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(RESEARCH ARTICLE)

Use of soy-cheese as egg replacer in the development of healthful snack for low-income household

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Abstract

Rolls are widely consumed snacks across the globe with the major ingredient as egg and flour. However, soy-cheese is a less expensive ingredient, which could replace egg. This study investigated the development of soy-cheese fortified roll as an alternative to egg roll. Soybean grains were processed into soy-cheese. Roll was formulated using the soy-cheese while egg roll was used as the control. The rolls were evaluated for nutritional, phytochemical, and sensory properties using standard procedures. The results showed protein, fibre and ash contents of the soy-cheese roll as 28.96 g/100 g, 3.27 g/100 g, and 4.38 g/100 g, respectively. The control (egg roll) had protein (12.14 mg/100 g), fibre (2.27 g/100 g), and ash (3.14 g/100 g). Mineral contents of soy-cheese roll showed calcium (258.92 mg/100 g), zinc (2.45 mg/100 g), and iron (5.29 mg/100 g), which were superior to 48.32 8mg/100 g, 1.88 mg/100 g, and 1.98 mg/100 g for calcium, iron, and zinc, respectively, of egg roll. Niacin (1.10 mg/100 g), and thiamin (0.25 mg/100 g) were recorded for soy-cheese roll and niacin (0.14 mg/100 g), and thiamin (0.09 mg/100 g) for egg roll. Soy-cheese roll was rich in phytochemicals (alkaloids and total phenolic) than egg roll. Soy-cheese roll outperformed the control in taste and general acceptability. The study indicated the potential application of soy-cheese in the formulation of functional roll and as egg replacer. The production method outlined is scalable, and it could be used industrially and on a small scale for self-entrepreneurs. The product's high protein content suggested that it might be utilized to lower protein-energy malnutrition in developing nations.

Keywords: Soy-cheese roll; Phytochemical; Nutritional property; Egg replacer

1. Introduction

In recent years, there has been a significant shift in consumer preferences towards healthier and plant-based food choices. Snacking, a prevalent eating habit, is an area where this shift is particularly noticeable. However, the challenge lies in making these healthier options accessible to all socio-economic groups, especially those with limited financial resources. Eggs, while a common and nutritious ingredient, can be a barrier due to their cost and potential health concerns. This study aims to explore the utilization of tofu as an egg replacer in snack development, specifically targeting low-income households. Tofu, derived from soybeans, offers a cost-effective and nutritionally dense alternative, making it an attractive option for snack innovation.

The use of tofu as an egg replacer in snack development for low-income households addresses several key issues in today's society. Low-income households often face challenges in accessing nutritious and affordable food options. Additionally, concerns about health and sustainability have led to an increased interest in plant-based alternatives.

Tofu, a versatile and protein-rich soy product, presents an excellent opportunity to create healthful snacks that are not only budget-friendly but also contribute to a balanced diet. Tofu is an excellent source of plant-based protein, essential

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amino acids, iron, and calcium, making it a nutritious alternative to eggs. By exploring the use of tofu as an egg replacer, this study aims to provide low-income households with an affordable and accessible snack option that aligns with their nutritional needs. Therefore, this study investigated the formulation and nutritional evaluation of healthful snack using soy-cheese as complete egg replacer in rolls.

2. Material and methods

2.1. Sources of raw material

Mature soybeans were collected from an acredited farm in Ebonyi State, Nigeria and threshed. The threshed grains were kept in an airtight container for further processing after being winnowed, wet-washed, and dried in a hot-air oven (SM9053, China) at 50 ^oC for 8 h. Wheat flour was purchased from Eke Market, Afikpo in Ebonyi State Nigeria.

