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Effect of combined cassava and young Thai jasmine rice flours on the nutritional, textural, physicochemical properties, and consumer acceptability of gluten-free cookies

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Abstract

Driven by the rising demand for gluten-free, health-focused bakery products, this study evaluated cassava (CF) and young Thai jasmine rice flours (YTJRF) as primary ingredients. A total of five CF:YTJRF ratios (100:0, 75:25, 50:50, 25:75, and 0:100) were compared with wheat flour-based control. Increasing YTJRF levels led to significant reductions in lightness (L*), redness (a*), and yellowness (b*), as well as in texture (hardness and fracturability). This study clearly showed that the appropriate ratio was 75:25, which resulted in color, spread ratio, and texture being similar to those of the highest control sample. The sensory evaluation showed that the liking scores ranged from 6.68 to 7.72. Additionally, producing gluten-free cookies using CF and YTJRF provides an effective strategy to reduce energy content by 5.70% while enhancing essential nutrients such as protein, dietary fiber, and vitamins A, B1, and B2. The added health benefits of CF-YTJRF derived cookies are likely due to the inherently higher levels of bioactive compounds, such as total phenolic and antioxidant activity derived from 2,2-diphenyl-1-picrylhydrazyl (DPPH). This formulation supports the development of nutritionally improved and sustainable gluten-free bakery products, with promising potential for future food innovation and health-oriented product development.

1. Introduction

Cookies are a type of baked product made from soft wheat flour with a low final water content. They are typically consumed as treats (Delcour and Hoseney, 2010) and are widely popular across the globe. Consumers range from children to the elderly, with the popularity of cookies largely attributed to their sweet taste, crisp texture, convenience, and relatively long shelf life (Grand View Research, 2025). According to the report by Verified Market Research (2024), the global cookies market was valued at USD 37.12 billion in 2023 and is expected to reach USD 56.75 billion by 2030, growing at a compound annual growth rate (CAGR) of 7.10% during the forecast period 2024–2030. However, cookies are typically made from wheat flour, sugar, and fat as the main ingredients, resulting in a high energy content. Additionally, most cookies are made with refined wheat flour, which has low nutritional value (Sozer et al., 2014). As concerns about gluten have increased, many consumers are reducing their wheat flour intake. Gluten is known to trigger the characteristic symptoms of celiac disease (CD) and non-celiac gluten sensitivity (NCGS) (Fernandes *et al*., 2025). Celiac disease is a well-known autoimmune disorder and inflammatory condition caused by the consumption of gluten, which damages the small intestine. A strict gluten-free diet is the only effective treatment for the disease (Grizzi and Hegazi, 2024). The demand for gluten-free bakery products is increasing, driven by individuals with celiac disease, gluten sensitivity, and health-conscious consumers. In addition to bread products, chemically leavened gluten-free baked goods—such as cookies, biscuits, cakes, muffins, and crackers—are gaining popularity due to their convenience, distinctive taste, and unique texture (Bolarinwa *et al*., 2019; Xu *et al*., 2020). Previous studies on gluten-free cookies have utilized flour derived from cereals (rice, maize, sorghum, and millet) and their blends. Among these, rice flour is one of the most commonly used gluten-free alternatives. It is frequently combined with other ingredients (Dierings de Souza *et al*., 2020), such as sweet potato (Baek *et al*., 2024) and potato starch/flour (Šarić *et al*., 2019), to enhance their nutritional quality (Xu *et al.,* 2020). Additionally, gluten-free cookies have also been developed using cassava flour (Jisha *et al*., 2010), as well as amaranth, quinoa, sorghum, and banana flour

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(Almeida *et al*., 2025). Thus, innovations in low-energy gluten-free cookie formulations have been achieved by replacing wheat flour and sucrose with alternative ingredients to develop healthier products.

