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Comparative Nutrients Composition of Smoothies Made from Fruits, Plant-Based Milk, and Eggshell Powder

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ABSTRACT
Aims*: To evaluate and compare the nutritional composition, phytochemical properties, and sensory acceptability of smoothies made with fruits, plant-based milk, and eggshell powder.*
Study Design*: This was an experimental study using sensory analysis and chemical evaluation techniques.*
Place and Duration of Study*: Conducted in the Department of Human Nutrition and Dietetics, Lead City University, between January and June 2024.*
Methodology*: Smoothies were prepared with combinations of watermelon, pineapple, banana, tiger nut milk, and powdered eggshell. Samples were evaluated for micronutrient composition, phytochemical properties, and sensory acceptability by trained panelists using standard methods.*
Results*: Sample 1 had the highest vitamin C content (14.88 ± 0.15 mg) and achieved the second-highest sensory ratings for flavor and overall acceptability. Sample 4 contained the most calcium (1739.45 ± 0.00 mg) and vitamin D (0.06 ± 0.00 mg), while Sample 3 was richer in potassium (615.67 ± 8.07 mg). Sensory analysis showed that Sample 1 and Sample 5 were the most preferred.*
Conclusion*: Incorporating eggshell powder into smoothies offers a cost-effective and sustainable approach to address calcium deficiencies in regions where dietary calcium intake is inadequate.*

Keywords*: Smoothies, Calcium-Supplements, Eggshell Powder, Plant-Based Milk, Nutrient Composition*

1. INTRODUCTION

Undernutrition remains a pressing public health issue globally, particularly in Sub-Saharan Africa (SSA), where limited access to diverse and high-quality food exacerbates the problem (Owolade, 2022). Among the key nutrients of concern, calcium plays a critical role in maintaining human health. Its functions include nerve signal transmission, muscle contraction and relaxation, blood clotting, and structural roles in bone and teeth formation (Piste et al., 2012). However, calcium deficiencies are common in SSA, where dietary diversity is often limited (Shalisky et al., 2022). This deficiency is linked to significant health issues such as osteoporosis, rickets in children, and osteomalacia in adults (Sahay, 2012). Osteoporosis alone contributes to millions of fractures annually, especially in older adults.

Smoothies, blended beverages made from fruits, vegetables, and other components, have gained popularity as a convenient way to enhance dietary intake (Mccartney, et al., 2018). They are typically prepared using a liquid base such as fruit juice, dairy milk, or plant-based milk, blended with fresh fruits and vegetables, and sometimes supplemented with additional ingredients like protein powders or crushed ice. Smoothies are rich in vitamins, minerals, antioxidants, and dietary fiber, which are critical for maintaining good health. Studies have shown that consuming smoothies can help bridge the gap between actual dietary intakes and recommended dietary allowances for essential nutrients, thereby reducing the risk of chronic diseases such as cardiovascular disease, diabetes, and certain types of cancer (Cherman, 2024).

Calcium intake in SSA is generally low due to economic and logistical challenges associated with conventional calcium-rich foods like cow's milk (Bourassa et al., 2022). In Nigeria, these challenges are compounded by limited milk production, poor infrastructure, and cultural preferences. As a result, alternative calcium sources are being explored. Plant-based milks, such as tiger nut milk, have emerged as a promising option. Tiger nut milk, widely consumed in Nigeria and other parts of Africa, is nutrient-dense and free from lactose, making it suitable for individuals with lactose intolerance or milk allergies (Yu et al., 2022). It is also locally available and culturally acceptable, making it an ideal alternative to dairy products.

Chicken eggshells, an underutilized waste product, offer another innovative solution to addressing calcium deficiencies. Eggshells are primarily composed of calcium carbonate, providing approximately 381–401 mg of calcium per gram (Bartter et al., 2018). Studies have highlighted the bioavailability of calcium from eggshells, demonstrating that it is comparable to conventional calcium supplements (Singh et al., 2021). Utilizing eggshell powder in food products not only enhances their calcium content but also addresses environmental concerns by repurposing waste material. This approach aligns with global efforts toward sustainable and cost-effective nutrition solutions.