2.2. Preparation of soy-cheese

Soy-cheese was processed as described by Zheng *et al.,* (2020) with some modifications. The dried soybean grains were immersed in distilled water (1:10, w/v) for 4 h, cleaned with distilled water, drained, and then milled at high speed for 4 minutes with warm water (1:2, w/v; 60 ^oC) supplied at intervals in a potable grinder. The final slurry was filtered through muslin cloth to remove the leftover material (okara). The residue was washed with distilled water three times before pooling with the filtrate. The resultant mixture was boiled for 10 minutes, removed from the heating mantle and allowed to cool to 70 ^oC. At 70 ^oC, 0.33% (v/v) vinegar (as coagulant) was added to the soymilk, gently stirred, and allowed to coagulate for 30 minutes while keeping a temperature of 70 ^oC.

2.3. Production of soy-cheese roll

As described by Nurminah *et al.,* (2019) with some modifications, the soy-cheese roll was produced using ratio 50:50 (soy-cheese : wheat flour). Similarly, the control, egg roll, was also prepared using ratio 50:50 (egg : wheat flour). The dry ingredients (flour, 100%; sugar, 40%; baking powder, 2.4% spices, 2.4%; margarine, 40%; baking powder, 2.4%; and salt, 0.6%) were sieved, weighed and mixed using a mixer. An accurately weighed quantity of margarine (30%) was added, mixed adequately after which the required amount of water (50%) was added gradually and mixed using a mixer and thereafter knead using a kneading tray until a smooth, non-sticky elastic batter was formed. The batter was divided into pieces (to ease handling) using a batter cutter and roll into balls. Then, the batter kneading tray was sprinkled with dry flour and the batter spread on it and wrap around already prepared (cooked, spiced and shaped pieces) soy-cheese and roll into a ball. This was repeated until each piece of batter (50 g) was rolled and wrapped around the prepared soy-cheese (50 g). Thereafter, the prepared batter rolls were deep-fried in already preheated soybean oil until golden brown and crunchy on the outside. The rolls were removed from the oil, drained, packaged and kept for further analyses. The control sample was prepared using a chicken egg (50 g) to replace soy-cheese. It was packaged and kept for further analyses.

2.4. Determination of flavonoids

The flavonoids concentration in the sample was measured spectrophotometrically using the Naheed *et al.,* (2017) technique. The sample (0.01 g) was dissolved in 5 ml of extraction solvent, diluted to a volume of 20 ml, and centrifuged (ESCO MCR-88, Singapore, Republic of Singapore). To clean dry test tubes (in triplicate), 0.5 ml of sample working solution was pipetted and mixed with 4.5 ml distilled water. Then, 0.3 ml of 5% (w/v) sodium nitrite ($NaNO_2$), 0.3 ml of 10% aluminium chloride ($AlCl_3$), and 4 ml of 4% (w/v) sodium hydroxide (NaOH) were added to each test tube. For 15 minutes, the resulting mixtures was incubated at room temperature. The absorbance was measured at 500 nm against a reagent blank comprising all reagents excluding the extract or, in the case of the standard curve, standard rutin. Pipetting 0.0, 0.2, 0.4, 0.6, 0.8, and 1.0 ml of 1 mg/ml rutin (1 mg/ml rutin standard solution) into clean dry test tubes yielded the standard calibration curve. With distilled water, the quantities were increased to 5 mL. To each tube, 0.3 ml of 5% (w/v) $NaNO_2$, 0.3 ml of 5% (w/v) $AlCl_3$, and 4 ml of 4% (w/v) NaOH were added. For 15 minutes, the resulting solution is incubated at ambient temperature (28 ± 2 ^oC). The absorbance at 500 nm was measured and plotted versus the concentration to produce the standard calibration curve. The flavonoids concentrations in the sample were calculated using the standard calibration curve and reported as milligramme rutin equivalent per gramme of the sample.

2.5. Nutritional evaluation

The proximate composition was determined using AOAC (2010). The vitamins in the roll were determined using the official methodology of the Association of Approved Analytical Chemists (AOAC, 2010). The mineral content of the roll was measured using the PG 990 Atomic Absorption Spectrophotometer, as reported by Ubwa (2015).

