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Influence of Selected Natural Antioxidant Sources on Oxidative Stability, Proximate and Mineral Composition of Egg Powder

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Abstract

This study was designed to evaluate the effect of some natural antioxidant (NA) sources (turmeric, ginger and clove) on the oxidative stability, proximate and mineral composition of whole egg powder. A total of one hundred and twenty (120) eggs were freshly purchased from a reputable farm and allotted to four (4) groups with the same mean weight and size. Each group had three (3) replicate(s) containing 10 eggs per replicate. All eggs in the various treatment groups were treated with; 0g/kg of natural antioxidant, 2.00g/kg of ginger, 2.00g/kg of turmeric and 2.00g/kg of clove, in a completely randomized design (CRD). Fresh whole eggs (yolk and albumen) treated with natural sources of antioxidants were 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 a period of three (3) month(s) in the laboratory for oxidative stability; Malondialdehyde (MDA), superoxide dismutase (SOD), catalase (CAT), and glutathione (GSH), proximate composition; (carbohydrate, protein, lipid, ash and moisture content) and mineral compositions (calcium, magnesium, potassium and phosphorus). Data generated was subjected to analysis of variance using SAS and differences in treatment means were separated using the Fischer's Least Significant Difference. From the result obtained, the oxidative parameters measured had no significant difference across treatment groups. The MDA values ranged between 2.09-3.78 mmol/mg, SOD ranged from 17.99- 20.17µmole, GSH ranged from 4.70- 5.38-µg/ml and CAT ranged from 14.1- 15.99µmole/mg. Results obtained for mineral composition varied based on the natural source of antioxidant used, phosphorus had higher values (156.25-190.00 mg/100g). The turmeric treated egg powder at 2g/kg demonstrated superior antioxidant properties, preserving proteins, stabilizing lipids, and minimizing moisture absorption during the 90 day storage period. While the ginger treated egg powder was more effective in lipid preservation.

Keywords: Egg powder, Storage, Oxidative stability, Proximate, Mineral composition

1.0 Introduction

Nigeria has an average rate of egg consumption of approximately 78.48 eggs per person per annum (FAO, 2022; USDA, 2022) which is below the World Health Organization recommended minimum standard and it is the most affordable animal protein in Nigeria. PAN (2018), reported that Nigeria is one of the highest egg producers in Africa with 10.3 billion eggs produced in a year; the short shelf life of eggs and the tendency for individuals to consume fewer eggs between February and May result in an annual glut for Nigerian poultry farmers. Fresh eggs are difficult to transport because of their size, breakability, and highly perishable nature (Jay, 2000; Sam 2023). Inadequate processing and storage facilities cause Nigerian egg producers and marketers to lose a great deal of money due to spoilage.

The need for adequate processing to increase shelf life for better storage and transportation is needed however, the nation's poultry farmers have not yet completely tapped into the vast production potential of eggs by processing them into powder, dry, frozen, salted, sugared, pasteurized, cooked, and other forms, increasing its shelf life and ensuring food safety. Poultry eggs are rich in nutrient and are a great source of protein therefore, adequate processing and utilization of eggs will lead to an increase in the protein intake in Nigeria. Studies have shown that dried powdered eggs solve the problem of bulkiness, easily breakable nature of fresh eggs and the storage challenges; under optimal storage conditions it is possible to store eggs for a year or beyond (Jay, 2000).

According to Tanvir *et al.*, (2017), antioxidants prevent oxidative damage through one-electron reactions with free radicals [superoxide radicals (O_2^-), hydroxyl radicals ($OH\cdot$), singlet oxygen ($O\cdot$), and hydrogen peroxide (H_2O_2)] that adversely alter cellular lipids, protein, DNA, and polysaccharides. Therefore, a balance between free radical and antioxidant concentrations is necessary to maintain proper physiological functions. Antioxidants in the form of commercial food additives have been manufactured synthetically and may contain high amounts of preservatives. Some synthetic antioxidants, such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and tertiary butyl hydroquinone (TBHQ), have been reported to produce toxins or act as carcinogens (Gandi, *et al.*, 2020). Therefore, identifying potential natural antioxidant sources such as clove, ginger and turmeric that can be a useful alternative to ensure sound health is important. This study was therefore designed to determine the effect of some natural sources of antioxidant (clove, ginger and turmeric) on the oxidative stability, proximate and mineral composition of egg powder.

