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Development and Quality Assessment of Functional Cookies from Wheat (*Triticum aestivum*) and Chicken Egg-Shell Composite Flours

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Abstract
Eggshell has been found to be an attractive source of calcium in food supplements, for the treatment of rickett and osteoporosis. It has the potential to be exploited in human diets. The efficacy of wheat-eggshell composite flours in the production of functional cookies was investigated. The technological properties of the composite flours as well as the physical, nutrient and sensory qualities of the cookies were studied. The result showed the functional properties of composite flours were significantly (P>0.05) affected by supplementing with eggshell powder. Sample E with 30% eggshell powder had the highest bulk density (0.72 g/mi) and least swelling index (1.15 g/ml). The nutrient content of cookies showed a significant (p<0.05) reduction in moisture (6.95-8.55%), protein (9.12-11.43%), fat (3.90-5.91%) and increase in carbohydrate (61.19-67.89%) and ash (5.27-8.72%) with increased eggshell powder. The addition of eggshell powders resulted in higher mineral values in the cookies. Samples D and E with 20% and 30% eggshell substitution had superior calcium content (513.61-536.30 mg/100g). The fortification with egg-shell powder, improved the texture (6.00-7.91) and overall sensory acceptance (6.13-7.16) of cookies. The functional cookies has the potential to be a cheap source of dietary calcium for treatment of calcium related diseases.

Keywords: Egg-shell, composite flour, minerals, cookies, sensory

Introduction

Chicken eggshells are agricultural wastes which could lead to environmental pollution when not properly disposed of (Khan *et al*., 2021; Aditya *et al*., 2021). They are found in hatcheries, homes and fast food industries, and are abundantly available for collection (Kingori, 2011). The rotting of eggshell wastes is a source of environmental pollution resulting from foul odour which attracts flies, hence a challenge to its disposal (Oliveira *et al*., 2013; Khan *et a*l., 2021). However, eggshells can be processed into more useful products such as fertilizer, animal feeds, medicines, and building materials (Aditya *et al*., 2021). It can also be used as additive in the food industry for human consumption, especially in this era of ever-increasing endeavors to convert waste to wealth (Oliveira *et al*., 2013; Merta *et al*., 2020). The eggshell is basically made of calcium carbonate and glycoprotein matrix. It contains calcium, magnesium, copper, iron, manganese, molybdenum, sulfur and many more other useful elements. It is an acceptable practice for eggshell to be dried and used as a source of calcium in animal feeds (Afzal *et al*., 2020). It is used on a moderate scale as additives in foods (Ndife, 2016; Khan *et al.,* 2021). Eggshell had been clinically proven to provide effective prevention of osteoporotic fractures in elderly community-dwelling residents (Afzal *et a*l., 2020). It is currently being used as human dietary calcium supplement especially for postmenopausal women (Aditya *et al.*, 2021)

The consumption of cereal snacks like cookies are popular because of their wider consumption rate and relatively long shelf life (Afzal *et al.*, 2020), and thus they should be enriched and improved nutritionally (Ali and Badawy, 2017), particularly in children feeding system, and for the elderly and low income groups (Wafiqah *et al.*, 2020; Aditya *et al*, 2021).It was suggested that eggshell calcium promoted strengthening of bones and improving their growth. To increase daily calcium intake, calcium supplements and calcium fortified foods are available in the market. These foods are fortified with many calcium sources such as calcium-carbonate, calcium-phosphate, cattle bone powder and milk calcium (Girma *et al.*, 2019; Khan *et al.*, 2021). Calcium supplements are however, expensive for the poor, unlike Calcium from eggshells which is readily available and easily absorbed in the small intestine more than commercial calcium-carbonate (Kingori, 2011; Girma *et al*., 2019). Cereal flour is currently the most frequently used vehicle for calcium fortification. Unfortunately, calcium in cereal is poorly bioavailable due to presence of anti-nutritional factors like phytic acid that reduces its intestinal absorption which leads to calcium deficiency (Khan *et al.,* 2021). Calcium intake from dairy products is an expensive alternative way to meet calcium requirements in chronic cases of deficiency. Notably, chicken eggshell is a rich source of calcium carbonate, which is abundant as waste and can be exploited for calcium supplementation (Wafiqah *et al*., 2020; Khan *et al*., 2021).

