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Functional and Some Chemical Properties on the Storage Stability of *Agidi* Produced from Maize, Soyabeans and Carrot Composite Flour

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ABSTRACT

Agidi (maize pudding) is a gel-like traditional fermented starchy food mainly made from maize. Maize used in the production of *Agidi* is limited to some essential nutrient like protein, fat and minerals. The study aims to assess the functional, pH and free fatty acid of *Agidi* produced from maize, soybean and carrot composite flour. Enriched *Agidi* was produced from the blends of maize, soybean and carrots at ratio; 100 maize flour for sample A (control), 85:10:5 sample B, 80:15:5 sample C, 75:20:5 sample D, and 70:25:5 sample E. The enriched *Agidi* samples were analyzed for functional, pH and free fatty acid while storing them under ambient and refrigeration temperatures for Day 1, 3, 5 and 7 after production using standard analytical methods. The functional properties values for loose bulk density, tapped bulk density, water absorption capacity, oil absorption capacity and dispensability ranged from 0.38-0.41 g/cm³, 0.63-0.69 g/cm³, 1.37-1.63 g/g, 1.18-1.32 g/g and 60.5-64.7% respectively. The pH of *Agidi* stored under ambient and refrigerated condition on the 1st day and 7th day ranged from 4.20-6.12 & 2.90-3.85 as well as 4.20-6.12 & 3.50-4.55 respectively. The use of soybean and carrots in agidi production has been seen to improve the product, based on the examined parameters.

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INTRODUCTION

Maize *(Zea mays L.)* is an important annual cereal crop of the world belonging to family Poaceae. It is the third most popular cereal crop after rice and wheat in the world and fourth in Nigeria after millet, sorghum and rice (FAO, 2009). Due to its highest yield potential among the cereals it is known globally as queen of the cereals. Maize is an important cereal which can be fermented to give various products important to the diet of many countries in Africa. Fermentation improves the products quality producing lactic acid which causes souring and improvement in its taste flavour and texture. Maize is generally processed and utilized in food preparations including breakfast cereal, weaning foods, and other snacks since it contains a lot of carbohydrates (70–87%), provides 365 Kcal of energy, 6–13% protein, 4% fat, 2–6% oil, and 1–3% sugar (FAO, 2009). *Agidi* "maize based pudding" is a gel like traditional fermented starchy food mainly made from maize (Adegbehingbe et al., 2018). It is a very popular food, widely recognized and enjoyed by different ethnic groups in Nigeria, for instance, the Yoruba refer to it as eko, the Igbos call it *Agidi*, and the Beninians called it akasan while the Hausa's called it kafa, (Ogiehor et al.,2005, Kolawole *et al.*,2020). *Agidi* Production is laborious, tedious and time taking. Currently, its production varies from one locality to another resulting in a non-uniform product (Ogiehor et al., 2005). In western part of Nigeria it is prepared by stirring of ogi paste in hot water over fire and stirring until a gel is formed. The cold gel is there after wrapped in leaves such as ewe eran (Abiodun et al., 2018). Generally, *Agidi* is wet milled sieved and cooked until a gel paste is formed (Ikya et al., 2013).It is typically eaten with stew, vegetables, bean cake, or bean pudding. According to Akusu et al. (2020) consumption of *Agidi* (maize pudding) has increased significantly as its consumption cuts across all economic classes of people, sex and age groups. However, it is commonly consumed by the vulnerable group, including the elderly and as a weaning food for children (Zakari et al., 2010).

According to Oguche et al. (2017) puddings made from maize contain higher proportion of carbohydrate (74.06%) but low in terms of fibre 1.92% and protein (8.92%). This led to emergence and incorporation of plant based nutrient source to enrich the final product. Sources such as legumes for protein and fruits for vitamins are recommended. Kolawole et al. (2020) also reported that *Agidi* is used as a convalescence and weaning food in infants due to its low fiber content.