Cassava flour (CF) is derived from Manihot esculenta and is a dry, fibrous, and free-flowing particulate product obtained from cassava roots, a vital crop for food security. It is produced either from milled dried chips or wet mash. CF is widely used in the food industry due to its high availability and physicochemical properties, making it an attractive ingredient (Sangroula *et al*., 2024). According to Gonçalves *et al*. (2024), flour is the most widely consumed cassava by-product, followed by starch. CF has gained significant attention in the scientific community for its excellent stability, remarkable thickening capacity, low retrogradation and gelatinization indices, strong adhesive properties, and gluten-free characteristics (Najjingo *et al*., 2024). Additionally, Bayata (2019) reported that cassava is a rich source of nutrients, including carbohydrates, proteins, and vitamins. As a result, CF is widely used in baking and serves as the base for various recipes worldwide. In the food industry, CF is processed into value-added products such as pre-gelatinized instant and convenience foods, including cookies, cakes, crackers (Xu *et al*., 2020), brownies (Marta *et al*., 2024), and breakfast cereals (Najjingo et al., 2024). To evaluate the potential of CF in cookies, it is essential to study its compatibility with other ingredients. One promising alternative is rice flour, a grain with significant ancestral importance in human nutrition.

Thai Jasmine rice (Hom Mali 105) variety (*Oryza sativa* L.) is highly valued for its aroma and strong export demand. Developing rice-based products offers an opportunity to boost Thai farmers' income, but effective marketing and further research are essential (Piyarach *et al*., 2021). Immature rice kernels are traditionally consumed in many Asian countries. In Thailand and Vietnam, they are used in a special snack made from flattened milky rice, sugar, and grated coconut. The milky stage of young rice has been reported to have higher nutritional value than its mature stage. However, as rice develops, increasing starch content leads to the degradation of bioactive compounds (Ngamsuk *et al*., 2020). Rice grains progress from flowering to full ripeness, with the milky stage being particularly suitable for healthy food applications (Ngammuangtueng *et al*., 2019). Piyarach *et al*. (2021) reported that immature rice kernels contain 1.43±0.12% ash, 6.98±0.57% protein, 0.107±0.002% fat, and 81.53% carbohydrates. Additionally, they exhibit strong antioxidant activity, with DPPH scavenging activity measured at 254.158 mg TE/g. While there is growing commercial interest in gluten-free bakery products, limited research has been conducted on rice as a potential source of these compounds.

Therefore, this study aimed to determine the optimal ratio of cassava flour to young Thai jasmine rice flour for the development of gluten-free cookies. Despite the growing interest in gluten-free products, limited research has explored the combined use of cassava flour and young Thai jasmine rice flour as a base for cookie formulations. The resulting product is intended to support the dietary needs of individuals with celiac disease, non-celiac gluten sensitivity, and health-conscious consumers. Utilizing these flours as alternative gluten-free ingredients offers a cost-effective and sustainable approach for producing bakery products, contributing to the advancement of future food innovations.

2. Materials and methods

2.1 Materials

Cassava flour (CF) was purchased from Tasuko (Bangkok, Thailand). It had a moisture content of 4.51% (wet basis, wb), a protein content of 0% and a fat content of 0% (dry basis, db).

Young Thai jasmine rice (*Oryza sativa* L. cv. KDML) was purchased from Malinin, Bangkok, Thailand. The young grains were harvested 8–14 days after flowering. The brown young rice grains were separated from the hull using a dehulling machine and stored in polyethylene vacuum bags covered with aluminum foil at room temperature until further use (Piyarach *et al*., 2021). The grains were then milled to a 100-mesh particle size using a Fitz Mill machine (Model M5, The Fitzpatrick Co., Ltd., USA). The resulting YTJRF had a moisture content of 9.02% (wb), along with 8.00% protein and 3.00% fat (db).