2.6. Determination of alkaloids, saponin, total phenolic

The alkaline substances were extracted by soaking 20 g of the sample in 200 ml of 10% acetic acid in ethanol for 2.5 hh before adding 100 ml of concentrated ammonium hydroxide. The resultant precipitate was washed with 1% ammonium hydroxide before being mixed with a few drops of ethanol. The alkaloid concentration was determined using the method given by Raji *et al.,* (2019). Saponins were extracted by mixing 20 g of material with 200 ml of 20% ethanol and heated at 75 °C with continual stirring for 3.5 h. After the initial filtering, it was filtered again to recover any leftover residue. The extracts were mixed and concentrated to make an 80 mL volume. The mixture was then placed into a separating funnel which had previously contained 50 cc of diethyl ether. The recovered aqueous layer was washed with 20 mL of 5% sodium chloride solution after being combined with 120 mL of N-butanol. The mixture was then separated using a separating funnel. Pang *et al.,* (2018) described the Folin-Ciocalteu colorimetric approach for quantifying total phenolic content using garlic acid as the standard.

2.7. Sensory evaluation

The protocols for the sensory study was reviewed and approved by the Akanu Ibiam Federal Polytechnic Unwana Ethics Committee (IRB) and informed consent was obtained from each participant prior to their participation in the sensory evaluation. The sensory examination of the roll was done using 50 trained panellists. The rolls were graded on a nine-point hedonic scale, with nine representing "like extremely," eight representing "like mostly," seven representing "liked moderately," six representing "liked," five representing "neither liked nor disliked," four representing "disliked," three "disliked" moderately," two representing "disliked mostly," and one representing "disliked extremely." The taste, look, and overall acceptability of the rolls were evaluated. The panellists were given water to clean their lips after each sample. The egg roll was used as the control.

2.8. Statistical analysis

A completely randomized experimentation technique was utilized to avoid systematic errors. Evaluation of significant differences among means at a 5% significant level by the Duncan Multiple Range Test was performed using the SPSS version 17.

3. Results and discussion

3.1. Proximate composition of soy-cheese roll

The results presented in Table 1 highlight significant differences ($p<0.05$) in the proximate composition of the soy-fortified rolls compared to the traditional egg rolls. Notably, the moisture content of the 50% soy-cheese + 50% wheat flour (50S+50W) rolls was higher (24.70±0.21 g/100 g) compared to the 50% egg + 50% wheat flour (50E+50W) rolls (20.10±0.15g/100 g). This suggests that the inclusion of soy-cheese contributes to increased moisture retention in the rolls.

Table 1 Proximate composition of soy-fortified roll (g/100 g)

Parameter	50% egg + 50%wheat flour	50%soy-cheese + 50%wheat flour
Moisture	20.10±0.15[b]	24.70±0.21[a]
Protein	12.14±0.24[b]	28.96±0.74[a]
Fat	9.05±0.15[a]	6.26±0.24[b]
Fibre	2.27±0.04[b]	3.77±0.18[a]
Ash	3.14±0.06[b]	4.38±0.04à
Carbohydrate	53.30±0.22[b]	31.93±058[a]

Results are means ± s.d (n = 4). Value with different letters in the same row are significantly different ($p<0.05$) using Duncan multiple range test

Moving on to protein content, the soy-fortified rolls exhibit a substantial increase in protein levels (28.96±0.74g/100 g) compared to the traditional rolls (12.14±0.24g/100 g). This result aligned with the objective of fortifying the rolls with soy, known for its rich protein content. The higher protein content could potentially enhance the nutritional value of the rolls, making them a more attractive option for consumers seeking non-expensive protein-rich alternatives. As reported by Kolade (2015), the protein content of commercially sold fish roll ranged between 27.69 g/100 g and 36.78 g/100 g. However, Norizan et al. (2018) reported a protein range of 9.15 – 8.72 g/100 g for sweet buns. Meanwhile, Adeyeye and Ayoola (2013) have a range of 8.69 – 16.24 g/100 for sausage roll, buns, scotched egg, doughnut, meat pie, gala, and bean cake.