This study evaluated the potential of smoothies made with fruits, plant-based milk, and powdered eggshell as a means to improve calcium intake and overall nutrient composition. The fruits used—watermelon, pineapple, and banana—are nutrient-rich and widely available in Nigeria. Each offers unique health benefits, including vitamins, antioxidants, and dietary fiber. Watermelon is an excellent source of hydration and vitamin C, pineapple provides manganese and vitamin B6, and banana is rich in potassium and dietary fiber. When combined with tiger nut milk and eggshell powder, these fruits create a nutrient-dense smoothie that can address both micronutrient deficiencies and overall dietary quality.

This study aimed to investigate the nutritional composition, phytochemical properties, and sensory acceptability of these smoothies. Specifically, it seeks to compare the micronutrient levels in various formulations, analyze their phytochemical content, and evaluate their sensory attributes,

such as flavor, texture, and overall acceptability. This research also emphasizes the sustainability of using eggshells as a food ingredient, showcasing their potential to contribute to public health nutrition, particularly in low- and middle-income countries (LMICs).

This study offers a practical solution to improving calcium intake in resource-constrained settings. By combining locally available ingredients with an innovative use of eggshell powder, the research provides insights into developing affordable, sustainable, and culturally acceptable dietary interventions. The findings could inform public health policies and nutritional programs aimed at addressing micronutrient deficiencies in SSA. Furthermore, the study contributes to waste reduction by promoting the use of eggshells, aligning with global sustainability goals.

2. MATERIALS AND METHODS

2.1 Procurement of Raw Materials

Fresh watermelon (Citrullus lanatus), pineapple (Ananas comosus), banana (Musa genus), tiger nuts, and chicken eggshells were sourced from local markets in Ibadan, Oyo State, Nigeria. The fruits selected were free of visible defects and at optimal ripeness. Tiger nuts were chosen for their high nutritional value and processed to extract plant-based milk. Chicken eggshells were collected from local farms, washed thoroughly, and heat-treated to ensure safety for consumption.

2.2 Preparation and Processing

2.2.1 Preparation of Fruit Smoothies

Fruits were washed with clean water and peeled to remove non-edible parts. They were diced into small pieces to facilitate blending. The smoothies were prepared by blending 200 g of fruit with 150 mL of liquid base (tiger nut milk or water) and 5 g of powdered eggshell using a high-speed blender.

2.2.2 Preparation of Tiger Nut Milk

Tiger nuts were soaked in water for 24 hours to soften and blended with water in a 1:3 ratio. The mixture was filtered using a muslin cloth to obtain a smooth, milk-like liquid, which was used as the base for some smoothie formulations.

2.2.3 Preparation of Eggshell Powder

Chicken eggshells were washed with warm water and mild detergent to remove debris and residual membrane. They were boiled for 10 minutes, dried in an oven at 100°C for 2 hours, and ground into a fine powder using a food processor. The powder was sieved to remove large particles, ensuring a uniform texture for incorporation into smoothies.

2.3 Experimental Design and Formulation

Five smoothie samples were prepared with varying proportions of watermelon, pineapple, banana, tiger nut milk, and eggshell powder:

- **Sample 1**: Watermelon, pineapple, banana, tiger nut milk, and eggshell powder.
- **Sample 2**: Pineapple, banana, tiger nut milk, and eggshell powder.
- **Sample 3**: Watermelon, banana, and tiger nut milk.
- **Sample 4**: Pineapple, tiger nut milk, and eggshell powder.
- **Control Sample**: Watermelon, pineapple, banana, and tiger nut milk (without eggshell powder).

Each formulation was prepared in triplicate to ensure reproducibility.

2.4 Nutritional Analysis

2.4.1 Micronutrient Analysis

Micronutrient contents were analyzed using standard procedures:

- **Calcium**: Determined by atomic absorption spectrophotometry (AAS) following AOAC method 927.02.
- **Vitamins (C, D, E, and B9)**: Measured using High-Performance Liquid Chromatography (HPLC).
- **Potassium**: Measured using a flame photometer.

2.4.2 Phytochemical Analysis

The smoothies were analyzed for phytochemicals using spectrophotometric methods:

- **Flavonoids**: Assayed using aluminum chloride colorimetric methods.
- **Phenolics**: Determined using the Folin-Ciocalteu reagent.

