

Production and Quality Evaluation of Soymilk Beverage Fortified with Watermelon Juice

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Abstract

The physicochemical, phytochemical and sensory properties of soymilk fortified with watermelon juice were evaluated to determine the optimal blend ratio for beverage development. Soymilk-watermelon juice beverages were formulated at ratios of 100:0 (control), 90:10, 80:20, 70:30, 60:40 and 50:50, and analyzed for physical properties, proximate composition, mineral and phytochemical contents, sensory acceptability as well as storage studies. The physical properties revealed that the pH of the samples was near neutral for day 1, with a range of 6.53 – 6.03 for samples A – F, and decreased during the 7 days of storage. Viscosity values ranged from 3.3 – 2.07 cP while TSS values ranged from 11.7 – 9.9 °Brix for samples A – F. The proximate composition showed a range of values for moisture (80.4 – 87.0 %), crude protein (2.45 – 1.18 %), lipid (3.04 – 1.88 %), ash (0.333 – 0.240 %), fibre (0.95 – 0.753 %) and carbohydrates (12.83 – 8.95 %) for samples A – F respectively. The values for zinc (0.3 – 2.2 mg/100mL), iron (0.417 – 0.449 mg/100mL), magnesium (19.0 – 26.2 mg/100mL) and potassium (122 – 199 mg/100mL) all increased with increasing watermelon juice addition while calcium content (23.4 – 19.2 mg/100mL) decreased. The values for phytochemicals showed a range of 0.203 – 0.7 mg/100mL for beta-carotene, 1.62 – 4.43 mg/100mL for total flavonoids and 32 – 62.7 mgGAE/100mL for total phenolic compound (samples A – F). The sensory scores showed that Sample F (50:50 soymilk-watermelon juice) was the most preferred sample and is therefore recommended for adoption by food processors. The study demonstrated that fortification of soymilk with watermelon juice improved the nutritional quality, phytochemical content and consumer acceptance.

Keywords: Soymilk, Watermelon Juice, Fortification, Quality Evaluation, Physicochemical Properties, Sensory Attributes.

Introduction

Functional foods are receiving increasing consumer attention due to their relation with health, well-being, and the reduction of the risk of several diseases. The consumption of fruits has increased all over the world due to the tasty flavour, protection from ailments, and various benefits to health provided by nutrients like fiber, minerals, vitamins, and other biologically active substances that the human body requires to stay healthy (Abobatta, 2021; Morais *et al.*, 2017). One of these beneficial fruits is watermelon, scientifically known as *Citrullus lanatus*, which has gained interest due to its refreshing taste and high nutritional value (Neglo *et al.*, 2021).

Watermelon is a nutrient-dense fruit that is rich in bioactive compounds such as phenolics, carotenoids – chiefly lycopene, citrulline, vitamins and minerals, which have been associated with antioxidant activity, cardiovascular health and improved metabolic functions (Choudhary *et al.*, 2015; Jebir & Mustafa, 2022). Watermelon juice represents a natural source of health-promoting compounds with improved sensory appeal.

Soymilk is one of the most widely available plant-based beverages worldwide and can be obtained from soybeans without complicated processes. It has long been acknowledged as the best alternative to the significant obstacles of dairy milk consumption (Mazumder & Begum, 2016; Vanga & Raghavan, 2018). It is high in protein, low in cholesterol, lactose-free, and rich in polyunsaturated fatty acids. The bioactive compounds in soybean contribute to the beneficial effects of soymilk and are reported to exert various bioactivities (Han *et al.*, 2021). Despite its nutritional benefits, the consumer acceptance of soymilk remains a concern due to its characteristic's beany flavour and bland sensory profile. Improving its sensory quality without compromising the nutritional value is a key challenge in soymilk-based product development.

The fortification of soymilk with watermelon juice will provide a complementary nutritional profile while enhancing consumer acceptability. The aim of this study was to evaluate the physicochemical, phytochemical and sensory properties of soymilk fortified with watermelon juice at different blending ratios in order to identify an optimal formulation for the development of a functional beverage.

Literature Review

Plant-Based Milk Alternatives and Soymilk

Plant-based milk alternatives have gained global attention due to increasing concerns about lactose intolerance, milk protein allergy, cholesterol intake, and the environmental impact of dairy production. Among these alternatives, soymilk is one of the most widely consumed and studied due to its close resemblance to dairy milk in appearance, energy value and functional properties (Mazumder & Begum, 2016). Soymilk is lactose-free, cholesterol-free and rich in high-quality plant protein, polyunsaturated fatty acids and several bioactive compounds that contribute to its nutritional and health benefits (Garima *et al.*, 2020).

Soy milk is considered an important source of essential amino acids and provides appreciable amounts of minerals such as potassium, magnesium and iron, although its

calcium content is generally lower than that of cow milk unless fortified (Vanga & Raghavan, 2018). It also contains bioactive compounds such as isoflavones, phytosterols, saponins and phenolic compounds, which have been associated with antioxidant, anti-inflammatory and cardio-protective effects (Olias *et al.*, 2023). The nutritional quality and bioactive composition of soymilk, however, depend largely on soybean variety and processing conditions.