Soybeans (*Glycine max*) is grown for its edible pulse, it contains significant amount of protein that may vary from 33 to 50 % depending on the varieties. Soybeans also contain all the essential amino acids except methionine and cysteine which must be supplied in the diet as the body cannot synthesize it (Abiodun et al., 2018). It also contains essential minerals like calcium, iron and zinc and vitamins A, B and C (Liu 2021).Soybean grains can be used in multiple ways, through processing into snacks, paste and milk like product for infant. It has potential for preparation into flour, roasted and eaten as peanut-like (Martinho et al., 2020). So ya-beans are known to possess some beany flavour and toxins which inhibits the availability of nutrients in them, some processing methods will help in making nutrients more accessible and palatability, as well as help in removing undesirable constituent (Adesokan Et al, 2011). Eating soybean-based foods may reduce the risk of various health problems, including cardiac disease, stroke, coronary heart disease (CHD),some cancers and also reduce osteoporosis hence improving bone health (Zakari et al.,2010).Soybean is also an excellent source of phytochemicals such as phytic acid, alpha-linolenic acid, and the isoflavones-genistein. However because of its availability and being cheap source of protein it has successfully been used to enrich Nigeria cereal products, for instance soy –ogi.

Carrot is a root vegetable that belongs to the Apiaceae family (Ascot et al., 2010).It is a popular vegetable worldwide and is known for its bright orange color, crunchy texture and sweet taste. Carrots are widely consumed both raw and cooked and are commonly used in salads, soups, stews, and various other dishes. Carrots storage root is a good source of carotenoids vitamin and dietary fiber and is also rich in minerals and antioxidants (Asco*t* et al., 2010). Dueto increase in health awareness, carrots are becoming more popular due to their abundant nutrient and health benefit. The vibrant orange color of carrots comes from beta-carotene, which is metabolized into vitamin A in the liver and is important for vision, boosting immune system, supporting healthy skin and overall health (Obinna-Echem et al., 2022). Carrots are also low in calories and can be a part of a balanced diet for weight management. Carrots being a good source of phytochemicals, e.g. phenolic ascorbic acids and carotenoids; is associated with reducing the risk of cardiovascular disease cancer, and building strong bones and healthy nervous system (Uchegbu et al., 2019). Dietary fiber in carrots is primarily in the form of soluble and insoluble fiber, contributes to digestive health and helps maintain regular bowel movement (Chantaro et al., 2018). Nutrient in carrots differ slightly in their composition depending on the size and variety of carrots as well as how they are prepared (cooked, boiled, or raw) (Obinna-Echem et al., 2022).

This study aimed to evaluate the effects of soybeans and carrot flour incorporation on the functional properties and storage stability of *Agidi* under ambient and refrigerated conditions.

MATERIALS AND METHODS

Maize (*Zea mays "amylacea") (*Flour Corn variety*)*, soybean (*Glycine max) (*Yellow Soybeans*)* and carrot (*Daucus carota "nantes"*) were obtained from the Wednesday market in Dutsin ma Katsina State, Nigeria and all the chemical used were analytical graded.

Fermented Maize Flour Production

The fermented maize flour was produced according to method describe by Ojo et al. (2016) as shown in Fig. 1.The maize was cleaned and soaked for 48 hours at room temperature. Thereafter the steeped water was decanted and the maize grain obtained was washed with portable water. The grains were subjected to wet milling using attrition mill after which the slurry was then sieved using 500 um aperture sieve. The slurry was allowed to settle for 6 hours and the supernatant decanted. The semi dried slurry was then dried in oven at 65 °C for 5 hours and milled, sieved before packing in an air tight nylon for further use.

Soybean Flour Production

One (1) kg of soybean was processed according to method as describe by Adesokan et al,. (2011), as shown in Fig 2, the soybean was cleaned, sorted and blanched at 90 °C for 3 minutes to inactivate the enzymes. The soybean was manually dehulled and oven-dried at 60 °C for 4 hours. The dried beans were milled using an attrition machine and filtered through a 1 mm mesh sieve.

Carrot Flour Production

The method as described by Obidiapo et al.(2017) with slight modification as shown in Fig 3 was used in the preparation of carrots powder. The carrots were sorted, brushed using knife then washed with portable water. They were grated using a grater and then oven-dried at 55°C for 24 hours. After drying, the carrots were milled using an electric blender and sieved through a 0.5mm mesh sieve. Finally, the carrot powder was packed in an airtight container.