Calcium deficiency manifests in children born with bone problems (rickets) and old people also suffer from osteoporosis (Islam *et al*, 2019 Khan *et al.,* 2021). People do not usually consume calcium in amounts established by clinical guidelines. Supplementation with tablets is expensive and sometimes includes problems of adherence to medication (Brun *et al.,* 2013; Aditya *et al.,* 2021). Calcium enriched foods could be a cheaper alternative to increase the calcium content of diets. Therefore, the efficacy of converting eggshells to beneficial food products is a novel idea worth exploring. In contrast, there is less work regarding the use of eggshell for calcium enrichment. This research sought to investigate the use of eggshell powder for the production of functional cookies and its sensory acceptability.

Materials and Methods

Source of materials

The eggshells were collected from household and commercial fast food restaurant as wastes in Wudil town. The commercial wheat flour and other baking ingredients used in this work were purchased in Sabongari market in Kano. All the chemicals used in this study were of analytical grade. The research work was performed at Kano University of Science and Technology, FST laboratory, Wudil, Kano State, Nigeria.

Preparation of the eggshell powder

The eggshell membranes were removed and the eggshells were washed, boiled in water for 30 min. to destroy harmful microbes and drained off water. The broken shells were oven dried at 110 °C for 3 h. The dried eggshells were pulverized, milled to a powder using a Moulinex grinder and sieved to a fine powder by using a 0.5-micrometre size sieve. The sieved eggshell powder was packaged with polyethylene and stored in refrigerator for further use.

Table 1: Formulation of composite flour (%)

Samples	Wheat flour	Eggshell powder
A	95	5
B	90	10
C	85	15
D	80	20
E	70	30
F	100	-

Production of cookies

The egg-shell powder was used to substitute wheat flour at different percentage levels of 5, 10, 15, 20 and 30 and was labeled A, B, C, D, and E respectively. Unsubsituted wheat flour (F) was used as control (Table 1). The composite flours were mixed with other baking ingredients (Table 2) and kneaded into dough which was flattened into uniform thickness of about 1.5 mm before sizing using a hand cutter. The cut out dough were baked at 200 °C for 10 min. in the oven. After baking, the cookies were allowed to cool to room temperature, packaged in polythene bags and kept in a refrigerator for further use.

Table 2: Recipe of cookies

Ingredient	Quantity
Composite flour	300 g
Sugar	20 g
Milk	30 ml
Butter	10 g
Baking powder	5 g
Water	50 ml
Groundnut oil	10 ml
Salt	3 g

Methods of Analyses
Proximate analysis
Moisture, ether extract, crude protein, ash and crude fiber contents of samples were determined using the methods described by Onwuka, (2018). Total carbohydrate was calculated by difference (Afzal *et al.,* 2020).

Functional properties analysis
Bulk density, water absorption capacity, dispersibility, and swelling index, were determined using the protocol of Onwuka (2018).

Determination of minerals
Minerals of samples were determined as described by AOAC (2012). The samples were digested in concentrated Nitric acid. The digest was quantitatively transferred to a volumetric flask and made up to 25 ml with deionized water. A blank digest was prepared the same way and mineral samples of known strength were used to prepare standard curves. Mineral determinations were made using flame photometer and Atomic Absorption Spectrophotometer.

Physical properties assessment
The cookies physical characteristics, such as; height, width, thickness were measured with digital vernier calipers with 0.01mm precision and the spread ratio calculated by the method described by Ndife *et al*. (2014).

Sensory evaluation
Sensory evaluation of cookies for consumer preference and overall acceptability was done using 20 semi-trained panelists which comprised of students and staff of Food Technology Department, Kano University of Science and Technology, Wudil. They evaluated the sensory properties of appearance, taste, aroma and overall acceptability using a nine-point Hedonic scale (Iwe, 2010).

Statistical analysis
In the experimental plan, a completely randomized design was used. All determinations were done in replicates. Means and standard deviations were calculated for values obtained from samples. The data generated was analyzed using Statistical Package for Social Sciences (SPSS version 16.0). Analysis of variance (ANOVA) was used to compare the values obtained. Level of significance was accepted at $p \leq 0.05$) (Onwuka, 2018).