Despite its nutritional advantages, consumer acceptance of soymilk is often limited by sensory challenges, particularly the characteristic beany flavour caused by lipoxygenase activity and lipid oxidation during processing (Tao *et al.*, 2022). Mild bitterness and astringency from phenolic compounds may also negatively affect acceptability. These limitations have encouraged the development of fortified and blended soymilk beverages aimed at improving flavour, nutritional value and overall consumer acceptance.

Fruit-Fortified Beverages and Watermelon Juice

Fruit fortification has become a common strategy for improving the nutritional and sensory quality of plant-based beverages. Fruits contribute natural sugars, organic acids, vitamins, minerals and phytochemicals, which enhance both health value and consumer appeal. Watermelon (*Citrullus lanatus*) is a widely consumed fruit known for its refreshing taste, high moisture content and rich composition of bioactive compounds (Neglo *et al.*, 2021).

Watermelon juice contains important phytochemicals such as lycopene, beta-carotene, phenolic compounds and flavonoids, which exhibit antioxidant and health-promoting properties (Jebir & Mustafa, 2022). Lycopene, the dominant carotenoid in watermelon, has been associated with reduced risk of cardiovascular diseases and oxidative stress-related conditions. Watermelon is also a notable source of citrulline, a non-protein amino acid linked to nitric oxide metabolism and cardiovascular health (Kyriacou *et al.*, 2018).

In addition to its phytochemical content, watermelon juice provides essential minerals including potassium, magnesium and iron, while being low in fat and calories. Its natural sweetness, attractive colour and pleasant flavour make it suitable for use in beverage formulation. Previous studies have shown that fruit juice incorporation can improve the sensory properties and acceptability of plant-based drinks while contributing additional nutritional benefits.

Research Gap and Study Justification

Although several studies have reported the nutritional and functional properties of soymilk and watermelon juice separately, limited information is available on the use of watermelon juice as a fortifying ingredient in soymilk beverages. Considering the complementary nutritional profiles of soymilk (protein-rich) and watermelon juice (phytochemical and mineral-rich), blending the two may enhance nutritional quality while improving sensory acceptance. This study therefore seeks to evaluate the physicochemical, phytochemical and sensory properties of soymilk fortified with watermelon juice at different blending ratios.

Materials and Methods

Sources of Raw Materials

Soybean was purchased from Modern Market while the watermelon fruits were purchased from Railway Market, all in Makurdi, Benue State, Nigeria. Reagents, laboratory equipment and other chemicals were sourced from Chemistry laboratory of Revd. Fr. Moses Orshio Adasu University and Joseph Sarwuan Tarka University, Makurdi, Benue State.

Preparation of Raw Materials

Soymilk was produced according to Bolarinwa *et al.*, (2021) with slight modifications. The dried soy beans were selected to remove sand, metal particles and other unwanted materials. After selection, the clean beans were washed and soaked in clean water for 12 h. The beans were then boiled to reduce some anti-nutrients, bitterness and kill bacteria, after which they were grinded, boiled, filtered and cooled as shown in Figure 1.

The watermelon fruits were first washed, then cut and the flesh scooped. After this, the juice was extracted, filtered, pasteurized and cooled according to Kumar *et al.*, (2021) with modifications.

The method used by Bolarinwa *et al.*, (2021) with slight modifications was followed to produce soymilk-watermelon RTS beverage. The watermelon juice was mixed with the soy milk by blending and homogenizing at 8000 rpm for 2 minutes in a homogenizer. The soymilk was blended in different proportions (soymilk: watermelon juice) with the watermelon juice, that is, 90:10, 80:20, 70:30, 60:40 and 50:50 respectively, as shown in Table 1. The obtained beverages were then pasteurized at 85 °C for 1 minute and hot filled into sterile bottles. Sample A with 100% soymilk was used as control. The beverage samples were stored in a refrigerator at 4 °C after which they were analyzed.