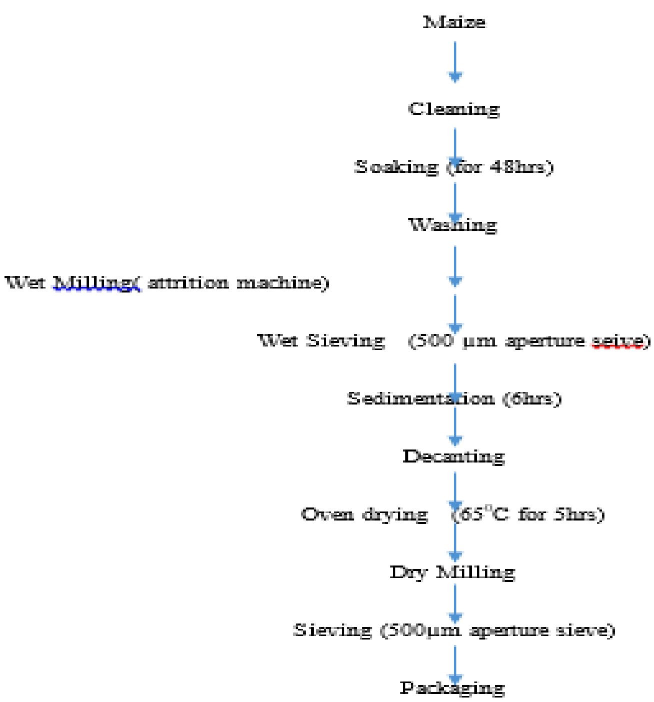

Figure 1: Production of fermented maize flour
Source: Ojo et al, (2016)

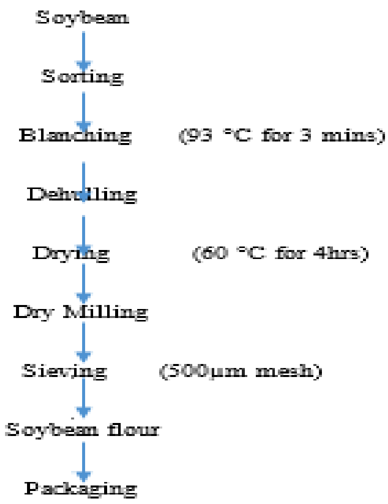

Figure 2: Production of soybean flour
Source: Adesokan et al.(2011)

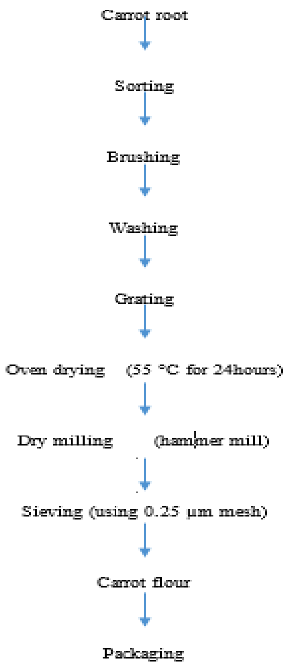

Figure 3: Production of carrot flour
Source: Ibidiapo et al. (2017).

Table 1: Formulation of Maize, Soybean and Carrot in *Agidi* (maize pudding)

Samples	Maize (%)	Soybean (%)	Carrot (%)
A	100	0	0
B	85	10	5
C	80	15	5
D	75	20	5
E	70	25	5

Enriched *Agidi* Production

Enriched *Agidi* was prepared using the method described by Kolawole et al.,(2020) with the formulation in Table 1 with slight modifications as shown in Fig 4. Fermented maize powder was mixed with soybean flour and carrot flour according to the specified percentages for each sample. 300ml of water was added to the mixture and was stirred thoroughly to avoid formation of lumps in the final product. This was then added into 1000mL capacity pot, it was allowed to boil with continuous stirring for about 10minutes until a gel-like semi-solid was formed. Each sample was dispensed into a well labelled aseptic disposable plastic package and sealed.