Results and Discussion
Functional properties of flours
Data presented in Table 3 shows the results of functional properties of flours. The water absorption capacity (WAC) of flours was in the range of 60.17-80.63%, the control F had the lowest (60.17 g/ml), while sample E with 30% eggshell powder had the highest (80.63%). The WAC of substituted flours (63.26-80.63) was higher than the control. The results were consistent with that of Ali and Badawy (2017) who found a considerable increase in water absorption in eggshell fortified bread strips. Rheological properties indicated an increase in water absorption from 63.60-67.527% in breads fortified with calcium extracted from chicken eggshells (Khan *et al*., 2021) and in eggshell fortified semolina flour (Girma *et al*., 2019). This may be due to eggshell powder being hydrophilic filler by nature. There was increase in bulk density (0.62-0.72 g/ml) of composite flours with eggshell powder addition. The value was lowest in control F (0.51 g/ml). Same trend was reported by Ray *et al.* (2017) for wheat flour (1.15 g/ml) and wheat-eggshell composite flours (2.68 – 4.96 g/ml). The bulk density depends on the particle size and initial moisture content of the flour. The bulk density will influence the suitability of the flour for use in food formulations. Similar trend was observed in the dispersibility properties of composite eggshell flours (63.11 – 71.25%) and wheat flour (61.31%). On the contrary, the swelling index which was highest in control F (1.62%) reduced with increase in eggshell powder. Sample A (1.40 g/ml) had the highest value followed by B (1.33g/ml), while E (1.15 g/ml) had the least. The functional and technological properties give insight into the potential behaviour of flours during processing and to a large extent influence dough development time and stability.

Proximate composition of cookies
The proximate composition of cookies is presented in Table 4. Control sample F, had higher nutrient contents, except for ash (4.73%) when compared to the cookies from eggshell substituted flours. A decline was observed in moisture content of cookies with increased eggshell powder from 8.55 to 6.95%. The cookies from wheat flour (F) had highest moisture content (10.50%). Khan *et al*. (2021) and Ali *et al.* (2019), both reported increase in ash levels in breads enriched with chicken eggshell powder. Afzal *et al*. (2020) observed that as the concentration of calcium source increased, moisture content of muffins decreased. Moisture content of is very important in predicting shelf life of foods; the lower the moisture, the better is its storage stability (Ndife, 2016). Protein content was found to vary between 9.12 to 12.14% in the samples. Cookies from wheat flour (F) had higher protein (12.14%) than those substituted with eggshell powder (9.12-11.43%). A reduction in protein content (9.89-9.79%) was reported by Khan *et al.* (2021) from the addition of eggshell powder in fortified breads. Control cookies (F) had higher fat (6.32%) and fibre (7.83%) contents than those supplemented with eggshell powder, which ranged from 3.90-5.91% and 5.42-7.65%. Sample E with 30% eggshell addition had the least fat (3.90%) and fibre (5.42%) contents. Fat (35.86% - 33.85) and fiber (1.76 - 0.91%) contents in muffins significantly ($P>0.05$) decreased as the fortification with other calcium sources increased (Afzal *et al*., 2020). Fortified cookies had a significant ($p<0.05$) increase in ash content (5.27-6.72%) compared to control F (4.73%). Merta *et al*. (2020) and Ray *et al.* (2017) also reported significant increase in ash (0.3-5.5%) by the addition of eggshell powder to fortified nuggets and biscuits. The high ash in

cookies with eggshell powder is indicative that the cookies contain higher minerals elements. Control cookies F had the lowest carbohydrate content (58.48%). This value was significantly different (P>0.05) from those of eggshell fortified cookies (61.19-67.89%). This could be due to its higher values in other nutrients except for ash. Several researchers have reported that supplementing with eggshell powder in bakery products resulted in a reduction in moisture, protein, fat and an increase in ash compared to the control (Hassan, 2015; Jumma *et al*, 2017; Ali *et al.,* 2019; Khan *et al.,* 2021).