2.2 Formulation and preparation of gluten-free cookies

The method reported by Wilasinee (2020) and Susanto *et al.* (2025) was used to prepare the control cookies with some modifications. The changes mainly focus on recipes, cookie size, and baking times. The basic dough recipe (based on 100 g of soft wheat flour) for making cookies was unsalted butter (100 g), sucrose (50 g), fresh chicken eggs (25 g), instant full cream milk powder (25 g), corn flour (5 g), and baking powder (1.25 g). Dry ingredients, including soft wheat flour, baking powder, corn flour, and instant full-cream milk powder, were sifted. Unsalted butter was creamed in a food mixer (KitchenAid, 5KPM50, USA) at speed 5 for 2 min until light and soft. Sucrose was gradually added while mixing at speed 3, followed by eggs, and mixed until well

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combined. The sifted dry ingredients were then incorporated and mixed at speed 3 for 2 min until a uniform dough formed. The cookie dough was placed between two rectangular bars (4 mm thickness), rolled out with a rolling pin, and then molded with a circular cutter (38 mm diameter), followed by baking in a combination oven (Electrolux, Air-O-Steam combination oven Gas, USA) at 140°C for 20 min. After cooling at room temperature (27±2°C) for 1 h, the cookies were stored in aluminum foil pouches before further measurement. The procedure mentioned above was also used for making gluten-free cookies made from CF and YTJRF. CF and YTJRF were blended in five different ratios: 100:0, 75:25, 50:50, 25:75, and 0:100 (w/w). Levels of substitution were defined by preliminary studies. A minimum of three replicates was carried out for each sample.

2.2.1 Moisture content and water activity (aw)

The moisture content (MC) of cookie samples (2 g) was determined using a hot air oven at 105°C for 24 hours or until a constant weight was reached (AOAC Official Method 925.10, 2019). The samples were measured using a water activity analyzer (AquaLab 4TE, Meter Group Inc., Pullman, USA) at 25±1°C. The experiments were conducted in triplicate.

2.2.2 Color

A Hunter Lab apparatus (Hunter Lab, UltraScan PRO, USA) was used to assess the color of the cookies. The measuring head was placed in the center of each sample after the instrument's calibration was completed using a white reference standard. Color values using the CIE L* a* b* scales were recorded using five samples for each cookie formulation. Following that, the mean values were documented as L* = lightness (100 = white, 0 = black), a* (-a* = greenness, +a* = redness), and b* (-b* = blueness, +b* = yellowness).

2.2.3 Spread ratio

The cookie diameter was measured by aligning six cookies edge-to-edge and recording their total length using a scale. The measurement was repeated after rotating each cookie by 90°, and the average diameter was calculated. To determine thickness, six cookies were stacked, and their total height was measured. The cookies were then restacked in a random order, and the measurement was repeated. The average thickness was then calculated. The spread ratio was determined by dividing the average diameter by the average thickness of the cookies (Mudgil *et al*., 2017).

2.2.4 Texture

A texture analyzer (TA.XT PlusC, Stable Micro Systems, UK) was used to measure the hardness and fracturability of cookies using a blade set (HDP/BS), trigger force of 25 g, and load cell of 50 kg. The textural studies were conducted at a pre-test speed of 1.0 mm/s, a test speed of 3.0 mm/s, and a post-test speed of 10 mm/s, and the distance between the two bottom supports was adjusted to 3.0 mm. The peak value of fracture force (maximum) was recorded as hardness at a point when the cookies were broken into two major pieces. This peak force (g) at the breaking point represented the breaking strength of the cookie, while fracturability (mm) was indicated by a sharp, narrow curve, typically resembling a thin triangular shape (Mudgil *et al*., 2017). Mean values in ten were reported.

2.2.5 Sensory acceptability

Sensory properties of cookies were evaluated by panels of 50 untrained panelists using a nine-point hedonic scale. The selection criteria included individuals aged 18–60 y who were regular cookie consumers with no history of food allergies. Panelists with asthma or allergies were excluded. Panelists were asked to evaluate the appearance and color of the cookies first and then to evaluate the odor, taste, and texture of the cookies. Freshly baked cookies were used for the evaluation of sensory attributes. Cookies were served on white plates with randomly coded three-digit codes to prevent any bias. During the sensory evaluation, the cookies were presented in randomized order. Water was provided to rinse the mouth between evaluations, and covered expectoration cups were also provided if the panelist did not want to eat the sample. Overall acceptability of cookies was calculated from the average of all the above sensory parameters (Gajera et al., 2010). A nine-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely) was used by the panelists to evaluate sensory attributes of experimental cookies (Meilgaard *et al*., 1999). The ethical approval for the sensory tests was obtained from the Research Ethics Committee of Suan Sunandha Rajabhat University (Approval no. COE. 1-041/2023), and all participants signed an informed consent form prior to participation.