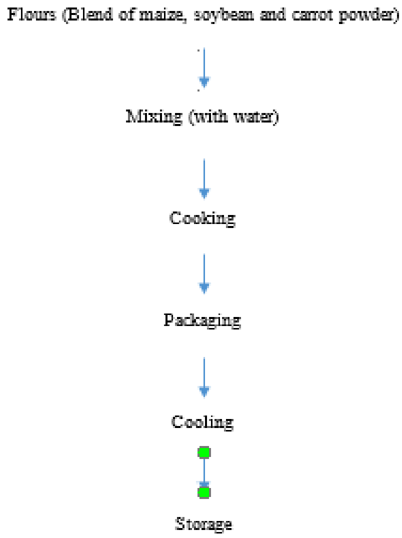

Figure 3: Production of *Agidi*
Source: Kolawole et al. (2020)

Functional Analysis of the Enriched *Agidi*

Determination of Loose Bulk Density

The method described by Onwuka (2018) was used. 10g of the composite flour was gently poured into a pre-weighed graduated cylinder, and the volume occupied by the flour was recorded. Loose bulk density was calculated as the ratio of the weight of the sample to the volume it occupied in the cylinder.

$$\text{Loose Bulk Density } (\text{g/cm}^3) = \frac{\text{Weight of sample}}{\text{Volume of sample}} \qquad (1)$$

Determination of Tapped Bulk Density

The method of Onwuka, (2018) was used to determine the bulk density of the composite flours. A 10ml capacity graduated measuring cylinder was gently filled with the sample and the bottom of the cylinder was tapped on the laboratory bench several times until thereno further dimunition of the sample level after filling to the 10ml mark. Bulk density was calculated by using the formular

Tapped Bulk Density (g/cm^3) = Weight of sample / Tapped volume of sample (2)

Determination of Water Absorption Capacity

The method of Onwuka (2018) was used. 1g of the flour sample was weighed into a 15 ML centrifuge tube and suspended in 10 MLof water. It was shaken on a platform tube rocker for 1 minute at room temperature. The sample was allowed to stand for 30 min and centrifuged using (Model SM 800B Uniscope Surgifriends Medicals, England) at 500 rpm for 30 min. The volume of free water was read directly from the centrifuge tube. Density of water was taken to be 1 g/cm^3.

$$\text{WAC} = \frac{\text{amount of water added} - \text{freewater}}{weight\ of\ sample} \times density\ of\ water \times 100 \ldots\ldots (x) \qquad (4)$$

Determination of Oil Absorption Capacity

The method as described by Onwuka (2018) was used. 1 gof the flour was mixed with 10 ml refined oil in a centrifuge tube and allowed to stand at room temperature (30 ± 2 °C) for 1 h. It was centrifuged (Model SM 800B Uniscope Surgifriends Medicals, England) at 500 rpm for 30 min. The volume of free oil was recorded and decanted. Fat absorption capacity was expressed as ml of oil bound by 100 g dried flour**.** Density of oil was taken to be 0.98 g/cm^3.

$$\text{OAC} = \frac{\text{amount of oil added} - \text{freeoil}}{weight\ of\ sample} \times density\ of\ oil \times 100 \ldots\ldots (xi) \qquad (3)$$

Determination of Dispersibility

The method described by Onitilo, et al. (2007) was adopted. 10g of the flour was dispersed in 100 MLof distilled water in a measuring cylinder and stirred vigorously. After allowing the mixture to settle for 3 minutes, the volume of sedimented flour was recorded, and the percentage dispersibility was calculated.

Dispersibility (%) = 100 - Volume of sediment (4)

Some of the Chemical parameters that where checked based on the storability of the enriched *Agidi* where the pH of the samples with the aid of a Digital pH meter (Hz 1345) and the free fatty acid of the products stored under ambient (27^{o}C at RH of 45%) and refrigeration (7-10^{o}C) temperature and observed for Day 1, Day 3, Day 5 and Day 7 after productions.

Determination Free Fatty Acid

According to Onwuka, (2018), Five (5) g of the sample was into a clean conical flask, with the addition of 50 mL of 95%–99% ethanol, and the mixture was gently warmed on a hot plate until the fat completely dissolves. After which 2 drops of 1% phenolphthalein indicator solution was added to the warm mixture. The supernatant was titrated against a standardized 0.1 N KOH solution from a burette, shaking vigorously until a faint pink color persists for at least 30 seconds as the endpoint.