2.0 Materials and Methods

The study was carried out at the Animal Products laboratory, Kaduna State University, Kafanchan Campus, Kaduna State. Kafanchan is located at latitude $9^{\circ}59'N$, longitude $8^{\circ}29'E$ and it is situated at an elevation of 733m above sea level (Gandi *et al.*, 2020). A total of 120 eggs averagely weighing 50 grams each 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). Eggs were dehydrated at $65^{\circ}C$ for 19 hours, the dry brittle egg was allowed to cool and then packed from the tray into a dry-cleaned blender, and blended into powder, sieved and weighed. Egg powder was packaged in plastic airtight containers. All procedure adopted were carried out aseptically. Egg powder samples were labelled and analyzed over a period of 90 days (Day 1, 45

and 90) at the Clinical Pathology Laboratory, National Veterinary Research Institute (NVRI) Jos, to determine the oxidative stability (Malondialdehyde (MDA), Superoxide Dismutase (SOD), Catalase (CAT), and Glutathione (GSH)) following procedures of Beutler, *et al.*, (1963) and Varshney and Kale (1990). Proximate and mineral compositions were also determined according to procedures of AOAC (2005) at the Biochemistry laboratory, Institute of Agricultural Research (IAR) Zaria. The experiment was designed as a 3×4 factorial arrangement in a completely randomized design. Data collected was subjected to analysis of variance (ANOVA) using the general linear model of SAS (2002), differences in treatment means were separated using the Fischer's Least Significant Difference.

3.0 Results and Discussion

The result of the effect of some natural antioxidant sources (ginger, turmeric and clove powder) on oxidative stability of whole egg powders are shown in Table 3.1. The result obtained showed that the values were significantly different ($p < 0.05$) across treatment groups (whole egg powder treated with: 0g/kg of EP, GTEP, TTEP and CTEP). Result obtained for malondialdehyde (MDA) ranged from 2.09-3.78 mmol/mg across treatment groups. The MDA level as an indicator of lipid peroxidation at high level is associated with oxidative damage to lipids and proteins often showing an imbalance between reactive oxygen species (ROS) production and antioxidant defences (Ayala *et al.*, 2014). Lower MDA level shows improved oxidative stability as recorded by Del *et al.*, (2005). Ginger treated egg powder showed the lowest ($p < 0.05$) MDA level (2.09 mmol/mg), indicating strong inhibition of lipid peroxidation. Egg powder treated with 0g/kg of natural sources of antioxidant and TTEP had statistically same values for MDA, but were however similar to values recorded for CTEP which had the highest value (3.78mmol/mg). The control sample (EP) was better (3.23 mmol/mg) compared to CTEP (3.78 mmol/mg) but less effective than TTEP and GTEP. The difference in MDA levels across other literatures are not just a result of the processing method adopted for egg powder preparation but also influenced by the measurement techniques used to determine MDA (Marshall *et al.*, 1994).

Superoxide dismutase (SOD) as an indicator of oxidative stability showed that there was no significant difference ($p > 0.05$) between treatment groups. Superoxide dismutase as an enzyme neutralizing superoxide radical, shows an adaptive response to increased oxidative stress at high level as recorded by Kumar *et al.*, (2020) while lower level of SOD suggests compromised antioxidant defenses leading to inability to effectively neutralize superoxide radicals (Zhao *et al.*, 2021). Superoxide dismutase (SOD) values ranged from 17.99 to 20.17 μ mole. Gulcin *et al.*, (2012) reported that clove contains eugenol which enhances enzymatic antioxidant defences same as SOD and CAT suggesting that clove may have improved enzymatic antioxidant defences. Ginger treated whole egg powder (GTEP) and TTEP showed lower SOD activity, indicating less stimulation of this enzyme, possibly due to direct scavenging of superoxide radicals by the added antioxidants as stated by Rahmani *et al.*, (2014).