In terms of fat content, the 50S+50W rolls have a higher fat content (9.05±0.15g/100 g) compared to the 50E+50W rolls (6.26±0.24g/100 g). This difference may influence the sensory attributes of the rolls, affecting factors such as texture and mouthfeel. The reduction in fat content in the soy-fortified rolls could be seen as a positive aspect for individuals aiming to reduce their fat intake.

The fiber content of the rolls also varies significantly (P<0.05), with the soy-fortified rolls (3.77±0.18g/100 g) containing higher levels of fiber compared to the traditional rolls (2.27±0.04g/100 g). This increase in fiber aligns with the objective of enhancing the nutritional profile of the rolls, as dietary fiber is known for its positive impact on digestive health. According to Adeyeye and Ayoola (2013), a commercial scotched egg had fibre content of 0.76 g/100 g and a sausage roll had a value of 0.37 g/100 g of fibre. Fibre prevents colon diseases and constipation. Fibre also reduces the levels of cholesterol in the blood and lowers cancers risk (Bello *et al.,* 2008).

Looking at ash content, the soy-fortified rolls (4.38±0.04g/100 g) surpassed the traditional rolls (3.14±0.06g/100 g). Ash content is often associated with mineral content, and the higher ash content in the soy-fortified rolls could indicate an increased presence of minerals, contributing to the overall nutritional value.

Carbohydrate content showed a significant difference (p<0.05) between the two types of rolls, with the traditional rolls (53.30±0.22g/100 g) having higher carbohydrate levels compared to the soy-fortified rolls (31.93±0.58g/100 g). This reduction in carbohydrates in the soy-fortified rolls could be beneficial for individuals managing their carbohydrate intake, such as those with specific dietary restrictions or preferences.

The proximate composition results indicated that the incorporation of soy-cheese in the rolls has notable effects on various nutritional parameters. The soy-fortified rolls exhibited higher protein, fiber, and ash content, while demonstrating lower levels of fat and carbohydrates compared to the traditional rolls. These findings suggested that the soy-fortified rolls have the potential to offer a nutritionally enhanced alternative, catering to specific dietary needs and preferences. However, further sensory evaluations and consumer acceptance studies would be valuable to assess the overall palatability and market potential of these soy-fortified rolls.

3.2. Mineral composition of soy-cheese roll

The results presented in Table 2 showcased the mineral contents of the two types of rolls: one fortified with a combination of 50% egg and 50% wheat flour (50E+50W), and the other with 50% soy-cheese and 50% wheat flour (50S+50W). The soy-cheese fortified roll stood out with significantly (p<0.05) higher levels of calcium (258.92 mg/100 g) compared to the egg-wheat roll (48.32 mg/100 g). Calcium is crucial for bone health, and this enhancement could contribute to the nutritional value of the soy-cheese fortified roll. The regulation of nerves and muscles depends on calcium, which is a key component of bone and teeth. Calcium is involved in the metabolism of vitamin D. For the development of teeth and bone, calcium-rich foods are advised for children, nursing women, and pregnant women (Olusanya *et al.,* 2019; Sui *et al.,* 2019). The soy-cheese roll could be a beneficial option for those seeking

Table 2 Mineral contents of soy-cheese fortified roll (mg/100 g)

Parameter	50% egg + 50%wheat flour	50%soy-cheese + 50%wheat flour
Na	102.33±0.18[a]	36.19±0.02[b]
K	120.77±1.20[a]	35.24±0.24[b]
Ca	48.32±0.11[b]	258.92±1.44[a]
Zn	1.98±0.04[b]	2.45±0.07[b]
Mg	6.55±0.06[b]	35.92±0.04[a]
Iron	1.88±0.01[b]	5.29±0.03[a]
Phosphorus	105.33±0.28[b]	309.47±0.28[a]

Copper	0.02±0.01[b]	0.77±0.02[a]

Results are means ± s.d (n = 4). Value with different letters in the same row are significantly different ($p<0.05$) using Duncan multiple range test

Higher calcium intake. Additionally, the soy-cheese roll also demonstrated higher levels of phosphorus (309.47 mg/100 g) compared to the egg-wheat roll (105.33 mg/100 g). Phosphorus plays a vital role in bone and teeth formation, energy metabolism, and acid-base balance.