%FFA = (V × N × $M_{equi.}$ × 100)/ W × 1000 (5)

Statistical Analysis

Triplicate samples of data were prepared and analyzed using one-way analysis of variance (ANOVA). Means were compared using the Fisher Least Significant Difference (LSD) test ($p \leq 0.05$) with the Statistical Package for the Social Sciences (SPSS) Version 16.0 for Windows (SPSS Inc., Chicago).

RESULTS AND DISCUSSION

Table 2: Functional Properties of *Agidi* Enriched with Soybean and Carrot Flour

Samples	Loose bulk density (g/cm^3)	Tapped bulk density (g/cm^3)	Water absorption capacity (g/g)	Oil absorption capacity (g/g)	Dispersibility (%)
A	0.39 ±0.01^c	0.63±0.04 ^{d}	1.37±0.06^e	1.18±0.02^d	69.5±0.71^a
B	0.40 ±0.03^b	0.66 ±0.01^c	1.42±0.01^d	1.26±0.01^c	68.0±0.5^b
C	0.41±0.03^a	0.66±0.03^c	1.50±0.01^c	1.29±0.03^b	65.5±0.14^c
D	0.38±0.02^d	0.67±0.01^b	1.57±0.02^b	1.31±0.05^a	64.7±0.42^d
E	0.38±0.01^d	0.69±0.07^a	1.63±0.01^a	1.32±0.03^a	60.5±0.71^e

KEY: Values are mean ± standard deviation of triplicate determined. Values with same superscript are not significantly different at p (<0.05)

A= 100% maize, 0% soybean, 0% carrot
B= 85% maize, 10% soybean, 5% carrot
C= 80% maize, 15% soybean, 5% carrot
D= 75% maize, 20% soybean, 5% carrot
E= 70% maize, 25% soybean, 5% carrot

Functional properties are the significant physicochemical properties that reflect the complex interaction between the composition, structure, molecular conformation, and physicochemical properties of food components, together with the nature of the environment in which they are measured. The functional properties discussed include Loose and tapped bulk density, water and oil absorption capacity.

Loose Bulk Density

Loose bulk density refers to the mass of a powder per unit volume without compression. Samples D and E recorded the lowest value of 0.38 g/cm³, while sample C had the highest. A lower bulk density suggests that a high volume of pack will be required to the food sample can be packed into a given volume. In contrast, a higher loose bulk density is less desirable in food packaging because it allows for a larger oxygen reservoir (Otegbayo et al., 2013). The range of values found in this study aligns with the findings of previous work by Ikya et al.,(2013), who recorded a loose bulk density range of 0.4-0.44 g/ml in a maize, soybean, and pumpkin blend. Increased loose bulk density may also indicate that more food is consumed (Abiona et al., 2023). Significant differences in loose bulk density were observed among samples A, D, and E.

Tapped Bulk Density

Tapped bulk density reflects the compressed state ofa flour after vibration or tapping, which can affect the product's appearance (Barbosa et al., 2005). It is calculated as the ratio of the weight of a powder to its volume in grams per milliliter. The higher bulk density in sample E may be attributed to the inclusion of 25% soybean, also indicating that soybean is denser than maize hence increase in the protein content of *Agidi*. This finding is in agreement with Omoniyi et al. (2016), who reported higher mass density values for sweet potato and soybean flour blends. High bulk density is also important for packaging and handling requirements (Liu, 2021). The bulk density of a sample helps to determine its packaging needs and is influenced by particle size and moisture content (Adeoti and Osundahunsi, 2011).

Water Absorption Capacity

Water absorption refers to the ability of material to absorb water when immersed in it (Schopf etal., 2021). Water absorption capacity is a critical processing parameter that affects viscosity (Sapirstein et al., 2018). From the result it was seen that the rate of water absorption increases with increase in the proportion of soybean added and the carrot which is constant all through, Thus sample E absorbs water more than sample A, the study is in line with that of Esumaba et al (2018) who reported an increase in water absorption of soybean maize and pumpkin flour. The increase could be that soybean have high-absorption capacities for water and also contain high-hydrophilic constituents such as starches and polar amino acid residues which influence their gelation and hydrophobicity capacity likewise the dietary structure of the carrots as well (Kaur & Singh, 2019) Significant variations were observed between samples A, C, D, and E. This finding aligns with the study by Obinna-Echem et al.(2022) who reported that the inclusion of soybean flour, along with a constant amount of carrot powder, enhanced the water absorption capacity of the flour blends.