2.5 Sensory Evaluation

Fifteen trained sensory panelists, consisting of students and staff from the Department of Human Nutrition and Dietetics, participated in the sensory evaluation. Samples were coded and presented in a randomized order to minimize bias. Panelists evaluated the smoothies based on the following attributes:

- **Appearance**
- **Aroma**
- **Flavor**
- **Texture**
- **Overall Acceptability**

A 9-point hedonic scale was used, where 1 represented "dislike extremely" and 9 represented "like extremely." Results were tabulated, and mean scores were calculated to determine the most preferred sample.

2.6 Statistical Analysis

Data obtained from nutritional and sensory analyses were analyzed using SPSS software version 25. Descriptive statistics were used to summarize data, and results were presented as means ± standard deviations. A one-way Analysis of Variance (ANOVA) was conducted to identify significant differences among the samples. Duncan's Multiple Range Test was used for post hoc analysis, with significance accepted at $P < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Nutritional Composition

The nutritional analysis revealed significant differences in the composition of smoothies across the samples. Sample 1, which included watermelon, pineapple, banana, tiger nut milk, and eggshell powder, recorded the highest vitamin C content (14.88 ± 0.15 mg). Sample 4, with a higher proportion of eggshell powder, demonstrated the highest calcium content (1739.45 ± 0.00 mg), indicating the potential of eggshell powder as an effective calcium supplement. Sample 3, which primarily comprised watermelon and banana, contained the highest potassium levels (615.67 ±

8.07 mg), and attributed to the natural richness of these fruits in potassium. Other micronutrients, such as vitamin D and vitamin E, varied depending on the combination of ingredients (Table 1).

Table 4.1 Nutrient Contents of Smoothies by Samples

SN	Parameter	($\underline{x}$ ± SD)				
		Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
Vitamin Content						
1	Vitamin B6	0.43 ± 0.01	0.49 ± 0.01	0.58 ± 0.03	**0.63 ± 0.01	*0.83 ± 0.01
2	Vitamin B9	**0.52 ± 0.01	0.47 ± 0.02	0.48 ± 0.03	0.44 ± 0.02	*0.60 ± 0.03
3	Vitamin D	0.04 ± 0.00	0.05 ± 0.00	0.05 ± 0.00	*0.06 ± 0.00	**0.06 ± 0.01
4	Vitamin C	*14.88 ± 0.15	**12.97 ± 0.03	10.57 ± 0.42	8.73 ± 1.07	8.37 ± 0.19
5	Vitamin E	0.13 ± 0.00	0.13 ± 0.00	0.13 ± 0.00	*0.15 ± 0.00	*0.15 ± 0.00
	Average	***3.20 ± 0.04**	****2.82 ± 0.01**	**2.36 ± 0.10**	**2.00 ± 0.22**	**2.00 ± 0.05**
Mineral Content						
1	Potassium	592.38 ± 0.00	573.74 ± 8.07	**615.67 ± 8.07	592.38 ± 0.00	*750.79 ± 16.14
2	Calcium	610.76 ± 0.00	658.23 ± 0.00	1602.32 ± 0.00	**1739.45 ± 0.00	*2135.02 ± 0.00
3	Phosphorus	190.86 ± 0.00	205.70 ± 0.00	500.73 ± 0.00	**543.58 ± 0.00	*667.19 ± 0.00
4	Magnesium	128.31 ± 0.00	138.28 ± 0.00	336.62 ± 0.00	**365.43 ± 0.00	*448.53 ± 0.00
5	Sodium	244.30 ± 0.00	263.29 ± 0.00	640.93 ± 0.00	**695.78 ± 0.00	*854.01 ± 0.00
6	Copper	0.09 ± 0.00	0.10 ± 0.00	0.25 ± 0.00	**0.27 ± 0.00	*0.33 ± 0.00
7	Zinc	0.29 ± 0.00	0.31 ± 0.00	0.76 ± 0.00	**0.82 ± 0.00	*1.01 ± 0.00
8	Iron	0.68 ± 0.00	0.73 ± 0.00	1.78 ± 0.00	**1.94 ± 0.00	*2.38 ± 0.00
	Average	**220.96 ± 0.00**	**230.05 ± 1.01**	**462.38 ± 1.01**	****492.46 ± 0.00**	***607.41 ± 2.02**

