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Effect of Selected Fruit Extracts on the Mineral and Fat-Soluble Vitamin Composition of Yoghurt Produced from Cow Milk

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***Abstract*: This study evaluated the effect of fruit extract fortification on the mineral and fat-soluble vitamin composition of yoghurt produced from raw cow milk. Fresh raw cow milk was fermented using a starter culture containing Lactobacillus delbrueckii subsp. bulgaricus and Streptococcus thermophilus at 42°C for 16 h. Extracts of blueberry, beetroot, kiwi, strawberry and soursop were incorporated into the yoghurt at inclusion levels of 5, 10, 15 and 20%, while plain yoghurt served as the control. The experiment was arranged in a 5 × 4 factorial arrangement within a Completely Randomized Design. Mineral composition (calcium, magnesium and phosphorus) and fat-soluble vitamins (A, D, E and K) were determined using standard analytical procedures. Data obtained were subjected to analysis of variance and treatment means were separated using Duncan's Multiple Range Test at P < 0.05. Significant differences (P < 0.05) were observed among treatments for all mineral and vitamin parameters evaluated. Calcium content ranged from 82.57 to 128.66 mg/100 g, with the highest value recorded in yoghurt fortified with 20% blueberry extract. Magnesium ranged from 15.42 to 21.45 mg/100 g, while phosphorus ranged from 102.11 to 134.12 mg/100 g. Vitamin A content varied from 248.68 to 326.40 µg/100 g, with the highest value observed in yoghurt fortified with 15% blueberry extract. Vitamins D, E and K also increased substantially in several fortified samples compared with the control. Fruit fortification significantly improved the micronutrient composition of yoghurt, with blueberry extract producing the greatest enhancement in most mineral and vitamin parameters. The findings demonstrate that selected fruit extracts, particularly blueberry extract, can be utilized as natural fortifying agents for the development of nutrient-enriched functional yoghurt with enhanced micronutrient quality.**

***Keywords*: Blueberry extract, Fat-soluble vitamins, Fruit fortification, Functional yoghurt, Mineral composition, Cow milk.**

1. Introduction

Yoghurt is one of the most widely consumed fermented dairy products globally due to its nutritional value, sensory acceptability and health-promoting properties. It is produced through the fermentation of milk by lactic acid bacteria, primarily *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*, resulting in a product with improved digestibility, desirable flavour and extended shelf life compared with fresh milk (Tamime & Robinson, 2007; Chandan and Kilara, 2013). The quality of raw cow milk used for yoghurt production is an important determinant of the nutritional composition, physicochemical properties and overall quality of the finished product (Olawoye *et al.,* 2022). Beyond serving as an excellent source of high-quality protein, yoghurt contributes essential minerals and vitamins required for normal physiological functions and has increasingly been recognized as a functional food because of its beneficial effects on gut health and overall wellbeing (Morelli and Capurso, 2021).

Minerals and vitamins are important micronutrients that play critical roles in growth, metabolism and disease prevention. Calcium, magnesium and phosphorus are among the major minerals present in dairy products and are essential for bone development, energy metabolism, muscle contraction and cellular regulation. Similarly, fat-soluble vitamins such as vitamins A, D, E and K are important for vision, immune function, antioxidant protection, blood coagulation and skeletal health. Although yoghurt naturally contains these nutrients, there is growing interest in improving its micronutrient profile through the incorporation of nutrient-rich plant materials (Kaur *et al.,* 2022).

The increasing consumer preference for functional foods has stimulated research into the development of value-added dairy products through fruit fortification. Fruits are recognized as rich sources of vitamins, minerals, dietary fibre and phytochemicals with antioxidant properties. The incorporation of fruit extracts into yoghurt has been reported to improve nutritional quality, sensory characteristics and consumer acceptance while contributing bioactive compounds that may enhance health benefits (Sharma *et al.,* 2021; Kumar and Mishra, 2020). Fruit fortification therefore represents a practical strategy for producing nutritionally enriched fermented dairy products capable of meeting the growing demand for healthier food alternatives.