Oil Absorption Capacity

Oil absorption capacity measures the ability of flour to absorb oil. The results showed that the rate of oil absorption increases as the proportion of soybean increase thus Sample E absorbs oil more than sample A. The result is in agreement with the result obtained from Ijabideniyi et al (2023) who reported slight increase in oil absorption as the rate of sprouted soybean is increased. The result is also in agreement with Horsfall et al. (2007) who reported increase from 110 to 130 % of oil capacity for blends of wheat and plantain flours.). Oil absorption capacity is the flavour retaining capacity of flour which is very important in food formulations (Sapirstein et al., 2018). Oil absorption capacity measures the ability of food material to absorb oil (Schopf et al., 2021). This is consistent with previous studies that showed differences in oil absorption capacity based on the composition of mixed flours (Edima-Nyah et al., 2020).

Table 3: pH of *Agidi* Enriched with Soybean and Carrots

Day	Day 1	Day 3	Day 5	Day 7
Ambient Temperature				
Sample A	5.50 ±0.10 ^{b}	4.30±0.12 ^{b}	4.00±0.15^c	3.80±0.14^b
Sample B	5.55±0.08^b	4.35±0.10^b	4.10±0.11^b	3.85±0.13^b
Sample C	4.20±0.12^d	3.70±0.09^d	3.15±0.14^d	2.90±0.15^d
Sample D	5.45±0.09^c	4.25±0.14^c	4.00±0.10^c	3.75±0.12^c
Sample E	6.12±0.11^a	5.50±0.13^a	4.20±0.12^a	4.00±0.10^a
Refrigerated Temperature				
Sample A	5.50±0.10^b	5.50±0.10^b	5.50±0.11^b	4.40±0.12^b

Day	Day 1	Day 3	Day 5	Day 7
Sample B	5.55±0.08^{b}	5.53±0.11^{c}	5.52±0.10^{b}	4.45±0.13^{bc}
Sample C	4.20±0.12^{d}	4.16±0.09^{e}	4.10±0.12d	4.05±0.10^{c}
Sample D	5.45±0.09^{c}	5.40±0.12^{d}	5.35±0.11^{c}	4.50±0.14^{a}
Sample E	6.12±0.11^{a}	5.70±0.11^{a}	5.65±0.10^{a}	4.55±0.11^{a}

KEY: Values are mean ± standard deviation of triplicate determined. Values with same superscript are not significantly different at p (<0.05)

A= 100% maize, 0% soybean, 0% carrot
B= 85% maize, 10% soybean, 5% carrot
C= 80% maize, 15% soybean, 5% carrot
D= 75% maize, 20% soybean, 5% carrot
E= 70% maize, 25% soybean, 5% carrot

pH

pH is a measure of how acidic or alkaline a substance is, ranging from 0 to 14, where a pH of 7 is neutral, below 7 is acidic, and above 7 is alkaline. In food science, pH affects product safety, taste, and shelf-life stability. The pH of freshly produced *Agidi* ranged from 4.20 for sample C to 6.12 for sample E. The pH of *Agidi* recorded for sample A is high when compared with the research carried out by (Obeta et al., 2023) who recorded a pH of 3.57 from Agidi slurry .The deviation could be due to production process adopted. The increase in pH of sample E is in agreement with the work of Obeta et al.(2023), who reported an increase in pH of *Agidi* enriched with cowpea. This could also be because soybean like cowpea used is a non-fermented protein food as such could increase the pH value of the enriched *Agidi*.