Moreover, the soy-cheese roll displayed elevated amounts of magnesium (35.92 mg/100 g) compared to the egg-wheat roll (6.55 mg/100 g). Magnesium is essential for various physiological functions, including muscle and nerve function, blood glucose control, and bone health. The increased magnesium content in the soy-cheese roll may contribute positively to its nutritional profile.

In contrast, the egg-wheat roll exhibited higher levels of sodium (102.33 mg/100 g), potassium (120.77 mg/100 g), and iron (1.88 mg/100 g) compared to the soy-cheese roll. These minerals are vital for various physiological processes, such as fluid balance, nerve function, and oxygen transport in the case of iron. The differences in mineral content between the two rolls could offer consumers options based on specific dietary requirements or preferences.

The results indicated that the choice of ingredients in the roll formulation significantly ($p<0.05$) impacts its mineral content. The soy-cheese fortified roll, in particular, stands out with elevated levels of calcium, phosphorus, and magnesium. These findings suggested that incorporating soy-cheese into the roll formulation could enhance its nutritional value, providing consumers with a product that not only meets their taste preferences but also offers potential health benefits.

3.3. Vitamin contents of soy-cheese roll

The vitamin contents of the soy-cheese roll and conventional egg roll are presented in Table 3. The soy-cheese roll consistently demonstrated higher levels of B-vitamins compared to the egg-roll. Notably, the soy-cheese roll exhibited significantly ($p<0.05$) higher levels of niacin (B_3), pyridoxine (B_6), and copper. Niacin plays a key role in energy metabolism, while pyridoxine is essential for the metabolism of amino acids and the formation of neurotransmitters. These higher vitamin levels in the soy-cheese roll suggested potential health benefits associated with its consumption.

Table 3 Vitamins contents of soy-cheese fortified roll (mg/100 g)

Parameter	**50% egg + 50%wheat flour**	**50%soy-cheese + 50%wheat flour**
Thiamin (B_1)	0.09±0.01[b]	0.25±0.01[a]
Riboflavin (B_2)	0.30±0.02[a]	0.32±0.02[a]
Niacin (B_3)	0.14±0.01[b]	1.10±0.07[a]
Pantothenic acid (B_5)	0.98±0.02[a]	0.25±0.02[b]
Pyridoxine (B_6)	0.14±0.01[b]	0.20±0.02[a]

Results are means ± s.d (n = 4). Value with different letters in the same row are significantly different ($p<0.05$) using Duncan multiple range test

3.4. Phytochemical properties of soy-cheese roll

The presented results in Table 4 provided insights into the phytochemical of soy-cheese fortified rolls (50%S+50%W) compared to rolls made with a combination of 50% egg and 50% wheat flour (50%E+50%W). In terms of phytochemical composition, the soy-cheese fortified rolls demonstrated substantially higher levels of flavonoids, alkaloids, tannins, saponins, and total phenolic content compared to the egg and wheat flour rolls. Particularly noteworthy is the remarkable difference in total phenolic content, with the soy-cheese fortified rolls exhibiting an exceptionally elevated value of 800.00 ± 1.54 mg GAE/100 g, while the egg and wheat flour rolls showed a significantly lower value of 38.00 ± 0.21 mg GAE/100 g. These findings suggested that the incorporation of soy-cheese into the rolls significantly enhances their phytochemical profile, which is indicative of potential health benefits attributed to these bioactive compounds. Tannins are polyphenolic substances with some health advantages connected to a decline in chronic diseases (Xu *et al.,* 2007). According to Gemede (2014), phytate has been shown to reduce the risk of developing kidney stones and to boost immunity against caries, atherosclerosis, and coronary heart disease. Alkaloids have been said to contain characteristics that have a propensity to lower blood sugar levels, anti-hypertensive, anti-cancer, and antioxidant activities (Zhang *et al.,* 2015). Phenolic substances have antioxidant properties that can defend the body against free radicals. According to Zhang *et al.,* (2015), flavonoids have biological properties like anti-inflammatory, anti-hyperglycemic, and anti-tumour effects.