Blueberry, beetroot, kiwi, strawberry and soursop are fruits of considerable nutritional importance. Blueberries are rich in anthocyanins, vitamins and antioxidant compounds that have been associated with various health benefits, including

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protection against oxidative stress and chronic diseases (Kalt *et al.,* 2020). Beetroot is valued for its betalains, dietary nitrates and mineral content, which contribute to its antioxidant and physiological properties (Clifford *et al.,* 2015). Kiwi fruit contains appreciable quantities of vitamin C, minerals and bioactive compounds and has been associated with improved digestive and immune functions (Hunter *et al.,* 2019). Strawberries are rich in vitamins, phenolic compounds and antioxidants that contribute to their nutritional and functional value (Seeram *et al.,* 2006). Soursop (*Annona muricata*) contains vitamins, minerals and several bioactive constituents that have attracted increasing interest in food and nutraceutical applications (George *et al.,* 2020).

Previous studies have demonstrated that fruit incorporation can improve the nutritional quality of yoghurt and other fermented dairy products (Fakolade and Oyeniyi, 2018; Sharma *et al.,* 2021). However, most available studies have focused on individual fruits or on physicochemical and sensory attributes, with comparatively limited information regarding the comparative effects of multiple fruit extracts on the mineral and vitamin composition of yoghurt. Furthermore, information on yoghurt produced from fresh raw cow milk fortified with blueberry, beetroot, kiwi, strawberry and soursop extracts remains limited in literature.

Therefore, this study was conducted to evaluate the effect of blueberry, beetroot, kiwi, strawberry and soursop extract fortification at varying inclusion levels on the mineral and fat-soluble vitamin composition of yoghurt produced from raw cow milk.

2. Materials and Methods

A. Source of Materials

Fresh raw cow milk used for yoghurt production was obtained from a dairy farm in Osun State, Nigeria. Fresh blueberry, beetroot, kiwi, strawberry and soursop fruits were purchased from a reputable fruit market within the metropolis. A commercial yoghurt starter culture containing *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* was used for fermentation.

B. Preparation of Fruit Extracts

The fruits were sorted to remove defective samples and thoroughly washed under running water. Beetroot was peeled prior to processing, while the edible portions of the remaining fruits were separated as appropriate. Each fruit was prepared as appropriate, and blended separately to obtain the fruit extract. The blended pulp was filtered through a clean muslin cloth to remove coarse particles, and the filtrate was collected for yoghurt fortification. The extracts were refrigerated prior to use.

C. Production of Fruit-Fortified Yoghurt

Raw cow milk was filtered and pasteurized before being cooled to inoculation temperature. The pasteurized milk was inoculated with a commercial yoghurt starter culture containing *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*. Fermentation was carried out at 42°C for 16 h.

Prior to fermentation, the fruit extracts were incorporated separately at inclusion levels of 5, 10, 15 and 20%. Plain yoghurt without fruit extract served as the control treatment.

The treatments consisted of Control, BBE5–BBE20, BTE5–BTE20, KWE5–KWE20, SBE5–SBE20 and SSE5–SSE20, giving a total of 21 treatments.

D. Experimental Design

The experiment was arranged in a 5 × 4 factorial arrangement within a Completely Randomized Design (CRD), consisting of five fruit extract types and four inclusion levels, in addition to a control treatment. All analyses were conducted in triplicate.

E. Mineral Analysis

Calcium, magnesium and phosphorus contents were determined using standard AOAC procedures (AOAC, 2010).

F. Vitamin Analysis

Fat-soluble vitamins (A, D, E and K) were determined using standard spectrophotometric methods as described by AOAC International (2010).

G. Statistical Analysis

Data obtained were subjected to analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS). Treatment means were separated using Duncan's Multiple Range Test at a 5% level of significance.

3. Results and Discussion

A. Results

The Table 1 and 2 shows the results.

B. Discussion

1) Mineral Composition of Fruit-Fortified Yoghurt

The mineral profile of the fruit-fortified yoghurt samples is presented in Table 1. Fruit fortification significantly ($P < 0.05$) influenced calcium, magnesium and phosphorus contents of the yoghurt samples. Calcium content ranged from 82.57 to 128.66 mg/100 g, with the highest value recorded in BBE20 and the lowest in the control sample. Similarly, magnesium content varied from 15.42 to 21.45 mg/100 g, while phosphorus ranged from 102.11 to 134.12 mg/100 g.