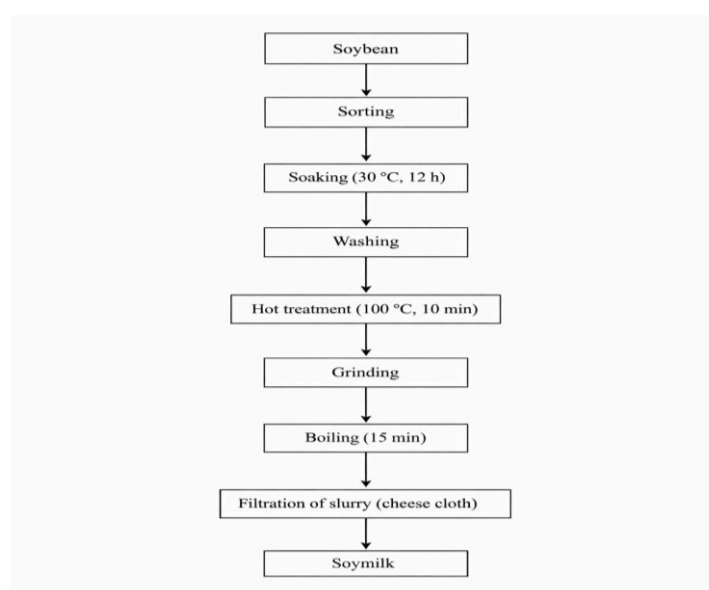


Fig 1: Flowchart for soymilk beverage production

Source: Bolarinwa *et al.*, 2021 modified

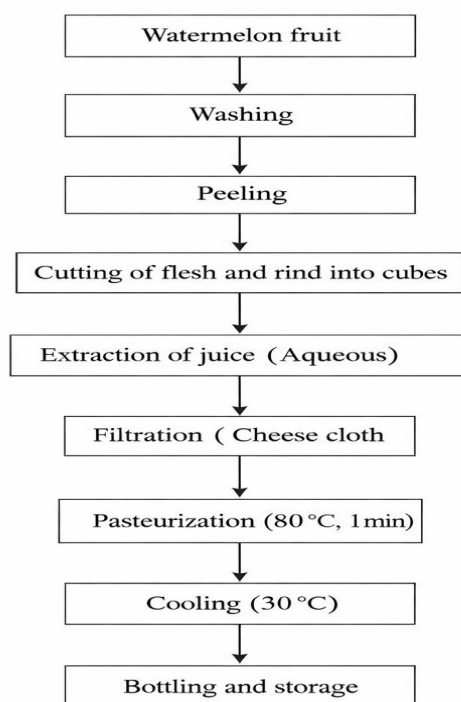


Fig 2: Flowchart for watermelon juice production

Source: Kumar *et al.*, 2021 *modified*

Table 1: Blends Formulation (%) for Preparation of Soymilk Fortified with Watermelon Juice

Sample Code	Soymilk (%)	Watermelon Juice
A (Control)	100	0
B	90	10
C	80	20
D	70	30
E	60	40
F	50	50

Source: Authors' formulation (this study)

Analysis

Physicochemical properties

The physicochemical properties of the soymilk-watermelon beverage were determined using AOAC (2019) methods of analysis. Moisture content was determined by the oven drying method, crude protein by the kjeldahl method, crude fat by the soxhlet extraction method and ash content by incineration at 550 °C. Crude fibre was determined by acid-alkali digestion while carbohydrate was obtained by difference.

pH was measured using a digital pH meter, viscosity was obtained using a viscometer while total soluble solids TSS was obtained using a digital hand-held refractometer according to AOAC (2019).

Mineral analysis

Magnesium, calcium, zinc and iron were obtained by atomic absorption spectrophotometer according to Ibitoye (2005) and Onwuka (2005).

Potassium was determined by the digital flame photometric method as described by Aworin and Udeozor (2014).

Phytochemical analysis

Beta-carotene determination

The AOAC (2004) method of analysis was used to determine the beta-carotene content of the beverage samples. Samples were extracted with organic solvents, followed by the separation of the fraction containing carotenoid. Absorbance was measured using UV-visible spectrophotometer and beta-carotene concentration was quantified and expressed as mg/100mL.

Determination of Total Phenolic Content (TPC)

The Folin-Ciocalteu colorimetric method was used to measure the total phenolic content as described by Ashari *et al.*, (2021) with slight modifications. The amounts of TPC were obtained using a calibration curve (with a line equation of $y=0.1419x-0.014$, $R^2=0.9846$) as mg of Gallic Acid Equivalent (GAE)/mL of sample.

Determination of Total Flavonoid Content (TFC)

The Aluminum Chloride technique was used to determine the flavonoid content (Zilic *et al.*, 2012) using rutin hydrate as a standard. Absorbance was measured in comparison to a blank sample at 510 nm.

Sensory evaluation

The beverage samples were evaluated in the Sensory Laboratory of Joseph Sarwuan Tarkaa University Makurdi, under white light, for attributes of appearance, flavour, mouth feel, taste and overall acceptability by a 24-member semi trained panel on a 9-point hedonic scale ranging from 1 (disliked extremely) to 9 (liked extremely) as described by Ihekoronye and Ngoddy (1985). The samples were coded (A to F) and presented in identical containers. A questionnaire for entering scores and potable water for mouth rinsing between tasting was made available to the panelists.

Statistical analysis

To analyze the results and compare all the samples, a one-way Analysis of Variance (ANOVA) was used and the Turkey test was used to compare the means at 95 % significance

level. All experiments were performed in triplicate and results were presented as the means of replicates. (Nanda *et al.*, 2021).