Key: ***$\underline{x}$= mean, SD = standard deviation, * = highest value, ** = second highest value***
Source: Laboratory Test (2023

3.1.2 Phytochemical Content

Phytochemical evaluation showed that Sample 4 had the highest levels of total phenolics (0.45 ± 0.00 mg) and flavonoids (5.25 ± 0.05 mg). This suggests that the addition of eggshell powder and

a higher proportion of pineapple enhanced the antioxidant properties of the smoothies. These findings are significant because phenolics and flavonoids play crucial roles in reducing oxidative stress and preventing chronic diseases (Table 2).

Table 4.2 Phytochemicals composition by samples

($\underline{x}$ ± SD)

SN	Parameter	Sample 1	Sample 2	Sample 3	Sample 4	
Phytochemical Content						
1	Phenolic	0.41 ± 0.01	0.42 ± 0.05	0.42 ± 0.00	**0.45 ± 0.00	*0.57 ± 0.01
2	Flavonoid	5.04 ± 0.01	5.20 ± 0.01	**5.25 ± 0.05	5.19 ± 0.09	*6.25 ± 0.11
3	Carotenoid	0.14 ± 0.00	0.15 ± 0.02	0.08 ± 0.01	**0.17 ± 0.00	*0.37 ± 0.01
4	Tannin	0.13 ± 0.00	0.13 ± 0.00	0.59 ± 0.01	**0.62 ± 0.00	*0.71 ± 0.05
6	Saponin	0.02 ± 0.00	0.05 ± 0.00	0.08 ± 0.00	**0.11 ± 0.00	*0.16 ± 0.01
7	Terpenoid	0.77 ± 0.03	0.54 ± 0.00	1.15 ± 0.00	**1.74 ± 0.01	*1.91 ± 0.01
	Average	**1.01 ± 0.01**	**1.03 ± 0.01**	**1.21 ± 0.01**	****1.44 ± 0.02**	***1.61 ± 0.03**

Key: ***$\underline{x}$= mean, SD = standard deviation, * = highest value, ** = second highest value***
Source: Laboratory Test

3.1.3 Sensory Evaluation

Sensory analysis indicated high acceptability for all samples. Sample 1 and Sample 5 were the most preferred, receiving top scores for flavor, texture, and overall acceptability. Sample 4 achieved the highest score for texture, likely due to the creaminess provided by the eggshell powder, while its flavor was rated slightly lower than the other two samples. There were no notable differences in color and aroma across all samples, suggesting that the addition of eggshell powder did not significantly affect these attributes (Table 3).

Table 4.3 Sensory Properties and General Acceptability of Smoothies by Samples

SN	Parameter	($\underline{x}$ ± SD)				
		Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
Sensory Evaluation						
1	Appearance	**8.33 ± 0.58	7.33 ± 1.53	7.67 ± 0.58	7.33 ± 0.58	*9.00 ± 0.00
2	Taste	**8.67 ± 0.58	7.67 ± 1.15	6.67 ± 0.58	7.00 ± 2.00	*9.00 ± 0.00
3	Texture	**7.67 ± 0.58	7.00 ± 0.00	6.33 ± 1.15	**7.67 ± 0.58	*9.00 ± 0.00
4	Aroma	**8.00 ± 0.00	8.00 ± 1.00	6.33 ± 1.15	8.00 ± 1.00	*9.00 ± 0.00
	Average	**8.17 ± 0.43**	**7.50 ± 0.92**	**6.75 ± 0.87**	**7.50 ± 1.04**	***9.00 ± 0.00**
GeneralAcceptability		7.67 ± 0.58	8.00 ± 1.00	8.00 ± 1.00	**8.00 ± 0.00	*9.00 ± 0.00

Key: ***$\underline{x}$= mean, SD = standard deviation, * = highest value, ** = second highest value***

Source: Laboratory Test (2023)

