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Research Article

Physicochemical, Nutritional, Microbiological, Glycemic Index, and Sensory Evaluation of A Novel Plant-Based Beverage as Milk Alternative from Local Sweetpotato (var. VitAto)

Norzaleha Kasim[1]*, Wan Nur Zahidah Wan Zainon[2], Nur Ilida Mohamad[2], Norhida Arnieza Muhsin[2], Mohd Fakhri Hashim[2], Noor Fadzlina Inche Zainal Abidin[2], Amsal Abdul Ghani[2], Maisarah Shamsulkamal[1] and Noreenyusnita Md Najib[1]

[1]Food Science & Technology Research Centre, Malaysian Agricultural Research & Development Institute (MARDI), MARDI Johor Bahru, Johor, Malaysia

[2]Food Science & Technology Research Centre, Malaysian Agricultural Research & Development Institute (MARDI), MARDI Headquarters, Persiaran MARDI-UPM, Selangor, Malaysia

Abstract

Environmental sustainability, health consciousness, and ethical considerations underpin the rising demand for Plant-Based Beverages as Milk Alternatives (PBMAs). The necessity to diversify PBMAs arises from the need for expanded options beyond allergen-based sources. While current offerings dominate the market, the absence of PBMA derived from sweet potatoes presents a compelling opportunity. This study introduces a novel PBMA from local sweet potatoes (var. VitAto), which are rich in Vitamin A precursor (beta-carotene) and possess natural sweetness. The development of PBMA VitAto involved a comprehensive process, including washing, alkaline soaking, peeling, steaming, liquid extraction, starch removal, blending with additional ingredients, pasteurization, filling, packaging, and retort processing. Analytical assessments confirmed that the final product contains macronutrients comparable to existing PBMAs available in the market and low glycemic index (e-GI=40). Furthermore, the study evaluated the stability and shelf-life of PBMA VitAto, demonstrating no detectable microbial growth after 12 months of storage, highlighting its robust preservation through retort processing. Sensory analysis revealed a favorable overall acceptability score of 5.4 out of 7, indicating a promising reception by consumers. The development and successful formulation of PBMA VitAto underscore its potential as a viable addition to the array of PBMAs, offering an allergen-free alternative, addressing nutritional needs with its high beta-carotene content, and demonstrating an appealing sensory profile with a notable shelf-life, thereby warranting further exploration and consideration within the milk alternative market.

Keywords: Allergen-free; Glycemic index; Milk alternatives; Plant-based beverage; Sweet potato

***Corresponding author:** Norzaleha Kasim, Food Science & Technology Research Centre, Malaysian Agricultural Research & Development Institute (MARDI), MARDI Johor Bahru, Johor, Malaysia, Tel: +60 72370766; Email: nzaleha@mardi.gov.my / norzalehakasim@gmail.com.my

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Introduction

The pursuit of novel, nutritionally robust alternatives to traditional dairy has surged due to concerns about allergens, environmental impact, dietary preferences, and health advantages [1,2]. Developing Plant-Based Milk Alternatives (PBMAs) has become pivotal, with a focus on sourcing allergen-free, abundant, and sustainable raw materials. The recognition of major food allergens-such as milk, peanuts, tree nuts, wheat (gluten), soybeans, and sesame-by the United States Food and Drug Administration (FDA) [3], underscores the need for alternative sources for individuals with specific dietary restrictions.

Sweet potato, boasting natural sweetness and a diverse nutrient profile, emerges as a promising avenue for a novel plant-based beverage, serving as an alternative to current PBMA. This investigation aims to contribute to the expanding field of plant-based beverages by exploring VitAto, a local orange-fleshed sweet potato known for its nutritional richness and technological feasibility [4]. While prior studies primarily investigated soy, almond, oat, rice, and coconut sources for plant-based milk alternatives [5], no exploration has centered on sweet potatoes as the primary constituent for a milk substitute.

This venture's novelty lies in diverging from conventional sources, opening avenues to broaden the non- dairy beverage market. Rooted in food science and technology research, this study delves into the feasibility of sweet potato-derived beverages as a palatable milk alternative. It aims to unveil the beverage's nutritional composition, consumer acceptance, and shelf life, establishing a scientific foundation for its potential as a commercially viable product.

Materials and Methods

Sources of Raw Materials

The primary raw material, fresh VitAto, was collected from a plantation field in MARDI Bachok, Kelantan. Other food-grade chemicals and ingredients were purchased from local suppliers.