Results and Discussion

Physicochemical analysis

Table 2 shows the physicochemical properties of soymilk fortified with watermelon juice. The moisture content of samples ranged from 80.4 % (for Sample F) to 87.0 % (for Sample A). This shows that the moisture content increased with the addition of watermelon juice as the juice contains more moisture. The values were similar to those reported by Bolanrinwa *et al.*, (2018) but were lower than those reported by Getu *et al.*, (2017) and Okwunodulu *et al.*, (2021). Ikegwu *et al.*, (2024) reported lower moisture content values of 73.0 – 81.3 % for soy-tigernut milk blends.

Protein values ranged from 2.45 % for Sample A to 1.18 % for Sample F. These values were similar to those (2.1 – 3.8 % for about 11 samples) reported by Olias *et al.*, (2023) in his review on soy beverages obtained from Sudanese markets. Bolarinwa *et al.*, (2018) also reported values of protein for soy-walnut milk drinks ranging from 1.7 – 2.87 %. The protein content values for soymilk fortified with watermelon juice decreased with the addition of watermelon juice due to the fruit's low protein content. Soymilk contains about 3 – 4 % protein (Olias *et al.*, 2023) but cooking raw soymilk results in the denaturation and polymerization of proteins to form other particles that vary in size, composition and morphology (Peng *et al.*, 2017; Olias *et al.*, 2023)

The lipid content of soymilk fortified with watermelon juice varied from 3.04 – 1.88 %. These were in line with most researches (Getu *et al.*, 2017; Ikegwu *et al.*, 2024; Okwunodulu *et al.*, 2021 and Olias *et al.*, 2023). The values were significantly different and decreased considerably with the addition of watermelon juice. Though soybean is abundant in lipids (18 – 24 % of dry weight), soymilk contains only about 2 – 3 % and is considered a low-fat beverage due to its relatively low lipid content compared to the original soybeans (Olias *et al.*, 2023).

The ash content of soymilk fortified with watermelon juice ranged from 0.33 – 0.24 %. These values were higher than those reported by Getu *et al.*, (2017) who reported a range of 0.17 – 0.12 % and Bolarinwa *et al.*, (2018) who reported a range of 0.14 – 0.3 %, but were lower than

Table 2: Physicochemical analysis

Sample Codes	Moisture (%)	Crude Protein (%)	Lipid (%)	Ash (%)	Fibre (%)	Carbohydrates (%)	pH	Viscosity (cP)	TSS (°Brix)
A	80.4±0.206 ^f	2.45±0.000 ^a	3.04±0.075 ^a	0.333±0.00 ^a	0.950±0.030 ^a	12.83±0.106 ^a	6.53±0.058 ^a	3.3±0.100 ^a	11.7±0.010 ^a

Sample Codes	Moisture (%)	Crude Protein (%)	Lipid (%)	Ash (%)	Fibre (%)	Carbohydrates (%)	pH	Viscosity (cP)	TSS (°Brix)
B	82.0±0.105 ^e	2.03±0.029 ^a	2.66±0.012 ^b	0.313±0.00 ^b	0.877±0.006 ^b	12.12±0.250 ^b	6.47±0.058 ^{ab}	3.17±0.058 ^{ab}	11.5±0.021 ^a
C	83.3±0.419 ^d	1.79±0.040 ^b	2.32±0.017 ^c	0.297±0.006 ^{bc}	0.847±0.025 ^{bc}	11.45±0.442 ^c	6.37±0.058 ^b	3.00±0.000 ^b	11.1±0.006 ^b
D	84.1±0.000 ^c	1.64±0.017 ^b	2.15±0.012 ^d	0.280±0.000 ^{cd}	0.837±0.015 ^{bc}	10.99±0.026 ^c	6.17±0.058 ^c	2.73±0.058 ^c	10.6±0.010 ^c
E	85.8±0.030 ^b	1.37±0.012 ^c	2.01±0.020 ^e	0.263±0.006 ^d	0.807±0.012 ^c	9.75±0.045 ^d	6.10±0.000 ^c	2.27±0.115 ^d	10.2±0.006 ^d
F	87.0±0.078 ^a	1.18±0.006 ^c	1.88±0.012 ^f	0.240±0.010 ^e	0.753±0.01 ^d	8.95±0.081 ^d	6.03±0.058 ^c	2.07±0.115 ^d	9.90±0.010 ^e

Values are expressed as means ± standard deviation of triplicate determinations. Means with the same letters along the same columns are not significantly different at 95 % significance level. Sample A = 100 % Soymilk, Sample B = 90 % Soymilk:10 % Watermelon juice, Sample C = 80 % Soymilk:20 % Watermelon Juice, Sample D = 70 % Soymilk:30 % Watermelon juice, Sample E = 60 % Soymilk:40 % Watermelon juice and Sample F = 50 % Soymilk:50 % Watermelon juice

Source: Authors' laboratory analysis (this study)

Those reported by Okwunodulu *et al.*, (2021) with a range of 0.6 – 0.36 % and Ikegwu *et al.*, (2024) with a range of 2.93 – 1.3 %. Ash content of food is an indication of the mineral content of the food (Okwunodulu *et al.*, 2021).