2.3 Nutritional values and bioactive potential of the final products developed

2.3.1 Nutritional values

2.3.1.1 Lipid

Lipid content was determined according to the

AOAC Official Method 920.39.

2.3.1.2 Protein

The micro-Kjeldahl technique was used to calculate the total nitrogen according to the AOAC Official Method 979.09 (AOAC INTERNATIONAL, 2019).

2.3.1.3 Ash

Ash content was determined according to the AOAC Official Method 923.03.

2.3.1.4 Dietary fiber

Dietary fiber was determined according to the AOAC Official Method 991.43.

2.3.1.5 Carbohydrate

Carbohydrate content was calculated by difference based on proximate composition, as: Carbohydrate = 100 - (lipid + protein + dietary fiber + ash).

2.3.1.6 Total energy

Total energy content was determined using the Atwater general factor system, where energy = 4 kcal/g (protein) + 9 kcal/g (fat) + 4 kcal/g (carbohydrates) (Najjingo *et al*., 2024).

2.3.1.7 Vitamin A

Vitamin A was analyzed according to the method of Rashid *et al*. (2024). A 10.0 g portion of the sample was transferred into a 50 mL volumetric flask, and 50 mL of extraction solution was added. The extraction solution consisted of 1 g of pyrogallol, 70 mL of ethanol (C_2H_5OH), and 30 mL of 50% potassium hydroxide (KOH). The mixture was vortexed for 15 min and incubated in a water bath at 50±2°C for saponification. The resulting extract was subjected to three successive extractions with ethyl ether ($C_2H_5OC_2H_5$) using volumes of 20 mL, 30 mL, and 50 mL, respectively. Deionized (DI) water was used to neutralize the solution, and anhydrous sodium sulfate (Na_2SO_4) was added to remove residual moisture. The extract was then concentrated to approximately 5–7 mL and adjusted to a final volume of 10 mL with methanol (CH_3OH). A 10 µL aliquot was injected into the HPLC system (Agilent HPLC 1260 Infinity II, Agilent Technologies, Inc., USA). For β-carotene determination, a C8 column was employed, with a mobile phase consisting of acetonitrile:methanol:ethyl acetate ($CH_3CN:CH_3OH:C_2H_5OOC_2H_5$) in a ratio of 88:10:2. Detection was carried out at a wavelength of 453 nm.

2.3.1.8 Vitamin B

Vitamin B1 (Thiamin) and B2 (Riboflavin) were analyzed according to the method of Rashid *et al.* (2024), with minor modifications. A 2.0 g portion of the homogenized sample was soaked in 25 mL of 0.1 N sulfuric acid (H_2SO_4) and heated at 120°C for 30 min. The pH of the solution was then adjusted to 4.5 using 2.5 M sodium acetate (CH_3COONa) solution, followed by the addition of 0.05 g of diastase enzyme. The mixture was incubated overnight at 37°C. After incubation, the solution was diluted to a final volume of 50.0 mL with deionized (DI) water, then filtered through a 0.45 µm syringe filter. A 10 µL aliquot of the filtrate was injected into an HPLC system. Chromatographic separation was performed using a reversed-phase high-performance liquid chromatography (RP-HPLC) column. The mobile phase consisted of phosphate buffer (mobile phase A) and acetonitrile (mobile phase B), delivered in gradient mode. The gradient elution program for mobile phase B was as follows: 0.0–3.0 min, 1%; 3.1–10.0 min, 50%; 10.1–16.0 min, 50%. The flow rate was maintained at 0.8 mL/min, and detection was carried out at a wavelength of 210 nm. This chromatographic condition was used for the quantification of vitamins B1 and B2.

