

Turmeric, on the other hand, had the highest value of 3.48 for appearance, causing it to have a positive effect on the food's appearance without destroying texture, despite not enhancing flavor or odor as much as ginger did.

Recommendation

It is recommended that food manufacturers consider incorporating ginger and clove into whole egg powder formulations to improve both microbial safety and sensory quality.

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