Mineral content of cookies

The results presented in Table 5 on the mineral content of cookies showed supplemented cookies had higher mineral elements analyzed, except for Potassium (61.45-109.21%) than control F (123.67 mg/100g). Calcium was the highest mineral (401.25-536.30 mg/100g) in fortified cookies. There was significant (p<0.05) difference in the calcium content of cookies with addition of eggshell powder compared to control F (172.18 mg/100g). Khan *et al.* (2021) reported the addition of eggshell fortification at different concentrations enhanced calcium content of fortified flour from 115.80 to 1135.1 (mg/kg). Also Hassan, (2015) noted that biscuits supplemented with chicken eggshell powder (3-9%) resulted in a prominent increase in calcium levels (607.33 - 2175.23 mg/100g). Ali and Badawy, (2017) and Khan *et al.* (2021) in clinical studies, reported that calcium salt from eggshell was better absorbed in the human body with no adverse effects. The magnesium content of cookies (50.64-131.20 mg/100g) increased significantly (P>0.05) with the levels of egg shell powder incorporation above control F (29.42 mg/100g). Wafiqah *et al.* (2020) also observed increase in calcium (219.97-646.70%) followed by magnesium (40.14-64.99%) in eggshell fortified bread compared with control wheat bread of (31.82%) and (30.58% respectively. Magnesium enhances the absorption of calcium. The obtained values implies that fortified cookies will be potent in meeting the recommended dietary allowance (RDA) of 1000-1200 mg for calcium (Aditya *et al*., 2021) and 400mg for magnesium (Animashaun *et a*l., 2016). Several researchers affirmed pronounced value of calcium, magnesium and iron contents in foods enriched with eggshell powder (Hassan, 2015; Jumma *et al*., 2017; Ray *et al*., 2017; Aditya *et al.*, 2021). These essential minerals play key roles as co-factors for various enzymatic reactions in the body (Islam *et al*., 2019). Calcium is important for structural and physiological roles in our body and is ultimately required in bone formation (Wafiqah *et al.*, 2020; Khan *et al*., 2021).

Physical characteristics of cookies

Table 6 shows the variation in the physical properties of cookies supplemented with eggshell powder. There was decrease in weight of cookies with added eggshell powder (8.30-6.98 g). Control F turned out with the highest cookie weight (8.80 g), while sample E had the lowest (6.98 g). This variation in weight could be due to the functional and chemical properties of the eggshell powder and wheat flour used in processing. The cookies width was highest in control F (5.45 mm) compared to eggshell supplemented cookies (4.01-5.13 mm). However, the thickness of the cookies was lower in control F (2.40 mm) and higher in cookies supplemented with eggshell powder (2.45-2.86 mm). The same trend for thickness was also recorded for spread ratio. The sample with the least spread ratio was sample E (1.40), while Control F had the highest (2.27 mm). Hassan (2015) also observed increase in thickness (5.97-6.01 mm) and decrease in diameter (45.8-45.0 mm) and spread ratio (7.67-7.49 mm) in biscuits with increasing level of eggshell powder. Substitution of wheat flour by calcium from the eggshell reduced the amount of amylose and amylopectin which are major components responsible for biscuit spread.

Sensory evaluation of cookies

The effect of egg shell powder supplement on sensorial properties of cookies is shown in Table 7. There was significant difference (P<0.05) in sensory parameters evaluated between fortified and unfortified (control) cookies. Cookie samples with 100% wheat flour (F) had the lowest appearance score of 5.93, while fortified cookies had higher scores (6.26-7.13). Addition of 30% eggshell powder resulted in significant (P<0.05) difference in appearance over control F. Brown color resulting from maillard reactions and caramelization experienced in sample F, is associated with baking quality of the product.

Supplemented cookies had lower taste (5.11-6.33) and aroma (4.02-6.97) scores when compared to control F of 6.87 and 7.80 respectively. Sample E with 30% eggshell powder had the least taste (5.11 and aroma (4.02) scores. According to Khan *et al.* (2021), addition of eggshell as fortificant at different levels significantly (P>0.05) reduced aroma of bread from 6.93 (control) to 3.96. Merta *et al.* (2020) also reported increased addition of eggshell powder significantly decreased taste scores for fortified nuggets.