Catalase as an enzyme reducing hydrogen peroxide to water and oxygen showed in the result that there was no significant difference ($p > 0.05$) across treatment groups of CAT values. Catalase enhance response to oxidative stress while lower level of CAT indicates an inability to effectively neutralize hydrogen peroxide leading to accumulation of ROS and cellular damage (Halliwell *et al.*, 2020). Ginger treated egg powder had the highest (15.99 μ mole/mg) CAT

activity, closely followed by CTEP (15.54 $\mu\text{mole/mg}$) but not statistically different. This may suggest that ginger offered at higher concentrations can enhance the breakdown of hydrogen peroxide. Turmeric treated egg powder value for CAT activity (14.12 $\mu\text{mole/mg}$) agrees with a report by Jayaprakash *et al.*, (2006) who recorded that turmeric's curcuminoids exhibited potent antioxidant properties by neutralizing free radicals and enhancing endogenous antioxidant systems.

High GSH shows enhanced cell's ability to neutralize oxygen species (ROS), reducing oxidative stress (Lu *et al.*, 2013) while decreased GSH increases oxidative stress as recorded by Townsend *et al.*, (2003). The results obtained showed that the values were not significantly different ($p < 0.05$). Clove treated whole egg powder had a value of 4.70 $\mu\text{g/ml}$, suggesting less effectiveness of clove in boosting cellular antioxidant capacity. Ginger treated whole egg powder recorded 5.38 $\mu\text{mole/mg}$ GSH level, consistent with its role in maintaining intracellular redox balance. Ginger contains bioactive compounds such as gingerols and shogaols, known for their ability to directly scavenge free radicals and reduce lipid peroxidation (Rahmani *et al.*, 2014).

The oxidative stability result of treated whole egg powder as affected by storage duration are shown in Table 3.1. The values obtained for storage intervals (Day 1, Day 45 and Day 90) of MDA ranged between 2.09-3.78 mmol/mg and were significantly different ($p < 0.05$) across storage interval for MDA. The MDA values decreased over time, from 3.31 mmol/mg to 2.59 mmol/mg. Superoxide dismutase (SOD) showed that there was no significant difference ($p > 0.05$) across storage interval of SOD values. Activity of SOD declined at Day 90 (13.66 μmole), showing enzyme degradation over time or reduced oxidative stress indicating less SOD activity.

The values obtained for CAT as a measure of natural source of antioxidant were significantly different ($p < 0.05$) across storage durations. Catalase increased over time reaching its peak (16.14 $\mu\text{mole/mg}$) at Day 90, this could be a compensatory response to prolonged exposure to oxidative conditions.

Glutathione (GSH) values showed that there was no statistically significant difference ($p > 0.05$) across storage intervals. Glutathione (GSH) levels had a value of 5.36 $\mu\text{g/ml}$ at Day 45 but declined (4.90 $\mu\text{g/ml}$) at Day 90, this agrees with a study by Srinivasan (2014) who reported antioxidant activity diminishing with prolonged storage due to degradation of natural antioxidants.

The interaction between natural sources of antioxidant and storage duration was not statistically significant ($p > 0.05$) for any parameter, suggesting that the main effects of natural sources of antioxidant and storage duration independently influence oxidative stability.

The result for the effect of some natural sources of antioxidant (ginger, turmeric and clove powder) on proximate composition of whole egg powders are shown in Table 3.2. The values obtained for carbohydrate ranged between 3.89- 9.49 % across treatment groups. 0g/kg of natural antioxidant (EP) and CTEP showed high carbohydrate levels (9.49% and 8.37%, respectively). Egg powder treated with turmeric (TTEP) had carbohydrate content of 3.89%, suggesting turmeric's potential in reducing carbohydrates. Carbohydrate level across treatment groups was higher than the values recorded by American Egg Board, (1999), with the values 0.5-1%. The result showed that there was no significant difference across treatment groups ($p > 0.05$) of carbohydrate values.