The decrease in pH of *Agidi* samples over time could be attributed to fermentions and microbial metabolisms which increases protein found in sample E and this result in a more acidic product, which may alter the texture or taste, potentially making it less palatable. The decrease in pH of *Agidi* stored in ambient condition for seven days and also the gradual decrease of *Agidi* pH stored in the refrigerated condition in this study is similar to the findings of Ogiehior et al., (2005), who noted a significant decrease in pH of *Agidi* from 4.15 to 3.10 for *Agidi* stored over seven days. However, the observed decrease in pH over time might also indicate a reduction in product quality which may leads to spoilage and undesired changes in texture. This highlights the importance of monitoring pH in the storage and preservation of *Agidi* to ensure both safety and quality.

Table 4: Changes in Free Fatty Acid (FFA) of the Enrich *Agidi*

Samples	Day 1 (%)	Day 3 (%)	Day 5 (%)	Day 7 (%)
Ambient				
A	8.5 ± 1.2^{c}	10.3 ± 1.5^{b}	12.1 ± 1.8^{c}	14.1 ± 2.0^{c}
B	9.8 ± 1.4^{b}	11.2 ± 1.6^{a}	12.9 ± 1.9^{b}	15.0 ± 2.2^{b}
C	11.2 ± 1.3^{a}	12.8 ± 1.6^{a}	14.4 ± 1.9^{a}	16.0 ± 2.1^{a}
D	10.1 ± 1.5^{b}	12.5 ± 1.8^{a}	13.8 ± 2.0^{ab}	15.5 ± 2.3^{b}
E	11.0 ± 1.1^{a}	12.7 ± 1.3^{a}	14.2 ± 1.6^{a}	15.8 ± 1.8^{b}
Refrigerated				
A	8.5 ± 1.2^{c}	11.0 ± 1.3^{a}	11.8 ± 1.5^{b}	12.5 ± 1.7^{a}
B	9.8 ± 1.4^{b}	10.3 ± 1.5^{b}	10.9 ± 1.6^{c}	11.4 ± 1.8^{c}
C	11.2 ± 1.3^{a}	11.7 ± 1.4^{a}	12.3 ± 1.5^{a}	12.6 ± 1.6^{a}
D	10.1 ± 1.5^{b}	10.6 ± 1.6^{b}	11.2 ± 1.7^{b}	11.7 ± 1.8^{b}
E	10.6 ± 1.1^{a}	11.1 ± 1.2^{a}	11.6 ± 1.3^{b}	12.0 ± 1.4^{ab}

KEYS

KEY: Values are mean ± standard deviation of triplicate determined. Values with same superscript are not significantly different at p (<0.05)

A= 100% maize, 0% soybean, 0% carrot
B= 85% maize, 10% soybean, 5% carrot
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D= 75% maize, 20% soybean, 5% carrot
E= 70% maize, 25% soybean, 5% carrot

Free Fatty Acid

Free fatty acids are unesterified fatty acids found in oils and fats. Measurement of FFA content indicates the extent of hydrolytic rancidity and it affects the flavor, stability, and shelf life of foods. The increase in FFA content at ambient temperature observed in this study, could be attributed to the oil in the soybeans since it's not defatted before use, but it's consistent with the findings of Oke et al., (2018), who reported a significant increase in FFA content in maize oil stored at room temperature for 14 days. Though the products if not properly handle could run rancide as a result of lipid hydrolysis.

However, the stable pH and FFA content at refrigerated temperatures in this study are in sharp contrast to the findings of (Nwokeocha et al., 2016), who reported a significant changes in pH and FFA content in maize-based products under refrigerated conditions. These differences may be due to changes in storage conditions, product formulations, or analytical methods used in these studies.

Overall, this study highlights the effect of physico- chemical stability of soybean enriched *Agidi* stored under ambient and refrigerated condition. Refrigeration is effective in maintaining product quality, whereas ambient temperature storage can cause significant changes in pH and FFA content over time.

CONCLUSION

This research work shows a significant differences in the functional properties, the addition of soybean and carrot also increase the water and oil capacity of the samples. The keeping quality of enriched *Agidi* stored under ambient temperature indicated high rate of free fatty acid and low rate of pH when compared with the control whereas refrigerated samples were fairly stable. The use of soybean at different proportion affected the functional and keeping quality based on the pH and free fatty acid of the product. However the findings shows great improvement in the product through the addition of soybean and carrot suggest that enriched *Agidi* could be used for dietary purpose.

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