2.3.2 Total phenolic content and antioxidant potential

Extraction of phenolic content. A 1 g sample was extracted using petroleum ether. After centrifugation (5 min at 2520×*g*), the supernatant was decanted and collected. Polyphenols were then extracted from the defatted sample following the method described by Itagi et al. (2023). Total phenolic content (TPC) was determined by mixing 200 µL of the extract with 800 µL of Folin–Ciocalteu reagent and 2 mL of sodium carbonate solution (7.5 g/100 mL). The volume was adjusted to 7 mL with deionized water and incubated in the dark for 30 min. Absorbance was measured at 725 nm. The antioxidant activity was assessed using the DPPH (1,1-diphenyl-2-picrylhydrazyl) assay, performed on 500 µL of the extract following the protocol of Itagi et al. (2023). Results were expressed as the percentage of DPPH radical scavenging activity.

2.4 Statistical analysis

Three batches of samples were prepared, and their values were expressed as mean±standard deviation (SD). Data for physicochemical properties and sensory evaluation of samples were analyzed by analysis of variance (ANOVA) using the IBM SPSS® version 26 software (IBM SPSS Inc., USA). The Duncan's Multiple Range Test was used to determine multiple comparisons of mean values with a statistically significant difference established at $p<0.05$.

3. Results and discussion

3.1 Effect of cassava flour-to- young Thai jasmine rice flours ratios and selection of an optimal formula for gluten-free cookies

3.1.1 Moisture content and water activity (aw)

Moisture is an important factor to take into consideration while evaluating the quality and the acceptability of the products (Devi *et al.,* 2024). The results of moisture content for gluten-free cookies formulated with varying ratios of CF and YTJRF at 100:0, 75:25, 50:50, 25:75, and 0:100, compared to the control sample (wheat flour cookies), are presented in Table 1. It was found that altering the ratio of CF to YTJRF significantly affected the moisture content ($p<0.05$). Specifically, CF–YTJRF formulations exhibited a lower average moisture content than the control, with values ranging from 1.03% to 1.56% on a wet basis (wb). This reduction is attributed to the low initial moisture content of CF (10.29%) and YTJRF (8.69%), combined with the baking process that effectively decreases moisture levels. The moisture content of all samples met the guideline of quality control in the Thai Community Product Standard. The guideline of quality control reported that moisture should be below 4.00% wb of cookies (TCPS, 2012). This contributes to the cookie's crisp texture and enhances shelf-life stability. Additionally, the observed moisture contents were closely correlated with water activity (aw), a critical factor influencing shelf-life, spoilage, and food safety (Beuchat and Mann, 2015). The results indicated that the ratio of CF to YTJRF had a statistically significant effect on aw ($p<0.05$). The observed increase in aw, as shown in Table 1, may be attributed to the higher proportion of YTJRF, potentially due to the greater water retention capacity of dietary fibers present in rice flour (Gularte *et al*., 2012). Nevertheless, all samples exhibited aw values below 0.30, within the acceptable range for cookies (0.30–0.40) and well below the spoilage threshold (aw<0.70). This indicates strong microbial stability and ensures product safety for consumption (Carter, 2022).

3.1.2 Color, spread ratio and texture

Table 1 also presents the physical characteristics of the gluten-free cookies, which showed significant differences among the various CF–YTJRF ratios ($p<0.05$). Varying the ratio of CF to YTJRF at 100:0, 75:25, 50:50, 25:75, and 0:100 significantly influenced the color attributes of the gluten-free cookies compared with the control (wheat flour cookies). Specifically, the lightness (L*) values tended to decrease, while the redness (a*) and yellowness (b*) values significantly increased ($p<0.05$). An increase in the proportion of YTJRF resulted in a noticeable decrease in lightness, producing cookies with a darker brown color than those made entirely from wheat flour or CF, as shown in Figure 1. This phenomenon can be attributed to the presence of natural pigments, such as polyphenols and carotenoids, in YTJRF, which is derived from brown rice and imparts a pale-yellow coloration to the final products (Sumargo *et al*., 2016). Moreover, the overall cookie color development predominantly occurred during baking via the Maillard reaction between reducing sugars and proteins present in the rice flour and other cookie ingredients, accelerated by thermal processes. This reaction generates brown-colored compounds, thereby contributing to the final appearance of the cookies