Processing of PBMA VitAto

The PBMA VitAto processing methodology followed a systematic series of steps, as depicted in Figure 1. Primarily aligned with conventional PBMA processing methods, the initial phase involved soaking the raw material in an alkaline solution, following the suggestion by Dhankhar and Kundu [6], aimed at augmenting the extractability of proteins. Subsequently, peeling of the VitAto was executed, as found by Dako et al. [7], primarily to reduce or eliminate antinutrients like phytate, oxalate, and tannin. The peeled VitAto underwent a steaming process to reduce off-odour and off-flavour and enhance the sensory properties [8]. Then, the liquid was extracted and filtered, followed by sedimentation to discard the starch to prevent thick slurry and gelatinization during heating [9]. Some studies used an enzymatic method to hydrolyse protein and starch for the preparation of PBMA [10]. However, our preliminary studies showed no significant effect on the protein and total soluble solid content of the liquid extract. Moreover, without enzyme addition, there will be no issues concerning veganism. The homogenization of post-formulation facilitated a comprehensive ingredient mixture and minimized separation tendencies. Pasteurization was conducted for microbial elimination, followed by retorting to support shelf life during storage, ensuring safety. This meticulous methodology adhered to established protocols and integrated crucial alterations specific to VitAto processing to yield a safe, palatable, and shelf-stable PBMA product.

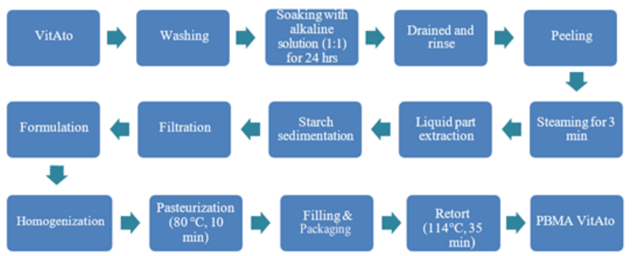

Figure 1: Flowchart of PBMA VitAto processing.

Determination of Physicochemical Properties of PBMA VitAto

Evaluating PBMA VitAto's physicochemical properties involves a multifaceted approach encompassing distinct measurements. Color assessment utilizes a Chroma meter Model CR-400/410 Konica Minolta (Japan), enabling quantification of color attributes expressed in terms of L*, a*, b* as defined by the International Commission on Lighting (CIE). The L* represents its color's clarity, while a* and b* represent their positions between red and green and yellow and blue, respectively. pH measurements, conducted via a Metler Toledo (Switzerland) pH meter, ascertain the acidity or alkalinity of the beverage. Total soluble solids are quantified using a digital refractometer (Model HI96801, Hanna Instrument, USA), which provides insights into the beverage's dissolved solids content, influencing sweetness and mouthfeel. Additionally, viscosity measurements employing a viscometer (Brookfield, USA) were conducted to aid in understanding the fluid's flow behavior, which is crucial for assessing texture and consistency. All analyses were performed in triplicate at room temperature.

Assessment of Nutritional Composition of PBMA VitAto

The AOAC methods (988.05, 963.15, 968.28, and 985.29) [11], facilitated the analysis of macronutrients (protein, fat, total sugar) and total dietary fibre in the PBMA VitAto. Determining energy and carbohydrate content employed methodologies derived from the Guide to Nutrition Labelling and Claims [12]. Additionally, salt (sodium) and beta-carotene were quantified using techniques outlined in AOAC methods 968.08 and 941.15 [11].

In Vitro Glycemic Index Analysis (eGI) Method

The in vitro Glycemic Index (GI) of the NutriVitA was determined according to the methodology described by Goñi et al. [13], with the following modifications: glucose concentration was determined using glucose kit GAGO 20 (Sigma-Aldrich) and the colour reaction was measured using a UV/VIS spectrophotometer, model DU 70 (Beckman, USA), at λ=510 nm. Glucose digestion rate was expressed through the percentage of glucose in each sample at each time interval (0, 30, 60, 90, 120, 150, and 180 minutes). Hydrolysis curves were built (disregarding the value at time 0), and the area below the hydrolysis curves was calculated (AUC). The Hydrolysis Index (HI) for each sample was calculated as the ratio between the AUC of each sample and the AUC of white bread, used as reference, and expressed in percentage. Finally, the GI was calculated according to equation (1); where GI=Glycemic Index (%); and HI=Hydrolysis Index (%).

$$GI = 39.71 + 0.549*HI \quad (1)$$

Sensory Evaluation

The sensory evaluation aims to assess the acceptability and preference of PBMA VitAto among 60 panellists using a Likert scale ranging from 1 to 7, where 1 represents "dislike very much" and 7 denotes "like very much." The participants comprised individuals from diverse demographics, age, gender, and dietary habits. The samples were labeled with random codes to anonymize the products and prevent bias. Panellists will taste the PBMA VitAto and rate their preference using the 1 to 7 Likert scale on a structured evaluation sheet, considering color, taste, aroma, viscosity, and overall acceptability.