Texture scores showed higher significant (p<0.05) difference in fortified cookies (6.00-7.91) than control cookie F (5.87). The higher the eggshell addition, the crispier the cookies. Animashaun *et al.* (2016) observed that fortified biscuits had better crispness score of 6.70-7.80. This shows that incorporation of egg shell powder in cookies improved the texture scores. Texture is considered as an imperative requirement of quality cookies. Substitution of wheat flour by mineral sources reduced the amount of gluten, amylose, amylopectin and moisture contents, thereby increasing texture of fortified foods. Both fortified (6.13-7.16) and unfortified (7.30) cookies samples were generally accepted considering that none of the sample scores was below 6. There were no significant (p>0.05) difference in the acceptability of the cookies, except at higher levels (20-30%) of eggshell addition (samples D and E). Salem *et al.* (2012) and Ray *et al.* (2017) reported no significant (p>0.05) difference between unfortified cake and cakes fortified with 10% and 20% egg shell in overall acceptability. It was suggested that the best way to use chicken eggshell as Calcium dietary supplement is incorporation into bread, muffin, pizza or spaghetti as there were no objections in sensory acceptance (Ndife, 2016; Aditya *et al*., 2021).

Conclusion

The study showed that supplementing of eggshell powder into wheat flour had significant effects on physico-chemical and sensory qualities of cookies. The mineral elements, especially calcium contents of cookies were enhanced. Most nutrients like moisture, protein, fat and fiber reduced, while there were increases in the ash and carbohydrate contents. There was no significant difference (P<0.05) in overall acceptability of the cookies. Chicken eggshells have great commercial prospects in the use of egg wastes as cheap source of dietary calcium. However, its consumption

Table 3: Functional Properties of Flours

Samples	WAC (%)	BD (g/ml)	DP (%)	SI (g/ml)
A	$63.26±0.94^{a}$	$0.62±0.11^{b}$	$63.11±0.89^{b}$	$1.40±0.15^{b}$
B	$70.41±0.19^{ab}$	$0.64±0.91^{b}$	$64.80±1.09^{b}$	$1.33±0.21^{b}$
C	$77.16±0.23^{b}$	$0.66±0.82^{bc}$	$66.21±1.12^{bc}$	$1.28±0.29^{b}$
D	$79.24±0.49^{b}$	$0.69±0.73^{c}$	$69.71±0.96^{c}$	$1.23±0.13^{b}$
E	$80.63±0.17^{c}$	$0.72±0.08^{c}$	$71.25±0.99^{c}$	$1.15±0.16^{c}$
F	$60.17±0.37^{a}$	$0.51±0.06^{a}$	$61.31±0.97^{a}$	$1.62±0.20^{a}$

Values are mean of replications ± SD; Samples on same column with the same Subscripts are not significantly different at (P ≤ 0.5).WAC - Water Absorption Capacity; BD - Bulk Density; DP – Dispersibility; SI - Swelling Index

Table 4: Proximate Composition (%) of Cookies

Samples	Moisture	Fat	Ash	Fibre	Protein	Carbohydrate
A	$8.55±0.84^{a}$	$5.91±0.51^{a}$	$5.27±0.78^{b}$	$7.65±0.07^{a}$	$11.43±0.16^{a}$	$61.19±1.06^{a}$
B	$8.11±0.46^{a}$	$5.24±0.43^{ab}$	$5.60±0.61^{b}$	$7.10±0.28^{a}$	$10.79±0.08^{a}$	$63.16±0.22^{ab}$
C	$7.80±0.75^{b}$	$4.78±0.82^{b}$	$5.91±0.85^{a}$	$6.82±0.35^{ab}$	$10.05±0.50^{ab}$	$64.64±1.30^{b}$
D	$7.26±0.50^{bc}$	$4.35±0.47^{b}$	$6.34±0.90^{a}$	$6.11±0.32^{ab}$	$9.65±1.04^{b}$	$66.29±0.83^{b}$
E	$6.95±0.47^{c}$	$3.90±0.36^{c}$	$6.72±0.67^{a}$	$5.42±0.07^{b}$	$9.12±1.23^{b}$	$67.89±1.51^{b}$
F	$10.50±0.36^{d}$	$6.32±0.48^{d}$	$4.73±0.71^{a}$	$7.83±0.594^{c}$	$12.14±0.39^{a}$	$58.48±2.03^{c}$

Values are mean of replications ± SD; Samples on same column with the same subscripts are not significantly different at (P ≤ 0.5)