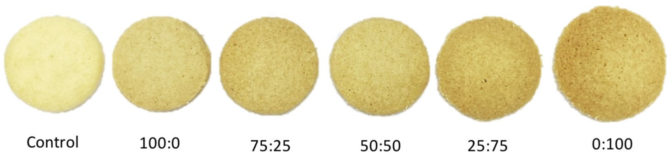

Figure 1. The color appearance of cookies prepared from wheat flour (control) and gluten-free cookies formulated with varying ratios of CF to YTJRF (100:0, 75:25, 50:50, 25:75, and 0:100).

Table 1. Moisture, water activity, and physical characteristics of gluten-free cookies formulated with varying ratios of CF to YTJRF.

Parameter	Control	Ratio of CF to YTJRF (%)				
		100:0	75:25	50:50	25:75	0:100
Moisture (% wb)	2.32±0.30^{a}	1.56±0.25^{b}	1.03±0.15^{c}	1.40±0.00^{bc}	1.43±0.12^{bc}	1.13±0.12^{c}
Water activity (a_w)	0.15±0.00^{c}	0.13±0.00^{c}	0.16±0.00^{c}	0.25±0.00^{b}	0.31±0.10^{ab}	0.35±0.00^{a}
L*	69.20±0.02^{a}	65.91±0.10^{b}	65.79±0.10^{b}	65.19±0.04^{c}	63.69±0.09^{d}	61.27±0.01^{e}
a*	6.06±0.05^{e}	6.55±0.10^{d}	7.10±0.04^{c}	7.17±0.04^{c}	7.96±0.00^{b}	8.33±0.06^{a}
b*	31.26±0.01^{d}	32.68±0.17^{cd}	32.35±0.09^{c}	32.77±0.11^{c}	33.15±0.14^{b}	34.31±1.10^{a}
Spread ratio	5.67±0.25^{c}	5.97±0.15^{c}	6.04±0.18^{c}	7.08±0.0.62^{b}	7.92±0.21^{a}	12.41±1.17^{a}
Hardness (g)	569.84±78.11^{a}	457.21±21.58^{b}	568.61±85.65^{a}	466.19±37.07^{b}	443.89±28.78^{b}	335.22±70.45^{c}
Fracturability (mm)	3.89±0.84^{d}	4.09±0.59^{cd}	4.34±0.62^{bcd}	4.59±0.36^{abc}	4.70±0.60^{ab}	4.98±0.47^{a}

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different ($p<0.05$). CF: cassava flour, YTJRF: young Thai jasmine rice flour, Control: the cookies made from wheat flour, wb: wet basis; L*: lightness; a*: red to green; b*: yellow to blue.

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(Gökmen *et al*., 2022). In contrast, CF, characterized by its fine white powder and low protein content, had a minimal impact on product color. These findings align with previous studies by Itagi *et al*. (2023) that observed a decreasing L* value with increasing levels of whole-grain rice flour substitution in gluten-free cookies. The spread ratio of cookies is an important parameter indicating their crumbliness and cohesiveness, with a higher spread ratio corresponding to greater susceptibility to breakage (Yang *et al*., 2022). Cookies developed using CF and YTJRF at ratios of 100:0 and 75:25 showed spread ratios similar to those of the control sample. This may be attributed to the high dietary fiber content in cassava flour, which can effectively bind with other components within the cookie matrix, promoting structural cohesion in a manner similar to the function of glutenin and gliadin proteins in wheat flour during baking (Matz, 1991; Jeddou *et al*., 2017). While YTJRF predominantly consists of carbohydrates, an excessive amount could interfere with the network formation during baking, resulting in higher spread ratios and producing cookies that are more crumbly and fragile (Preecha *et al.,* 2000). These findings are further supported by texture measurements, particularly hardness and fracturability. It was found that combining CF with YTJRF produced cookies with textural properties most closely resembling those of the control sample, especially at ratios of 75:25. Using 100% CF resulted in the lowest hardness values due to the higher dietary fiber content of cassava flour compared to wheat flour. This fiber contributes to a softer and more elastic cookie structure (Mudgil *et al*., 2017). On the other hand, cookies made solely from YTJRF exhibited increased fracturability. The reduction of gluten in cookie dough through substitution with rice flour delayed the formation of gluten matrices, leading to a substantial decrease in hardness. Similar observations were reported by Chung *et al*. (2014), who found that cookies made from whole-grain rice flour had lower hardness compared to those made with wheat flour.