Table 3.1: Effect of natural sources of antioxidant and storage duration on oxidative stability of whole egg powders

Parameters	MDA (mmol/mg)	SOD (μ mole)	CAT (μ mole/mg)	GSH (μ g/ml)
Treatment				
EP	3.23 ^{ab}	19.33	15.25	5.27
GTEP	2.09 ^a	18.41	15.99	5.38
TTEP	2.61 ^{ab}	17.99	14.12	5.09
CTEP	3.78 ^b	20.17	15.54	4.70
LSD	1.65	3.47	3.07	0.98
Storage duration				
Day 1	3.31	21.56 ^a	13.69 ^a	5.07
Day 45	2.89	21.71 ^a	15.84 ^{ab}	5.36
Day 90	2.59	13.66 ^a	16.14 ^b	4.90
LSD	1.34	2.88	2.29	0.76
LSD Interaction				
T*S	0.85 ^{NS}	0.38 ^{NS}	0.76 ^{NS}	0.66 ^{NS}

NB: the values marked with different letters in superscript vary significantly ($P < 0.05$) across the column, MDA: Malondialdehyde, GSH: Glutathione, SOD: Superoxide dismutase, LSD: Least significant difference, EP: 0g/kg of natural antioxidant, GTEP: 2g/kg of ginger, TTEP: 2g/kg of turmeric, CTEP: 2g/kg of clove, T: treatments of natural sources of antioxidant, S: storage duration

The values obtained for crude protein showed that egg powder treated with turmeric (TTEP) recorded the highest ($p < 0.05$) protein content (51.58%). Turmeric has been reported to stabilize protein structures under thermal and oxidative stress (Jayaprakasha *et al.*, 2006). The protein value (45%-50%) of egg powder recorded by Akpobomeh *et al.*, (2022) agrees with the values obtained in this study. The result showed that there was significant difference ($p < 0.05$) across treatment groups.

Data collected for ether extract as a measure of lipid showed that GTEP (33.30%) and TTEP (33.01%) both maintained higher lipid levels and had statistically same values, indicating that ginger and turmeric may prevent lipid degradation better than CTEP (30.98%) and EP (30.81%). Ginger has been shown to maintain lipid stability (El-Gendy *et al.*, 2020). In another study by Goswami, *et al.*, (2013), who recorded 30-35% as lipid value of egg powder which is within the range of values obtained in this result.

Ash content reflects the mineral content left after complete combustion, mainly from salts and inorganic compounds. The control group, 0g/kg of natural antioxidant and GTEP had Ash levels of 8.67% and 8.62% respectively which were statistically the same, while TTEP (7.26%) and CTEP (7.46%) showed reduced levels. Ash values were within the range for egg powder reported by Zhang, *et al.*, (2019).

The values obtained for moisture content (MC) showed that there was significant difference ($p < 0.05$) across treatment groups and storage duration. Moisture content was lowest ($p < 0.05$) in TTEP (4.28%), indicating turmeric may aid in effective dehydration. Effective dehydration with turmeric was consistent with findings by Srinivasan (2014), that curcumin reduces moisture absorption. GTEP had the highest ($p < 0.05$) moisture content (5.31%). Moisture values were within the range of 3-4 %, generally below 5% as also reported by Lechevalier, *et al.*, (2007).

The proximate composition values of treated egg powder as affected by storage duration are shown in Table 3.2. The values showed that higher protein (51.18%) and lower carbohydrate (3.54%) contents were obtained at day 1. Lipid, ash, and moisture values were stable during this period. A significant increase (11.93%) in carbohydrates and decrease (43.60%) in protein were obtained in day 90, likely due to storage-induced biochemical changes. The interaction between treatment and storage time was significant for all parameters ($p < 0.05$), indicating that the effectiveness of each antioxidant depends on the storage duration while effect of storage duration on proximate composition was not significant for some parameters ($p > 0.05$).