Table 5: Mineral Content (mg/100g) of Cookies

Samples	Calcium	Magnesium	Sodium	Potassium	Iron	Zinc
A	$401.25±1.52^{b}$	$50.64±1.25^{b}$	$211.10±0.15^{b}$	$109.21±0.26^{b}$	$2.17±0.27^{a}$	$0.75±0.07^{b}$
B	$442.54±1.37^{b}$	$82.15±1.96^{c}$	$224.42±0.12^{b}$	$97.00±0.49^{c}$	$2.64±0.27^{a}$	$0.84±0.05^{b}$
C	$485.31±1.50^{bc}$	$96.43±0.99^{c}$	$236.15±0.11^{bc}$	$85.2±0.51^{c}$	$3.18±0.15^{b}$	$0.90±0.08^{bc}$
D	$513.61±1.42^{c}$	$117.23±1.48^{d}$	$248.49±0.19^{c}$	$76.27±0.26^{c}$	$3.56±0.13^{bc}$	$0.96±0.07^{bc}$
E	$536.30±1.81^{c}$	$131.20±1.56^{d}$	$262.86±0.15^{c}$	$61.45±0.28^{d}$	$4.03±0.25^{c}$	$1.13±0.08^{c}$
F	$172.18±1.25^{a}$	$29.42±1.69^{a}$	$210.42±0.11^{a}$	$123.67±0.32^{a}$	$1.73±0.14^{a}$	$0.45±0.07^{a}$

Values are mean of replications ± SD; Samples on same column with the same subscripts are not significantly different at (P ≤ 0.5)

Table 6: Physical Properties of Cookies

Samples	Weight (g)	Width (mm)	Thickness (mm)	Spread Ratio
A	$8.30 ± 0.77^{a}$	$5.13 ± 0.16^{a}$	$2.45 ± 0.20^{a}$	$2.09 ± 0.03^{a}$
B	$8.05 ± 0.59^{a}$	$4.80 ± 0.10^{a}$	$2.55 ± 0.10^{a}$	$1.88±0.05^{b}$
C	$7.82 ± 0.38^{a}$	$4.55 ± 0.17^{a}$	$2.61 ± 0.25^{a}$	$1.74±0.05^{b}$
D	$7.20 ± 0.44^{b}$	$4.26 ± 0.15^{a}$	$2.74 ± 0.15^{a}$	$1.55± 0.00^{b}$
E	$6.98 ± 0.62^{b}$	$4.01 ± 0.11^{b}$	$2.86 ± 0.45^{b}$	$1.40± 0.01^{b}$
F	$8.80 ± 0.45^{b}$	$5.45 ± 0.10^{a}$	$2.40 ± 0.32^{b}$	$2.27± 0.02^{b}$

Values are mean of replications ± SD; Samples on same column with the same subscripts are not significantly different at (P ≤ 0.5).

Table 7: Sensory Scores of Cookies

Samples	Aroma	Texture	Taste	Appearance	Acceptability
A	6.97 ± 1.10^{ab}	6.00 ± 1.95^{a}	6.33 ± 0.62^{a}	6.26 ± 0.35^{ab}	7.16 ± 0.74^{a}
B	6.53 ± 0.61^{b}	6.33 ± 1.11^{ab}	6.16 ± 0.59^{b}	6.53 ± 0.64^{ab}	6.80 ± 0.50^{a}
C	6.19 ± 0.98^{b}	6.87 ± 1.06^{b}	5.83 ± 0.88^{bc}	6.81 ± 0.86^{b}	6.50 ± 0.86^{ab}
D	5.51 ± 1.19^{c}	7.42 ± 0.82^{bc}	5.40 ± 1.10^{c}	6.90 ± 1.13^{b}	6.27 ± 0.89^{ab}
E	4.02 ± 0.56^{d}	7.91 ± 0.74^{d}	5.11 ± 0.99^{c}	7.13 ± 0.79^{b}	6.13 ± 0.49^{b}
F	7.80 ± 0.86^{a}	5.87 ± 1.06^{a}	6.87 ± 0.92^{a}	5.93 ± 1.03^{a}	7.30 ± 0.76^{a}

Values are mean of replications ± SD; Samples on same column with the same subscripts are not significantly different at (P ≤ 0.5)

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