3.1.3 Sensory acceptability

Figure 2 shows the sensory acceptability scores of gluten-free cookies. It was found that the cookies with a CF to YTJRF ratio of 75:25 received appearance, texture, and overall liking scores (7.38–7.72) comparable to those of the control sample (7.66–7.96) and significantly higher than the other formulations (5.76–7.14) ($p<0.05$). However, the substitution ratio did not significantly affect the odor of the cookies ($p>0.05$). Similar findings were reported by Chung *et al*. (2014) on cookies made with whole-grain rice flour. Yildiz and Gocmen (2021) noted that gluten-free bakery products have weaker sensory properties and may not meet consumer expectations due to darker color, unpleasant appearance, and dry-sandy feeling in the mouth compared to conventional gluten-containing products. However, our results suggest that CF and YTJRF cookies could compete with wheat flour-based cookies and thus may be preferred by consumers.

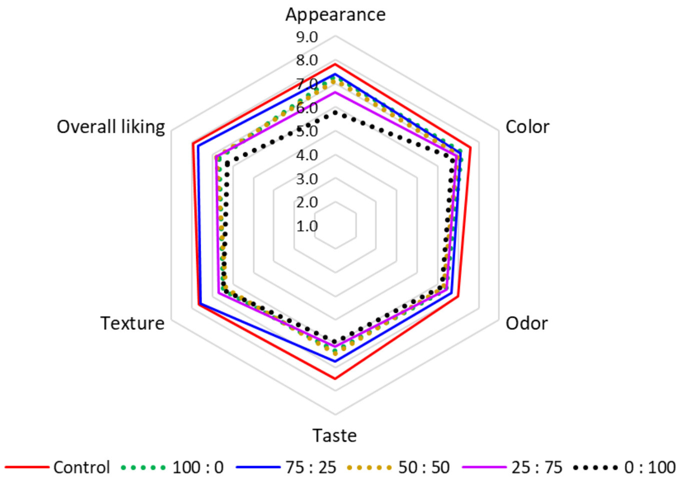

Figure 2. Spider plots of sensory acceptability scores in gluten-free cookies formulated with varying ratios of CF to YTJRF.

3.2 Nutritional values and bioactive potential of the final products developed

The final products were gluten-free cookies formulated with 75% cassava flour (CF) and 25% young Thai jasmine rice flour (YTJRF), as shown in Table 2. The nutritional values contained 543.06 kcal of energy, 4.02 g of protein, 30.02 g of total fat, 64.20 g of carbohydrate, and 1.05 g of dietary fiber per 100 g of sample. Compared to the control (575.75 kcal), the gluten-free cookies exhibited a 5.70% reduction in energy content ($p<0.05$). This decrease is primarily due to the lower lipid and protein contributions and the incorporation of cassava and jasmine rice flours (Das and Chakraborty, 2016; Piyarach *et al*., 2021). This reduction aligns with objectives for low-energy bakery products aimed at health-conscious consumers. Moreover, it was observed that the developed gluten-free cookies had more ash content (0.71 g/100 g) than the control (0.53 g/100 g). The ash content reflects the minerals, fiber, and inorganics remaining in the sample after it has been heated to a very high temperature, eradicating moisture, volatiles, and organic compounds (Itagi *et al*., 2023). Micronutrient analysis demonstrated that the reformulated gluten-free cookies contained 52.41 µg vitamin A, 0.06 mg thiamine (vitamin B1), and 0.04 mg riboflavin (vitamin B2) /100 g. These enhancements are attributable to the incorporation of young Thai jasmine rice flour—a brown rice derivative with high levels of provitamin A (carotenoids) and B vitamins (Piyarach *et al*., 2021). In addition, Table 2 presents the levels of phenolics and total antioxidant capacities in the gluten-