Microbiological Analysis during Storage

The PBMA VitAto samples underwent storage in an accelerated chamber set at specific conditions mimicking an extended duration. Maintaining a relative humidity of 75% and a temperature of 40 °C within the accelerated chamber simulated an equivalent of one year under ambient temperature conditions over two months. The PBMA VitAto samples were regularly assessed monthly throughout the storage period. The microbiological analysis encompassed several vital parameters. Total Plate Count (TPC), Total Anaerobic Count (TAC), and total psychrotrophic count in the samples were determined by ISO [14], and ISO [15]. Analyses of yeast & mold count were referred to ISO [16], and coliform and Escherichia coli growth was assessed according to AOAC [17]. Results from the microbiological study were systematically recorded at each monthly interval and were monitored to determine any changes in microbial counts or presence.

Results and Discussion

Physicochemical Properties of PBMA VitAto

Table 1 presents the physicochemical properties of PBMA VitAto. Like other PBMAs, it exhibits a more neutral pH (6.16), albeit slightly lower than the typical range of 6.5 to 8.0 for common PBMAs [18-20]. However, Aydar et al. [21], review revealed that some plant-based milk substitutes from almond, rice, walnut, and tiger nuts also have a pH below 6.0. These differences are likely due to the varying ingredients in the formulations. Meanwhile, the total soluble solids of PBMA VitAto were much higher than those of the novel plant-based milk based on chickpea and coconut developed by Rincon and his colleagues [22]. This disparity may stem from the different processing techniques applied to both PBMAs, which can cause rupture or denaturation of solids in the samples [23]. In terms of color assessment, the lightness (L*) was lower than that of common PBMAs, while the yellowness (b*) was much higher [20]. These results are expected as the orange color of VitAto reduces the lightness of the sample and increases the yellowness. The positive a* value of PBMA VitAto contradicts most of the commercial UHT-treated plant-based beverages [20]. This finding is most likely due to the raw materials used in PBMA VitAto, which impart a slightly red color rather than the pale green tones observed in commercial PBMAs. Furthermore, the viscosity of PBMA VitAto was low and comparable to that of other PBMAs [24]. However, some PBMAs from almond, coconut, hazelnut, and hemp exhibited higher viscosity (ranging from 19.08 to 47.80 mPas). These PBMAs contained hydrocolloids that influenced their flow behavior.

Parameter		Value
pH		6.16±0.02
Total soluble solid		11.01±0.14°Brix
Colour	L*	43.75±0.03
	a*	3.75±0.03
	b*	31.17±0.08
Viscosity		4.44±0.06 mPas

Table 1: Physicochemical properties of PBMA VitAto.

Nutritional composition of PBMA VitAto

The nutritional details of PBMA VitAto are outlined in table 2. For every 100grams, PBMA VitAto contains 58.0kcal, positioning it moderately in terms of energy when compared to other non-dairy beverages detailed by Pérez-Rodríguez et al. [25], which ranged between 28.9 to 78.8kcal per 100mL. Notably, PBMA VitAto maintains a well-balanced macronutrient composition, consisting of 1.2grams of protein, 2.1grams of total fat, and 8.4 grams of carbohydrates per 100 grams. Compared to various Plant-Based Beverages (PBB), excluding soy, PBMA VitAto showcases higher protein content [21,26,27], potentially appealing to consumers seeking protein-rich alternatives. While some studies have reported higher protein content in other PBBs than PBMA VitAto [28], most of these alternatives were derived from soy, nuts, or sesame-ingredients regulated as major food allergens by the U.S. Food and Drug Administration [3]. Allergenicity concerns have also been highlighted in studies on immune reactivity to coconut milk substitutes [29].

Nutrient	Unit	Value (per 100 g)
Energy	kcal	58
Protein	g	1.2
Total fat	g	2.1
Carbohydrate	g	8.4
Total dietary fibre	g	1.8
Total sugar	g	2.2
Salt (sodium)	mg	23.1
Beta carotene	mg	7.1

Table 2: Nutritional composition of PBMA VitAto.

The fat content of PBMA VitAto falls within a moderate range compared to other beverages, except for coconut, ranging approximately between 0.9 to 2.9grams per 100grams [30], a trend similarly observed in prior research by Smith et al. [27]. Concerning carbohydrates, PBMA VitAto exhibits higher carbohydrate content (8.4grams/100grams) than most milk alternatives, except for PBMA rice [21,28]. These findings primarily stem from the high starch content found in sweet potato and rice [26]. However, the presence of 2.2 grams of total sugars in PBMA VitAto is lower than other PBBs, notably in rice-based alternatives [21,26,28], which could influence consumer acceptance, especially among those seeking lower sugar intake. According to the Malaysia Food Act 1983 and Regulations concerning nutrition labeling and claims [31], a total sugar content of at least 2.5 grams per 100 milliliters is considered low sugar.