Calcium concentration increased significantly following fruit fortification, with yoghurt containing 20% blueberry extract (BBE20) recording the highest value. The increase may be attributed to the intrinsic calcium content of blueberries and the contribution of fruit solids to the mineral fraction of the yoghurt. In addition, organic acids naturally present in blueberries may enhance mineral retention during fermentation by improving mineral solubility. Similar increases in calcium concentration have been reported in fruit-fortified fermented dairy products (Karp *et al.,* 2019; Sharma *et al.,* 2021; Kaur *et al.,* 2022). Calcium is essential for skeletal development, muscle contraction and nerve transmission; therefore, the elevated calcium levels observed in the fortified treatments indicate improved nutritional quality of the yoghurt.

Table 1
Vitamin composition of yoghurt samples fortified with selected fruit extracts

Treatment Parameter	Control	BBE 5	BBE 10	BBE 15	BBE 20	BTE 5	BTE 10	BTE 15	BTE 20	KWE 5	KWE 10	KWE 15	KWE 20	SBE 5	SBE 10	SBE 15	SBE 20	SSE 5	SSE 10	SSE 15	SSE 20	SEM
Vit A (µg/100 g)	248.70^{f}	248.68^{f}	260.67^{f}	326.40^{a}	312.09^{ab}	260.16^{f}	292.76^{cd}	263.16^{f}	270.07^{ef}	301.39^{bc}	280.15^{de}	284.14^{de}	308.58^{ab}	280.18^{de}	282.62^{de}	250.78^{f}	256.78^{f}	296.52^{bc}	301.42^{bc}	292.48^{cd}	268.57^{ef}	**0.11**
Vit D (mg/100 g)	0.49^{f}	0.71^{ef}	0.60^{f}	1.30^{a}	1.22^{ab}	0.72^{ef}	0.91^{de}	0.64^{f}	0.61^{f}	1.22^{ab}	0.87^{de}	0.67^{f}	1.07^{bc}	0.66^{f}	0.89^{de}	0.55^{f}	0.52^{f}	1.01^{cd}	0.89^{de}	1.14^{bc}	0.80^{ef}	**0.02**
Vit E (mg/100 g)	0.84^{f}	1.41^{ab}	0.93^{f}	1.61^{a}	1.40^{ab}	1.14^{de}	1.26^{bc}	0.77^{f}	1.03^{ef}	1.45^{ab}	1.20^{cd}	1.02^{ef}	1.21^{cd}	0.86^{f}	1.30^{bc}	0.91^{f}	0.75^{f}	0.97^{ef}	1.18^{cd}	1.06^{de}	1.08^{de}	**0.04**
Vit K (mg/100 g)	0.64^{f}	1.04^{bc}	0.57^{f}	1.12^{ab}	1.15^{ab}	0.93^{cd}	0.73^{ef}	0.92^{cd}	0.77^{ef}	1.10^{ab}	0.82^{de}	0.68^{f}	1.03^{bc}	1.10^{ab}	1.25^{a}	0.65^{f}	0.46^{f}	0.83^{de}	0.84^{de}	0.92^{cd}	0.83^{de}	**0.02**

Note: Values are presented as mean ± standard error of triplicate determinations. BBE = Blueberry extract; BTE = Beetroot extract; KWE = Kiwi extract; SBE = Strawberry extract; SSE = Soursop extract. Numerals (5, 10, 15 and 20) indicate fruit extract inclusion levels (%). Means within the same row bearing different superscript letters differ significantly (P < 0.05) according to Duncan's Multiple Range Test.