The crude fibre content of the samples ranged from 0.950 – 0.753 % reflecting the thickness of the beverage samples. The fibre content decreased with the addition of watermelon juice. The values reported were similar to those of Olias *et al.*, (2023) but lower than those reported by Ebabhamiegbegho *et al.*, (2020) for pineapple-soybean drink. Ikegwu *et al.*, (2024) reported fibre content values of 0.07 – 1.83 % for soy-tigernut milk samples. High crude fibre contents suggests that the samples are thicker and healthier.

Carbohydrate content is seen to range from 12.83 – 8.95 %. These values were high compared to most studies (Bolarinwa *et al.*, 2018; Ebabhamiegbegho *et al.*, 2020; Getu *et al.*, 2017; Modanwal & Singh, 2024; Okwunodulu *et al.*, 2021; Olias *et al.*, 2023) but were within the range of those reported by Oladele and Ofure (2020) whose values ranged from 5.83 – 11.67 % and Liamngee *et al.*, (2013) whose values ranged from 3.09 – 13.39 %. Ikegwu *et al.*, (2024) also reported values of 6.34 – 16.93 % for soy-tigernut milk. High values of carbohydrates (especially when the carbohydrate content is gotten by difference) indicates that the moisture content of samples were low (at least lower than 90 %) compared to commercial soymilk beverages. Carbohydrates are considered the major dietary energy sources that provide energy to the body cells, especially those of the brain (Mata *et al.*, 2019).

The pH values ranged from 6.53 for Sample A to 6.03 for Sample F. The decrease in pH values is as a result of the addition of watermelon juice which has acidic pH values. The pH values gotten in this study are similar to those reported by Rui *et al.*, (2019) and Okwunodulu *et al.*, (2020) who obtained a pH value of 6.38 for 100 % soymilk and a decrease in pH as supplementation increased. The values are also in line with those (6.07 – 6.67) reported by Teshome *et al.*, (2015) for cow milk, making the product conducive for lovers of cow milk who are lactose-intolerant.

The values of viscosity ranged from 3.3 – 2.07 cP for Sample A through F and decreased with the addition of watermelon juice. These values were low compared to those reported by Bolarinwa *et al.*, (2021) for pawpaw enriched soymilk (values ranged from 19.9 cP to 26.7 cP), but were similar to that of Tao *et al.*, (2022) who recorded a value of 3.4 cP for plain soymilk. Okwunodulu *et al.*, (2021) however reported very low values of 0.41 – 0.48 mPa for soymilk-breadfruit milk blends. The viscosity of soymilk fortified with watermelon juice decreased with the addition of watermelon juice chiefly because of the dilution effect of the juice which mostly contain water.

The Total Soluble Solids (TSS) values of soymilk fortified with watermelon juice ranged from 11.7 – 9.90 °Brix. These were similar to those reported by Basharat *et al.*, (2020) but higher than those reported by Bolarinwa *et al.*, (2018) and Getu *et al.*, (2017). Bolarinwa *et al.*, (2021)

also reported TSS values of 5.8 – 8.5 °Brix for soy-pawpaw beverage while Banigo *et al.*, (2015) reported values of 8.17 – 9.91 °Brix for soy-carrot beverage flavoured with beetroot.

Mineral Composition

The mineral content of soymilk fortified with watermelon juice is summarized in Table 3. Zinc values ranged from 0.3 – 2.2 mg/100mL. The values increased with the addition of watermelon juice. These values were similar to most researches (Bolarinwa *et al.*, 2018; Delgado-Andrade *et al.*, 2025; Idowu-Adebayo *et al.*, 2022; Nti *et al.*, 2016;) with a range of values for soy or soy-mixed beverages. USDA (2019) recorded a value of 0.5 mg/240mL for soy beverages while Okwunodulu *et al.*, (2021) reported values of 0.4 – 0.79 mg/100g for soymilk-breadfruit beverage.

Table 3: Mineral Content of Soymilk Fortified with Watermelon Juice (mg/100mL)

Sample Codes	Zinc	Iron	Calcium	Magnesium	Potassium
A	0.3±0.001 ^e	0.417±0.006 ^e	23.4±0.010 ^a	19.0±0.000 ^e	122±0.015 ^f
B	0.9±0.001 ^d	0.432±0.001 ^d	20.2±0.002 ^b	20.7±0.002 ^d	132±0.012 ^e
C	1.6±0.007 ^c	0.436±0.001 ^{cd}	19.9±0.011 ^c	21.1±0.001 ^d	146±0.012 ^d
D	1.6±0.001 ^c	0.440±0.000 ^{bc}	19.6±0.004 ^d	23.2±0.001 ^c	165±0.025 ^c
E	1.8±0.000 ^b	0.444±0.001 ^{ab}	19.3±0.001 ^e	25.0±0.002 ^b	179±0.015 ^b
F	2.2±0.001 ^a	0.449±0.001 ^a	19.2±0.003 ^e	26.2±0.004 ^a	199±0.025 ^a