Moreover, PBMA VitAto contains 1.8grams of dietary fiber per 100 grams, positioning it as a source of dietary fiber [31]. This finding contrasts with other milk alternatives without detectable fiber content, except for oats [28,29]. While oats show promise as milk alternatives, they have been associated with allergenic concerns [32]. The dietary fiber content in PBMA VitAto holds potential health benefits, contributing to improved digestive health and a feeling of fullness, appealing to health-conscious consumers. Furthermore, the sodium content in PBMA VitAto, measured as salt, amounts to 23.1 milligrams per 100 grams, indicating lower sodium content than most common non-dairy beverages available in the market [21,28]. Given that VitAto is an orange-fleshed tuber, the analysis revealed a high beta-carotene content of 7.1 milligrams per 100 grams, surpassing or matching the levels found in common tubers, fruits and vegetables [33]. This high beta-carotene content can contribute significantly to Vitamin A intake in daily diets.

Glycemic Index (GI) of Plant-Based Beverages as Milk Alternative (PBMA) VitAto

PBMA VitAto has a low e-GI value of 40, which is significantly lower than other plant-based milk alternatives [34]. In comparison, coconut-based PBMA has a very high e-GI of 96.82, whereas rice-based PBMA ranges between 79 and 99. Oat-based PBMA has a moderate e-GI of 59.61, whereas soy drinks have an e-GI of around 48. The glycemic responses of these plant-based drinks are influenced by their carbohydrate composition and sugar content, with PBMA VitAto notably having a lower e-GI.

Sensory Acceptance for PBMA VitAto

Despite the growing demand for plant-based milk alternatives, the reluctance of mainstream consumers to explore unfamiliar foods deemed unappealing could pose a constraining element. Therefore, this sensory evaluation is conducted to get early information about consumer preferences to see the potential of PBMA VitAto to be marketed [9]. Table 3 depicts the results for sensory acceptance of PBMA VitAto. All attributes (color, aroma, viscosity, taste, and overall acceptance) had mean scores above 5, indicating the sensory panelists' liking of the sample, and it can be concluded that PBMA VitAto is well accepted. The result also exhibited that the processing method of this PBMA VitAto has overcome the common problems of off-odor and off-flavor in most plant-based milk substitutes [5].

Attributes	Colour	Aroma	Viscosity	Taste	Overall Acceptance
Score*	5.23±1.03	5.40±1.17	5.26±1.24	5.46±1.04	5.40±1.06

Table 3: Sensory acceptance of PBMA VitAto.

Note: *Values are means±standard deviations (n=60). The scoring scale is from 1 to 7 (dislike very much to like very much)

Microbiological Analysis of PBMA VitAto during Storage

Table 4 shows the results of microbiological analyses on PBMA VitAto during two months of storage in an accelerated chamber. No microbial growth for all tests during the period demonstrated that the combination of pasteurization and retort processing ensured the safety of PBMA VitAto for a year at ambient temperature. Although heat treatment has been utilized to enhance the shelf life of plant-based milk, excessive heat exposure will induce adverse effects such as browning and a cooked flavor [5]. However, the selected optimum temperature and time used to process PBMA VitAto successfully prolong its shelf life and protect its organoleptic properties (as discussed above). This result aligns with previous studies by Anandh et al. [35], and Sandhya and Anandakumar [36], who also used retort to improve the shelf life without much effect on sensory attributes and physico-chemical properties of their rose-flavored and blended vegan milk, respectively.

Microbiological Analysis (CFU/ml)						
Month	Total Plate Count (TPC)	Total Yeast & Mould Count (Y&M)	Total Coliform	Escherichia coli	Total Anaerobic Count (TAC)	Total Psychrotrophic Count
0	<1.0 x 10	<1.0 x 10	<1.0 x 10	<1.0 x 10	<1.0 x 10	<1.0 x 10
1	<1.0 x 10	<1.0 x 10	<1.0 x 10	<1.0 x 10	<1.0 x 10	<1.0 x 10
2	<1.0 x 10	<1.0 x 10	<1.0 x 10	<1.0 x 10	<1.0 x 10	<1.0 x 10

Table 4: Results for microbiological analyses during storage.

Conclusion

In conclusion, PBMA VitAto presents a promising alternative to plant-based milk beverages. Its balanced macronutrient profile, notably higher protein content, moderate fat content, and significant dietary fiber and low sugar and salt (sodium) content compared to some plant-based milk substitutes, and also well accepted for its sensory attributes as well as its shelf life could position it as an attractive option for consumers seeking diverse and nutritionally rich milk alternatives. PBMA VitAto also contains high beta carotene and no allergen source, which is good for improving health. However, further research on the bioavailability of the nutrients must be conducted to confirm.

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