The egg powder treated with turmeric (TTEP) was recorded to be a more effective antioxidant for preserving proteins and reducing moisture, making it suitable for extended storage, GTEP may be effective for lipid stability but retains higher moisture, which could limit shelf life and clove has moderate effects on proximate composition but may require further optimization. Clove's eugenol slows spoilage but may be less effective than ginger or turmeric in lipid and protein preservation, as also reported by Gulcin *et al.*, (2012). These natural sources of antioxidant reduce oxidative damage to proteins and lipids, this agrees with the study done by Rahmani *et al.*, (2014) and Araujo *et al.*, (2021).

Table 3.2: Effect of natural sources of antioxidant and storage duration on proximate composition

	CHO (%)	CP (%)	LIPID (%)	ASH (%)	MC (%)
Treatments					
EP	9.49	46.04 ^{ab}	30.81 ^b	8.67 ^a	5.00 ^b
GTEP	9.19	43.58 ^b	33.30 ^a	8.62 ^a	5.31 ^c
TTEP	3.89	51.58 ^a	33.01 ^a	7.26 ^b	4.28 ^a
CTEP	8.37	48.37 ^{ab}	30.98 ^b	7.46 ^b	4.83 ^b
LSD	7.70	6.93	0.97	0.24	0.26
Storage Duration					
Day 1	3.54 ^b	51.18 ^a	32.49	8.08	4.71
Day 90	11.93 ^a	43.60 ^b	31.56	7.92	4.99
LSD	2.87	3.53	1.34	0.75	0.43
Interaction					
T*S	0.001	0.001	0.001	0.001	0.011

NB: Values with different alphabet super scripts across the columns are significant at 95% probability level. LSD: Least significant difference, CHO: carbohydrate, CP: crude protein, MC: moisture content, EP: 0g/kg of natural antioxidant, GTEP: 2g/kg of ginger treated egg powder, TTEP: 2g/kg of turmeric treated egg powder, CTEP: 2g/kg of clove treated egg powder.

The result on the effect of some sources of natural antioxidants on the mineral composition of egg powders is shown in Figure 3.1. The values obtained for calcium showed the highest level in TTEP, turmeric contains trace amounts of calcium, with approximately 28 mg of calcium per 100g, which may explain the increase in calcium at TTEP followed closely by egg powder treated with ginger GTEP (29.00 mg/100g), a study by Shah *et al.* (2020) recorded that ginger is a good source of calcium, with an average of 16 mg of calcium per 100g of raw ginger. This variation could be due to the intrinsic mineral content of the antioxidants, as turmeric and ginger

naturally contain small amounts of calcium. Additionally, antioxidants may stabilize or enhance mineral retention during storage, contributing to these differences compared to the EP.

Magnesium levels had slight increase in CTEP and GTEP (50.25 mg/100g). Magnesium content in ginger is relatively modest, contributing around 43 mg per 100g, the value obtained in this study agrees with the values observed in the ginger-treated samples (Cui *et al.*, 2021). Clove, rich in minerals like magnesium with around 274 mg per 100g, may contribute to the increase. This could explain the increase in magnesium levels obtained in the CTEP (Chandra *et al.*, 2021).

Potassium obtained values was moderately higher in CTEP, which is known for its high potassium content (Chandra *et al.*, 2021). Kim *et al.*, (2019) stated that potassium in eggs generally remains stable across processing variables, given its role in cellular function and osmotic balance. The consistency here suggests minimal variation in potassium bioavailability. Egg powder treated with ginger (70.00mg/100g) and TTEP (70.00mg/100g) were significantly the same, but moderately higher compared to the EP. This could indicate a minor contribution from these antioxidants to potassium content, with clove having a slightly stronger effect due to its natural mineral profile.