Table 2
Mineral composition (mg/100 g) of yoghurt samples fortified with selected fruit extracts

Treatment Parameter	Control	BBE 5	BBE 10	BBE 15	BBE 20	BTE 5	BTE 10	BTE 15	BTE 20	KWE 5	KWE 10	KWE 15	KWE 20	SBE 5	SBE 10	SBE 15	SBE 20	SSE 5	SSE 10	SSE 15	SSE 20	SEM
Calcium (mg/100 g)	82.57^{f}	87.29^{f}	98.47^{e}	89.15^{ef}	128.66^{a}	109.74^{cd}	123.83^{ab}	98.45^{e}	112.67^{c}	107.20^{cd}	120.58^{b}	95.11^{e}	118.41^{bc}	90.07^{ef}	126.45^{a}	86.13^{f}	102.32^{d}	98.67^{e}	122.80^{ab}	102.81^{d}	92.69^{ef}	**0.05**
Magnesium (mg/100 g)	15.42^{f}	16.34^{e}	18.52^{cd}	17.12^{de}	21.45^{a}	19.33^{c}	20.87^{ab}	18.11^{cd}	19.24^{c}	18.44^{cd}	20.15^{b}	17.92^{d}	19.82^{bc}	17.15^{de}	21.11^{a}	16.02^{e}	18.56^{cd}	18.05^{cd}	20.64^{ab}	18.72^{c}	17.43^{de}	**0.01**
Phosphorus (mg/100 g)	102.32^{f}	104.57^{f}	112.44^{de}	108.91^{e}	134.12^{a}	120.55^{c}	130.47^{ab}	110.23^{e}	122.19^{c}	118.62^{cd}	128.34^{b}	109.84^{e}	125.43^{bc}	107.54^{ef}	132.88^{a}	102.11^{f}	114.23^{d}	111.90^{de}	129.51^{ab}	115.76^{d}	106.12^{ef}	**0.05**

Note: Values are presented as mean ± standard error of triplicate determinations. BBE = Blueberry extract; BTE = Beetroot extract; KWE = Kiwi extract; SBE = Strawberry extract; SSE = Soursop extract. Numerals (5, 10, 15 and 20) indicate fruit extract inclusion levels (%). Means within the same row bearing different superscript letters differ significantly (P < 0.05) according to Duncan's Multiple Range Test.

2) Magnesium

Magnesium content increased from 15.42 mg/100 g in the control to 21.45 mg/100 g in BBE20. The elevated magnesium levels observed in blueberry- and strawberry-fortified treatments may be attributed to the naturally occurring mineral constituents of these fruits. Magnesium plays an important role in enzyme function, energy metabolism and bone health, making these fortified products nutritionally advantageous (Kaur *et al.,* 2022; Granato *et al.,* 2020). The higher magnesium concentrations observed in blueberry and strawberry-fortified yoghurt further demonstrate the capacity of fruit fortification to improve the micronutrient density of fermented dairy products. Magnesium functions as a cofactor for numerous enzymatic reactions involved in carbohydrate metabolism, protein synthesis and ATP production. Consequently, the observed increases may enhance the nutritional value of yoghurt intended for health-conscious consumers and populations vulnerable to micronutrient deficiencies.

3) Phosphorus

Phosphorus concentration also increased significantly following fruit fortification, with BBE20 recording the highest value (134.12 mg/100 g). Phosphorus is closely associated with calcium metabolism and plays indispensable roles in bone mineralization, nucleic acid synthesis and cellular energy transfer through ATP. The concurrent increases observed for calcium and phosphorus indicate that fruit fortification improved the overall mineral balance of the yoghurt. Similar observations have been reported for fruit-enriched dairy products, where fruit solids contributed additional minerals and enhanced nutritional quality (Kaur *et al.,* 2022; Kumar & Mishra, 2020).

4) Fat-Soluble Vitamin Composition of Fruit-Fortified Yoghurt

The fat-soluble vitamin composition of the fruit-fortified yoghurt samples is presented in Table 2. Fruit extract fortification significantly (P < 0.05) influenced the concentrations of vitamins A, D, E and K in the yoghurt samples. Vitamin A content ranged from 248.68 to 326.40 µg/100 g, with the highest concentration recorded in BBE15, while the control and BBE5 samples contained the lowest values. Vitamin D varied from 0.49 to 1.30 mg/100 g, whereas vitamins E and K ranged from 0.75 to 1.61 mg/100 g and 0.46 to 1.25 mg/100 g, respectively.