3.2 Discussion

The high calcium content in Sample 4 demonstrates the effectiveness of incorporating eggshell powder into food products as a calcium source. Eggshells are known to provide approximately 40% calcium by weight, making them a sustainable alternative to conventional calcium supplements. This finding aligns with Atiase et al. (2020), who emphasized the importance of calcium supplementation in preventing osteoporosis, particularly in regions where dairy products are scarce or unaffordable. Additionally, the levels of calcium observed in this study are consistent with prior research that documented high calcium availability in eggshell powder-based food products (Bartter et al., 2018). The potassium content in Sample 3 highlights the nutritional contributions of watermelon and banana. Potassium is essential for regulating muscle contractions, maintaining fluid balance, and supporting cardiovascular health. Previous studies, such as those by Nweze et al. (2019), reported similar findings, where potassium-rich fruits like bananas significantly enhanced the mineral content of smoothies. This underscores the role of fruit selection in tailoring nutrient-dense beverages to specific dietary needs. Vitamin C levels were highest in Sample 1, likely due to the synergistic combination of watermelon and pineapple, both of which are known for their ascorbic acid content. This corroborates earlier research that demonstrated a positive correlation between fruit variety and vitamin C concentration in smoothies (Razola-Diaz et al., 2022). High vitamin C levels are particularly valuable for boosting immunity, enhancing iron absorption, and protecting cells from oxidative stress.

The elevated phenolic and flavonoid content in Sample 4 suggests that eggshell powder and specific fruit combinations may enhance the antioxidant potential of the smoothies. Phenolics are known to neutralize free radicals, reducing the risk of chronic diseases such as cancer and cardiovascular disorders. This finding is supported by a study conducted by Waszkiewicz et al. (2023), which demonstrated that phenolic compounds in fortified smoothies contributed significantly to their health-promoting properties. Similarly, flavonoids have been shown to exhibit anti-inflammatory and cardioprotective effects, making these smoothies beneficial for overall health. The high antioxidant properties in the samples are consistent with the nutrient profiles of

pineapple and banana, which have been extensively documented as rich sources of bioactive compounds (Axelle et al., 2016). Moreover, the inclusion of eggshell powder did not appear to inhibit antioxidant activity, suggesting its compatibility with other smoothie ingredients.

The sensory evaluation results highlight the importance of balancing nutritional enhancement with consumer preferences. Sample 1 and Sample 5, which achieved the highest scores for flavor and overall acceptability, underscore the value of combining fruits with complementary flavor profiles. The addition of eggshell powder in Sample 4 improved texture but slightly reduced its flavor score, emphasizing the need for careful formulation to optimize sensory attributes without compromising palatability. These findings align with a study by Baingana (2024), who noted that consumer preferences for smoothies are driven by a balance of flavor, texture, and nutritional value. In particular, they highlighted that textures perceived as "creamy" or "smooth" were associated with higher acceptability ratings, consistent with the sensory outcomes for Sample 4 in this study.

The utilization of eggshell powder in smoothies represents a sustainable approach to addressing calcium deficiencies while reducing food waste. Eggshells, often discarded as waste, are repurposed into a valuable nutritional resource, aligning with global efforts to promote sustainability in the food industry. This circular approach not only supports environmental conservation but also provides a cost-effective strategy to enhance public health nutrition. Similar conclusions were drawn by Cormick and Belizán (2019), who advocated for the use of waste-derived ingredients to combat micronutrient deficiencies in low- and middle-income countries (LMICs). The findings of this study demonstrate that smoothies fortified with eggshell powder can provide significant health benefits while maintaining high consumer acceptability.

RECCOMENDATION

1. Industries can get large quantity of eggshell waste from poultries, process it and make it available in capsules and other readymade options.
2. Eggshell powder easy and safe processing methods in low income countries should be addressed in community advocacies.

CONCLUSION

The findings demonstrated that incorporating powdered eggshells significantly enhanced the calcium content of the smoothies, providing a cost-effective solution to addressing calcium deficiencies, particularly in low-resource settings. The sensory evaluation revealed high acceptability for smoothies with a balanced blend of fruits and plant-based milk, suggesting that this formulation maintains palatability while offering enhanced nutritional value. Additionally, the phytochemical analysis highlighted the smoothies' potential as a functional food due to their antioxidant properties. Future research could explore larger-scale production, shelf-life stability, and commercialization to ensure wider adoption and impact.

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COMPETING INTERESTS

The author declares no competing interests.

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