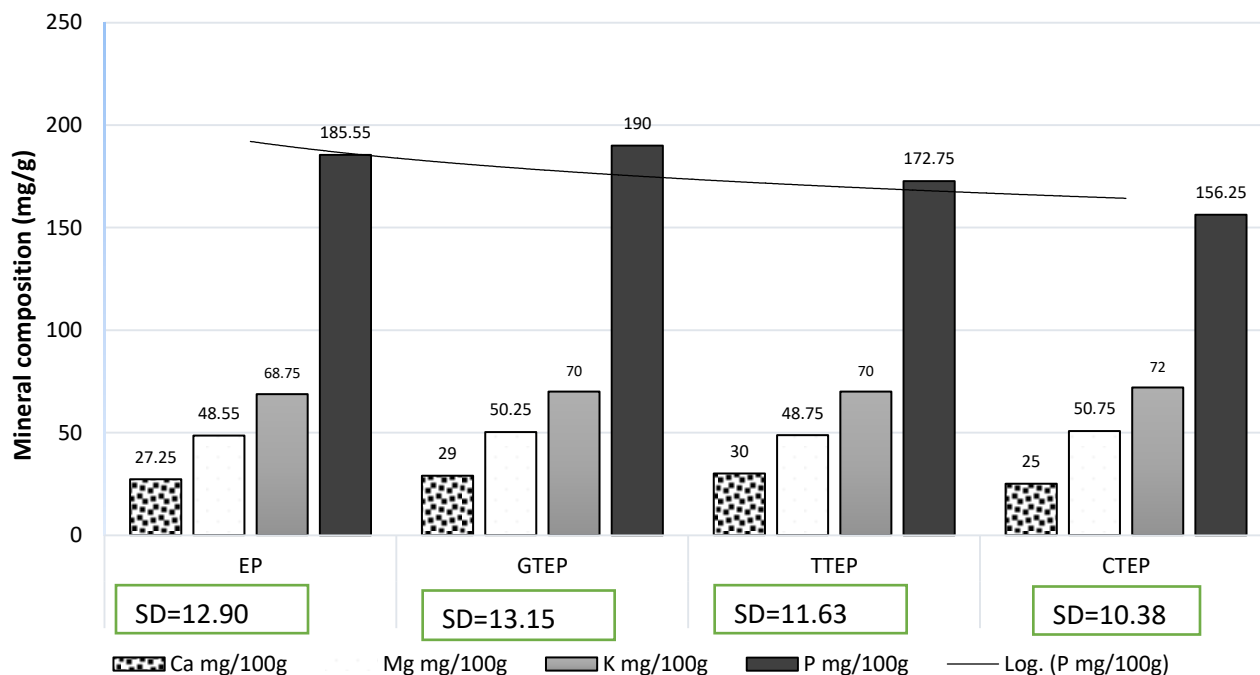


Figure 3.1: Effect of natural sources of antioxidant on mineral composition of whole egg powder. SD: Standard deviation, EP: 0g/kg of natural antioxidant, GTEP: 2g/kg of ginger, TTEP: 2g/kg of turmeric, CTEP: 2g/kg of clove

The values obtained for phosphorus showed the most variability among minerals. Egg powder treated with ginger had the highest (190.00 mg/100g) phosphorus content, CTEP had the lowest (156.25 mg/100g). This difference could be due to the natural variations in how each antioxidant interacts with phosphorus compounds. Ginger may help stabilize phosphorus levels or prevent degradation more effectively than clove. Clove's lower phosphorus content could also reflect its different binding or retention properties.

4.0 Conclusion

Turmeric treated egg powder at 2g/kg demonstrated superior antioxidant properties, preserving proteins, stabilizing lipids, and minimizing moisture absorption. Ginger treated egg powder at 2g/kg was more effective in lipid preservation; while clove treated egg powder moderately enhanced enzymatic activity.

Recommendation

Turmeric is recommended for processing egg powder due to its superior ability in maintaining protein and lipid stability particularly over 90 days of storage.

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