5) Vitamin A and Vitamin D

Vitamin A concentration increased significantly following fruit fortification, particularly in blueberry- and kiwi-fortified yoghurt samples. The highest vitamin A content was recorded in BBE15 (326.40 µg/100 g), indicating that blueberry extract substantially enhanced the provitamin A content of the yoghurt. Blueberries are recognized as rich sources of anthocyanins, vitamins and other phytochemicals that contribute to the antioxidant capacity and nutritional quality of foods (Kalt *et al.,* 2020). The observed increase may therefore be attributed to the contribution of naturally occurring carotenoid precursors and other bioactive compounds present in the fruit extracts. Similar improvements in vitamin content following fruit fortification have been reported by Sharma et al. (2021) and Kaur et al. (2022), who observed enhanced nutritional quality in fruit-enriched fermented dairy products.

Vitamin D also differed significantly among treatments, with the highest concentration observed in BBE15 (1.30 mg/100 g). Although milk naturally contains small quantities of vitamin D, the increased concentrations recorded in fortified samples may reflect the contribution of fruit-derived bioactive compounds and improved nutrient retention during yoghurt fermentation. Vitamin D plays an essential role in calcium absorption, bone mineralization and immune regulation; consequently, its improvement alongside calcium content further enhances the nutritional value of fruit-fortified yoghurt (Morelli & Capurso, 2021). The concurrent enhancement of vitamins A and D

suggests that fruit fortification can improve micronutrient density while supporting the functional properties of fermented dairy products.

6) Vitamin E and Vitamin K

Fruit fortification also significantly improved the vitamin E and vitamin K contents of the yoghurt samples. Vitamin E ranged from 0.75 to 1.61 mg/100 g, with BBE15 recording the highest concentration, whereas vitamin K varied between 0.46 and 1.25 mg/100 g, reaching its maximum value in SBE10. The elevated vitamin E concentrations observed in blueberry-, kiwi- and strawberry-fortified yoghurt may be attributed to the antioxidant constituents naturally present in these fruits. Vitamin E functions as a major lipid-soluble antioxidant that protects cellular membranes against oxidative damage and contributes to product stability during storage (Granato *et al.,* 2020). Likewise, vitamin K is required for normal blood coagulation and bone metabolism, making its increased concentration nutritionally desirable in fortified dairy products. Similar improvements in antioxidant vitamins following fruit incorporation into yoghurt have been reported by Kalt et al. (2020) and Hunter et al. (2019), who highlighted the rich phytochemical composition of berries and kiwifruit.

7) Nutritional Implications of Fruit Fortification

The enhancement of both mineral and fat-soluble vitamin contents observed in the present study demonstrates the nutritional potential of fruit extract fortification in fermented dairy products. The significant increases in calcium, magnesium and phosphorus, together with improvements in vitamins A, D, E and K, indicate that the selected fruit extracts contributed substantially to the micronutrient density of yoghurt. Beyond their mineral and vitamin contributions, these fruits also contain naturally occurring phytochemicals and antioxidant compounds that may complement the probiotic benefits of yoghurt and further enhance its functional properties (Granato *et al.,* 2020; Dahiya *et al.,* 2022). Consequently, fruit-fortified yoghurt may contribute to dietary strategies aimed at improving micronutrient intake while meeting the growing consumer demand for healthier, naturally fortified dairy products. The findings further support the utilization of locally available fruit resources in the development of value-added functional foods with enhanced nutritional quality.

4. Conclusion and Recommendation

The incorporation of fruit extracts significantly improved the mineral and fat-soluble vitamin composition of yoghurt produced from fresh raw cow milk. Fruit fortification enhanced the micronutrient quality of the yoghurt, with blueberry extract producing the greatest improvements in most mineral and vitamin parameters. Specifically, yoghurt fortified with 20% blueberry extract exhibited the highest calcium, magnesium and phosphorus contents, while 15% blueberry extract produced the highest vitamin A concentration. These findings demonstrate that selected fruit extracts, particularly blueberry extract, can serve as effective natural fortifying agents for the production of micronutrient-enriched yoghurt with enhanced nutritional quality and functional food potential.