Values are expressed as means $\pm$ standard deviation of triplicate determinations. Means with the same letters along the same columns are not significantly different at 95 % significance level. Sample A = 100 % Soymilk, Sample B = 90 % Soymilk:10 % Watermelon juice, Sample C = 80 % Soymilk:20 % Watermelon Juice, Sample D = 70 % Soymilk:30 % Watermelon juice, Sample E = 60 % Soymilk:40 % Watermelon juice and Sample F = 50 % Soymilk:50 % Watermelon juice

Source: Authors' laboratory analysis (this study)

The values for iron ranged from 0.417 – 0.449 mg/100mL and increased progressively with the addition of watermelon juice. The values were similar to those of Idowu-Adebayo *et al.*, (2022) and Nti *et al.*, (2016) but lower than those of Bolarinwa *et al.*, (2018) and Okwunodulu *et al.*, (2021) who reported values of 0.64 – 2.38 and 0.59 – 0.49 mg/100mL respectively. Delgado-Andrade *et al.*, (2025) also reported values of 0.18 – 0.52 mg/100mL.

Calcium recorded values of 23.4 – 19.2 mg/100mL for sample A to F. The values decreased with the addition of watermelon juice due to the dilution of calcium-rich soymilk with low-calcium watermelon juice, combined with acidification effects (Olias *et al.*, 2023; Shkempi & Huppertz 2021). The values were within the range of values recorded by Nti *et al.*, (2016) and Idowu-Adebayo *et al.*, (2022). Delgado-Andrade *et al.*, (2025) however reported values of 12.20 – 34 mg/100mL while Bolarinwa *et al.*, (2018) reported values of 23.63 – 35.08 mg/100mL.

Magnesium values ranged from 19.0 – 26.2 mg/100mL and the values increased with the addition of watermelon juice. These values were higher than those reported by Redan *et al.*, (2023) who reported a value of 16.1 mg/100mL for soy-plant-based milk, but were similar to those of Nti *et al.*, (2016) and USDA (2019) with values of 22 mg/100mL and 21.5 mg/100mL respectively. Delgado-Andrade *et al.*, (2025) also reported values of 10.6 – 23.1 mg/100mL while Bolarinwa *et al.*, (2018) recorded values of 22.13 – 59.51 ppm.

The values for potassium ranged from 122 – 199 mg/100mL and were significantly different. The values increased with the addition of watermelon juice and were lower than that of Nti *et al.*, (2016) who reported a value of 206 mg/100mL. Smith *et al.*, (2022) reported values of 143 – 260 mg/100mL while Delgado-Andrade *et al.*, (2025) reported values of 255 – 112 mg/100mL for different soy beverages. USDA (2019) recorded a value of approximately 116.7 mg/100mL for soy beverage.

The mineral improvement observed with increasing watermelon juice addition is due to the complementary contribution from the juice. Also, the presence of vitamin c and organic acids in the juice may improve the bioavailability of these minerals.

Phytochemical Composition

The phytochemical content of soymilk fortified with watermelon juice is shown in Table 4. The beta-carotene content ranged from 0.203 – 0.700 mg/100mL. The values increased with the addition of watermelon juice as watermelon is known to contain appreciable amounts of beta-carotene. The values reported were similar to those reported by Matabura and Rweyemamu (2022) for soy-moringa beverage for different methods of formulation. The

reported values were also higher than those reported by Getu *et al.*, (2017) and lower than those reported by Matabura and Rweyemamu (2022) for different methods. Beta-carotene cannot be synthesized by the body therefore, is primarily derived from plant-based foods such as watermelon, carrots and mangoes (Chen *et al.*, 2017). It is a precursor for Vitamin A (Jebir & Mustafa 2022).

Flavonoid content ranged from 1.62 – 4.43 mg/100mL. These values were higher than those reported by Okwunodulu *et al.*, (2021) but lower than those reported by Ikegwu *et al.*, (2024). According to Chi and Cho (2016), soya products contain bioactive compounds such as flavonoids up to 1.5 mg/mL.

Total phenolic values ranged from 32.0 – 62.70 mgGAE/100mL. These values were higher than those reported by Ikegwu *et al.*, (2024) with values ranging from 11.6 – 12.96 mg/100mL for phenols of soy-tigernut milk beverage, and Turco *et al.*, (2023) with an approximate value of 20.61 mgGAE/100mL for soymilk beverage. The reported values were however lower than those of Punoo *et al.*, (2023) whose values were 112 – 181 mgGAE/100mL for soy whey fortified orange.