Table 2. Nutritional values and bioactive potential of the final products developed based on 100 g.

Nutritional values	Control	The final products
Total energy (kcal)	575.75±0.80^{a}	543.06±1.32^{b}
Moisture (g)^{ns}	3.13±0.16	2.75±0.30
Protein (g)^{ns}	5.16±0.10	4.02±0.21
Total fat (g)	36.47±0.07^{a}	30.02±0.10^{b}
Carbohydrate (g)	56.72±0.31^{b}	64.20±0.29^{a}
Ash (g)	0.53±0.04^{b}	0.71±0.02^{a}
Dietary fiber (g)^{ns}	1.12±0.05	1.05±0.08
Vitamin A (µg)	46.45±0.02^{b}	52.41±0.13^{a}
Vitamin B$_1$ (mg)^{ns}	0.02±0.00	0.06±0.00
Vitamin B$_2$ (mg)^{ns}	0.04±0.00	0.04±0.00
Total phenolic (mg GAE)	24.76±1.31^{b}	68.40±.71^{a}
DPPH radical scavenging activity (%)	12.32±1.12^{b}	28.51±1.55^{a}

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different ($p<0.05$). Control: the cookies made from wheat flour.

free cookie samples. In general, our findings concur with previous research indicating that young Thai jasmine rice flour is an abundant source of bioactive compounds. Furthermore, pigmented whole grain rice is far superior to non-pigmented rice with enriched nutraceutical properties (Ngamsuk *et al*., 2020; Itagi *et al*., 2023). The final products exhibited a TPC value of 68.40 mg GAE/100 g and a DPPH radical scavenging activity of 28.51%, which were 2.76 and 2.31 times higher, respectively, than the control. Phenolic and bioactive compounds in the flour matrix may interact with starch molecules through inclusion (within starch helices) or non-inclusion (between helices) complexation. These interactions likely occurred during baking (Sudlapa and Suwannaporn, 2023). These findings highlight the potential of low-energy, gluten-free cookies formulated with cassava and young Thai jasmine rice flours and nutrient-dense sweeteners as nutritious alternatives to traditional wheat-based products. Their enhanced nutraceutical benefits make them particularly suitable for health-conscious consumers and those with gluten intolerance.

4. Conclusion

Cookies are a globally popular snack, but their reliance on wheat flour and sucrose excludes individuals with gluten intolerance and contributes to high caloric content. This study investigated the effects of varying the ratios of cassava flour (CF) to young Thai jasmine rice flour (YTJRF) on the physicochemical and sensory properties of gluten-free cookies. The formulation with a 75:25 CF to YTJRF ratio yielded cookies with favorable moisture content, color, texture, and sensory acceptability. Additionally, the cookies demonstrated good shelf-life stability, with water activity (aw) levels below 0.70. The final product provided reduced energy content and enhanced nutritional value, including higher levels of protein, dietary fiber, vitamins A, B1, and B2, as well as bioactive compounds. This study illustrates that cassava flour and young Thai jasmine rice flour can be utilized as cost-effective, gluten-free flour sources for producing acceptable cookies, offering sustainable and economically valuable solutions for the future food industry. Future studies should focus on optimizing the nutritional quality of gluten-free cookies through ingredient fortification, as the inclusion of micronutrients may further improve their health benefits and consumer acceptance.

Conflict of interest

The authors declare no conflict of interest.

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