Table 4 Phytochemical contents of soy-cheese fortified roll

Parameter	50% egg + 50%wheat flour	50%soy-cheese + 50%wheat flour
Flavonoids (mg RE/100 g)	2.48 ± 0.31[b]	18.77±0.15[a]
Alkaloids (mg/100 g)	1.20 ± 0.02[b]	8.52±0.04[a]
Tannin (mg/100 g)	0.01 ± 0.00[b]	0.17±0.001[a]
Saponins (mg/100 g)	0.02 ± 0.01[b]	0.33±0.02[a]
Total phenolic content (mg GAE /100 g)	38.00 ± 0.21[b]	800.00±1.54[a]

Results are means ± s.d (n = 4).; Mean values in the same row with different letters are significantly different at a 5% significant level. GAE – Gallic acid equivalent; RE – Rutin equivalent

3.5. Sensory attributes of soy-cheese roll

The sensory attributes of the soy-cheese fortified rolls consistently outperformed the conventional egg roll in appearance, aroma, taste, and texture (Table 5). Notably, the sensory evaluation revealed similar scores ($p>0.05$) for the soy-cheese rolls and egg roll in appearance, aroma, and texture. However, soy-cheese roll was preferred in taste (95.54%), and overall acceptability index (96.41%) compared to the egg roll (82.27% and 90.47% for taste and acceptability index, respectively). These results indicated that not only did the soy-cheese fortified rolls offer improved nutritional content but also enhanced the overall sensory experience, making them more palatable and acceptable to consumers.

Table 5 Sensory attributes of soy-cheese fortified roll

Parameter	50% egg + 50%wheat flour	50%soy-cheese + 50%wheat flour
Appearance (%)	93.11±1.77[a]	95.20±1.90[a]
Aroma (%)	85.33±1.46[a]	87.70±1.63[a]
Taste (%)	82.27±0.11[b]	95.54±1.22[a]
Texture (%)	88.32±1.14[a]	90.04±1.83[a]
Acceptability index (%)	90.47±0.33[b]	96.41±1.85[a]

Results are means ± s.d (n = 4); Mean values in the same row with different letters are significantly different at a 5% significant level. GAE – Gallic acid equivalent; RE – Rutin equivalent

4. Conclusion

Soy-cheese roll was formulated to serve as complete replacer of egg. The developed product was dense in protein, calcium, zinc, magnesium, iron, and phosphorus. The use of soy-cheese to replace eggs in the formulation of rolls enhanced the niacin, thiamin, and pyridoxine contents of the product. Moreover, the soy-cheese roll was rich in phytochemicals such as alkaloids and phenolic compounds. In terms of taste and acceptability index, the soy-cheese roll outperformed the control. The production method outlined in this study is scalable, and it could be used both industrially and on a small scale for self-entrepreneurs. The product's high protein content suggested that it might be utilized to lower protein-energy malnutrition in developing nations.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no competing interest among authors.

Statement of ethical approval

The protocols for the sensory study was reviewed and approved by the Akanu Ibiam Federal Polytechnic Unwana Ethics Committee (IRB).

Statement of informed consent

Informed consent was obtained from each participant prior to their participation in the sensory evaluation.

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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