Table 4: Phytochemical Content of Soymilk Fortified with Watermelon Juice

Sample Codes	Beta-Carotene (mg/100mL)	Total Flavonoids (mg/100mL)	Total Phenolics (mgGAE/100mL)
A	0.203±0.015 ^f	1.62±0.047 ^f	32.00±0.000 ^d
B	0.300±0.010 ^e	2.22±0.010 ^e	39.00±0.010 ^c
C	0.380±0.000 ^d	2.72±0.047 ^d	41.30±0.006 ^c
D	0.450±0.010 ^c	3.09±0.012 ^c	47.70±0.012 ^b
E	0.543±0.025 ^b	3.36±0.010 ^b	51.70±0.015 ^b
F	0.700±0.010 ^a	4.43±0.012 ^a	62.70±0.031 ^a

Values are expressed as means ± standard deviation of triplicate determinations. Means with the same letters along the same columns are not significantly different at 95 % significance level. Sample A = 100 % Soymilk, Sample B = 90 % Soymilk:10 % Watermelon juice, Sample C = 80 % Soymilk:20 % Watermelon Juice, Sample D = 70 % Soymilk:30 % Watermelon juice, Sample E = 60 % Soymilk:40 % Watermelon juice and Sample F = 50 % Soymilk:50 % Watermelon juice

Source: Authors' laboratory analysis (this study)

Juice beverage. Moretto *et al.*, (2021) also reported a range of 25 – 30 mgGAE/100mL for soy-based beverages. The consumption of foods rich in phytochemicals have long-term benefits to human health (Makaepa *et al.*, 2019). These benefits include the reduction of chronic diseases such as cancers.

Sensory Attributes

The results for the sensory evaluation of soymilk fortified with watermelon juice are shown in Table 5. Sensory attributes affect the perception of food and therefore play a critical role

in determining the consumer acceptability of such foods (Ikegwu *et al.*, 2017). The appearance, flavour, mouthfeel, taste and overall acceptability of the samples ranged from 5.8 – 7.7, 5.33 – 7.54, 5.79 – 7.92, 4.75 – 8.08 and 5.33 – 8.00 respectively. The results show that for all quality attributes (appearance, flavour, mouthfeel, taste and overall acceptability), there was increased preference from Sample A (100 % soymilk) to Sample F (50 % soymilk:50 % watermelon juice).

The least preferred sample was Sample A since the attributes were that of the regular soymilk, and without the addition of sugar. The samples were prepared without sugar to make it a completely natural beverage, devoid of artificial sweeteners, and suitable for people with special needs such as diabetes patients.

Apart from Sample A, all other samples were liked in various degrees. Samples D, E and F were well accepted but Sample F was the most preferred of all samples with a taste score of 8.08 and overall acceptability score of 8.00. The acceptance rating of the soymilk fortified with watermelon juice beverages reported in this study are within the range of the acceptance value (6.05 – 7.80) reported for fruits incorporated soy beverages (Banigo *et al.*, (2015).

Table 5: Sensory Attributes of Soymilk Fortified with Watermelon Juice

Sample Codes	Appearance	Flavour/Aroma	Mouth Feel	Taste	Acceptability
A	5.83±2.51 ^b	5.33±2.08 ^b	5.79±2.13 ^c	4.75±2.17 ^c	5.33±2.18 ^c
B	6.12±1.80 ^{ab}	6.29±1.94 ^{ab}	6.08±2.10 ^{bc}	5.67±1.81 ^{bc}	6.29±1.73 ^{bc}
C	6.88±1.57 ^{ab}	6.79±1.93 ^{ab}	7.25±1.19 ^{ab}	6.96±1.33 ^{ab}	6.88±1.68 ^{ab}
D	7.04±1.73 ^{ab}	7.33±1.79 ^a	7.21±1.56 ^{ab}	7.00±1.67 ^{ab}	7.17±1.55 ^{ab}
E	7.50±1.56 ^a	7.50±1.44 ^a	7.46±1.47 ^{ab}	7.71±1.37 ^a	7.75±1.19 ^a
F	7.71±2.24 ^a	7.54±2.17 ^a	7.92±1.21 ^a	8.08±1.53 ^a	8.00±1.69 ^a

Values are expressed as means ± standard deviation of triplicate determinations. Means with the same letters along the same columns are not significantly different at 95 % significance level. Sample A = 100 % Soymilk, Sample B = 90 % Soymilk:10 % Watermelon juice, Sample C = 80 % Soymilk:20 % Watermelon Juice, Sample D = 70 % Soymilk:30 % Watermelon juice, Sample E = 60 % Soymilk:40 % Watermelon juice and Sample F = 50 % Soymilk:50 % Watermelon juice

Source: Authors' sensory analysis (this study)

pH Values of Soymilk Fortified with Watermelon Juice at Varying Time

For Day 1, the pH values ranged from 6.57 for Sample A and decreased down the column to 6.03 for Sample F. These values were near-neutral values (7 is the neutral value) although values below 7 are in the acidic region, therefore the values could be described as mildly acidic. The values decreased with the addition of watermelon juice depicting the acidic nature of the juice. The pH values for Day 1 were similar to those reported by Rui *et al.*, (2019) and Okwunodulu *et al.*, (2020), and were also similar to those of cow milk (Teshome *et al.*, 2015).