Based on the findings of this study, the incorporation of blueberry extract into yoghurt is recommended as a natural strategy for improving mineral and fat-soluble vitamin contents. The application of selected fruit extracts in yoghurt production may contribute to the development of functional dairy products with enhanced nutritional value. Further studies should evaluate the antioxidant properties, storage stability, micronutrient bioavailability and consumer acceptance of fruit-fortified yoghurt under commercial production and storage conditions.

References

[1] AOAC International, *Official Methods of Analysis*, 19th ed. Gaithersburg, MD, USA: AOAC International, 2010.

[2] R. C. Chandan and A. Kilara, *Manufacturing Yoghurt and Fermented Milks*, 2nd ed. Oxford, U.K.: Wiley-Blackwell, 2013.

[3] T. Clifford, G. Howatson, D. J. West, and E. J. Stevenson, "The potential benefits of red beetroot supplementation in health and disease," *Nutrients*, vol. 7, no. 4, pp. 2801–2822, 2015.

[4] D. Dahiya, P. Nigam, and A. Jha, "Functional foods: Role in prevention and management of chronic diseases," *Food Bioscience*, vol. 47, p. 101632, 2022.

[5] P. O. Fakolade and T. M. Oyeniyi, "Effect of ginger inclusion in yoghurt production and its acceptability," *CPQ Nutrition*, vol. 3, no. 2, pp. 1–10, 2018.

[6] M. George, S. I. Inya-Agha, and M. O. Emeje, "Nutritional composition and ethnomedicinal uses of soursop (*Annona muricata* L.): A review," *Journal of Ethnopharmacology*, vol. 263, p. 113236, 2020.

[7] D. Granato, F. J. Barba, D. B. Kovačević, J. M. Lorenzo, A. G. Cruz, and P. Putnik, "Functional foods: Product development, technological trends, efficacy testing, and safety," *Annual Review of Food Science and Technology*, vol. 11, pp. 93–118, 2020.

[8] D. C. Hunter, B. Burlingame, and M. G. Ferruzzi, "Kiwi fruit and health: A comprehensive review," *Critical Reviews in Food Science and Nutrition*, vol. 59, no. 6, pp. 933–945, 2019.

[9] W. Kalt *et al*., "Recent research on the health benefits of blueberries and their anthocyanins," *Advances in Nutrition*, vol. 11, no. 2, pp. 224–236, 2020.

[10] H. J. Karp, M. Kolehmainen, U. Schwab, and M. Mäki, "Dairy products and bone health," *Nutrients*, vol. 11, no. 11, p. 2896, 2019, doi: 10.3390/nu11112896.

[11] R. Kaur, R. Sharma, and J. Singh, "Nutritional enhancement of dairy products using fruits: A review," *Trends in Food Science and Technology*, vol. 124, pp. 234–246, 2022.

[12] P. Kumar and H. N. Mishra, "Fortification of yoghurt with fruit and herb extracts: A review," *Journal of Food Science and Technology*, vol. 57, no. 4, pp. 1220–1230, 2020.

[13] L. Morelli and L. Capurso, "Probiotics, yoghurt, and gut microbiota: A review of the evidence," *International Journal of Food Microbiology*, vol. 334, p. 108854, 2021.

[14] B. F. Olawoye, M. O. Odetayo, and M. O. Alagbe, "Physicochemical properties and microbial safety of cow milk used for yoghurt production," *African Journal of Food Science*, vol. 16, no. 2, pp. 50–59, 2022.

[15] N. P. Seeram, R. Lee, and D. Heber, "Strawberry phytochemicals and human health," *Journal of Medicinal Food*, vol. 9, no. 1, pp. 1–6, 2006.

[16] A. Sharma, A. P. Singh, and S. Rana, "Application of fruits in dairy: Impacts on sensory, nutritional and microbial quality of yoghurt," *Journal of Food Measurement and Characterization*, vol. 15, no. 3, pp. 2743–2754, 2021.

[17] A. Y. Tamime and R. K. Robinson, *Yoghurt: Science and Technology*, 3rd ed. Cambridge, U.K.: Woodhead Publishing, 2007.