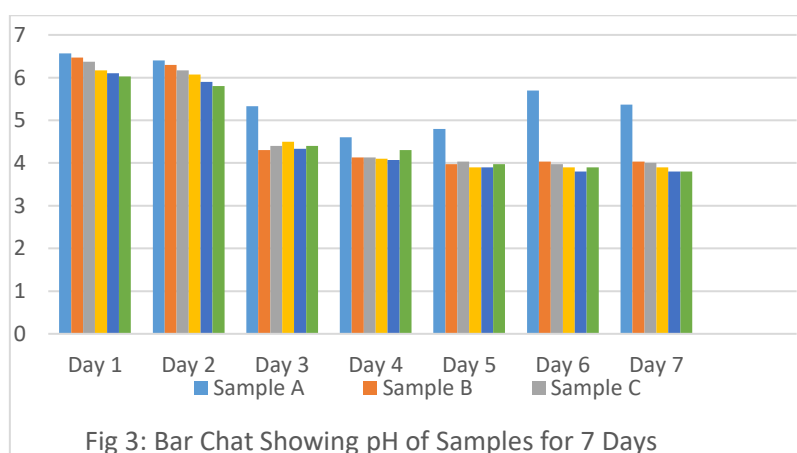
Day 2 recorded a slight decrease in pH values across all samples with a range of 6.40 for Sample A and 5.80 for Sample F, maintaining a definite pattern. The results indicated an onset of acidification and is similar with reports on protein-based beverages, where slight decreases in pH during first days of storage are attributed to microbial metabolism of sugars to organic acids. According to Malgorzata *et al.*, (2023), fermented soy beverages exhibit a steady post-fermentation pH decline due to lactic acid bacteria activity. Emilija *et al.*, (2022) also reported that whey-fruit beverages undergo unpredictable pH decreases within the first week of storage.

For days 3 and 4, the samples continued to exhibit a decrease in pH although the progression no longer followed the initial definite pattern. This can be likened to changes in microbial metabolism, where initial acid-producing species are succeeded by slower or variable acid producers (acid tolerant species of microorganisms). Kaddumukasa *et al.*, (2017) in a similar report on pasteurized juices observed early predictable pH degradations that became more variable over time as microbial population evolved.

Days 5, 6 and 7 recorded unusual increase in pH for the various samples. Sample A recorded an increase in pH from 4.6 (for Day 4) to 4.8 (for Day 5) to 5.7 (for Day 6). At Day 7, there was a drop in pH for Sample A to 5.37. Sample B recorded an increase on day 6 and maintained the same value of 4.03 on day 7. Sample C recorded an increase on day 7 while Sample D maintained a value of 3.9 for days 5, 6 and 7. This could be due to amino acid catabolism during storage releasing ammonia, or decarboxylation which produces biogenic amines. These processes are capable of consuming protons and elevating pH in protein-rich beverages. In a case of mixed cultures, yeast succession can also lead to a decrease in pH values (Banicod *et al.*, 2025; Yang *et al.*, 2024; Yerlikaya *et al.*, 2025).

Samples E and F did not record increments although Sample E recorded the same value for days 6 and 7 while Sample F maintained a definite decrease in pH values from day 1 through 7. The continued decrease in pH for sample F could be due to sustained acidification by lactic acid bacteria (Li *et al.*, 2019).

The pH of all the samples for a period of 7 days is shown in Fig 3.



Source: Authors' laboratory analysis (this study)

Conclusion

The study has shown the production and quality evaluation of soymilk fortified with varying proportions of watermelon juice. Results revealed that fortification significantly improved the chemical, physical as well as sensory attributes of the ready-to-serve beverage, compared to plain soymilk. Among the different formulations, sample F (50 % soymilk:50 % watermelon juice) consistently exhibited superior qualities in terms of proximate composition, mineral and phytochemical improvement, as well as sensory appeal.

From this study, it is concluded that it is possible to develop a healthy beverage with good physicochemical and sensory qualities by fortifying soymilk with watermelon juice. The beverage was without the addition of sugars and other chemical additives, thus, making it suitable for all age groups especially the old. It is also suitable for people with lactose intolerance, diabetes and cancers. Consuming this beverage will provide the necessary energy, nutritional needs as well as compounds (phytochemicals) that will keep the body healthy and help fight diseases.

Recommendations

1. Food industries and small-scale processors should consider producing soymilk fortified with watermelon juice in the ratio of 50:50 (for soymilk and watermelon juice), since this blend formulation yielded the best results.
2. Pilot scale production should be carried out to optimize processing techniques for large scale production while maintaining beverage quality as well as consumer acceptability.
3. Soymilk fortified with watermelon juice can serve as a healthy, plant-based alternative to dairy milk, appealing to consumers who are health conscious, lactose-intolerant, diabetic or vegetarians.
4. Future studies should investigate extended shelf-life under different storage conditions (ambient and refrigerated), focusing on changes in physicochemical properties, microbial stability and sensory acceptability over time.

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