Research Article

Physicochemical and Pasting Properties of Rice Flour, Banana Flour, and Job's Tears Flour: Flour Blends and Application in Gluten-free Cookies

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Abstract
This research aimed to study some properties of three flour alternative sources from rice flour (RF), banana flour (BF), and job's tears flour (JTF) when applied for cookies preparation. Physicochemical properties including water absorption index (WAI), water solubility index (WSI), oil absorption capacity (OAC), and pasting profiles of the flours, as well as of flour blends were determined. JTF presented the highest WAI (5.51 g/g) whereas RF indicated the highest WSI (2.73 g/g), and WF and RF exhibited the highest OAC (1.01, and 0.96 g/g, respectively). The flour blends from various ratios of RF, BF, and JTF as RF60 (60:30:10), RF50 (50:35:15), RF40 (40:40:20) were prepared and used to substitute wheat flour in cookies products. Appearance, spread ratio, color, hardness and sensory evaluation (9 points-hedonic test) of the produced cookies were evaluated and compared with the products using wheat flour (control). The products from RF60 exhibited comparable appearance and crispiness to control while their overall acceptability scores were a bit lower (5.79) than that of the control (7.20). However, considering gluten-free as a health concern, 80% of the panelists were willing to buy the cookies product from RF60 while only 36.67% had chosen the product from wheat flour. The results demonstrated the flour blend produced from rice, banana, and job's tears has a high potential for application in gluten-free cookies products.

Keywords: Pasting properties, Flour blend, Physicochemical properties, Rice flour, Banana flour, Job's tears flour, Cookies

1 Introduction

Gluten, a protein found in many types of cereals such as wheat, rye, and barley, is considered as a trigger substance for celiac disease. Wheat allergy and its ingestion leads to system immune-mediated disease or celiac disease. Gliadin, the major component of wheat gluten, has been identified as a significant allergen for fatal anaphylaxis through the immunoglobulin E (IgE) response [1]. Around 1% of Europeans suffer from celiac disease due to the consumption of gluten from foods included in their daily diet [1]. Using flour from alternative sources requires extensive scientific studies to expand its use for gluten-free products, which would improve the life quality of people with celiac disease. In this sense, many attempts have been made for food product development with the substitution of wheat flour with gluten-free sources. Chokchaithanawiwat *et al.*, [2] studied the development of dried noodles from wheat flour substituted with riceberry rice flour by extrusion. They found that the substitution with riceberry flour up to 15% yielded a product comparable to wheat noodles made by a conventional method. Extrusion of gluten-free spaghetti from rice flour with defatted soy flour was also reported [3]–[7]. Substitution of wheat flour by job's tear flour (at 20%) for butter cake production resulted in the highest score for just - about right test [8]. Seguchi *et al.*, [9] reported the use of banana flour for the preparation of gluten-free baked bread. They also found using black banana flour resulted in a good texture of the bread.

Presently, bakery products such as cake, cookies, muffins, cupcakes, and crackers, are widely consumed in many countries in the world. Cookies are one of the most popular confectionery products, and their market size had raised to US$ 34.08 billion in 2020, having grown about 5.5% in North America, Europe and Asia Pacific [10]. Cookies are baked products that are typically made from three major ingredients; flour, sugar, and fat. Many sources of flour or food ingredients have been studied for wheat flour substitution for cookies products. Olawoye *et al.*, [11] used a low glycemic index and high resistant starch from banana starch to produce gluten-free cookies. da Silva and Conti-Silva [12] reported that the addition of inulin/oligofructose led to the high potentiality of gluten-free chocolate cookies. Mancebo *et al.*, [13] found that using rice flour-starch-protein in gluten-free sugar-snap cookies increased the hydration properties of the mixture and dough consistency of the products obtained.

Thailand is an agricultural-based country. The country is well known for the production and exportation of high-quality food products, and serves as the "Kitchen of the World". The country is also one of the top world exporters of rice (*Oryza sativa* L.). Rice flour is a candidate ingredient to be used in the production of gluten-free bread since it does not contain gliadin. However, rice bread without a gluten network is significantly inferior in quality compared to wheat bread because of its low viscoelasticity [1]. Thus, to produce gluten-free rice bread, various additives such as emulsifiers, enzymes, glutathione, hydrocolloids, protein, and thickeners have been utilized [14]. Banana (*Musa* L.) is a good source of carbohydrates, dietary fiber, vitamin B, vitamin C, resistant starch and other bioactive compounds such as total phenolic and antioxidant compounds, and other mineral elements [15]. Agama - Acevedo *et al.*, [16] reported that the resistant starch content in cookie products increased from 2.3% to 8.4%, with 50% substitution of wheat flour by banana flour.

Job's tear *Coix lacryma-jobi* L.)has high protein and calcium content, which is beneficial to human health. It also exhibits nutritional and medicinal properties such as prevention and inhibition of the lung and liver-cancer cell growth and prevention of coronary heart disease. Job's tear predominantly contains carbohydrate (81.71%), protein (13.28%), lipid (3.21%), ash (1.12%), fiber (0.67%), and trace minerals and vitamins such as calcium, phosphorus, niacin, thiamine, and riboflavin. Ferulic acid found in Job's tear can inhibit carcinogenic and cancer growth, and also avoids virus spread in the human body [17].

Based on the above mentioned, it would be interesting to study the use of gluten-free flour blend to substitute wheat flour in cookies products. So, the objectives of this study were to study the physicochemical and pasting properties of rice flour, banana flour, and job's tears flour, as well as their flour blends and application in cookies preparation. The properties of the cookies from each flour blend and sensory evaluation were determined and compared to the products produced with wheat flour.

2 Materials and Methods

2.1 *Raw materials*

Rice (*Oryza sativa* L.) flour (RF), green banana (*Musa* L.) flour (BF), job's tears (*Coix lacryma-jobi* L.) flour (JTF), sugar, sodium bicarbonate (baking soda), salt, rice bran oil shortening, and anhydrous dextrose were supplied from Abbra Corporation Limited Co., Ltd. (Thailand). Wheat flour was purchased from United Flour Mill Public Corporation Limited Co., Ltd. (Thailand). The moisture content of all flours and flour blends was determined following [18]. The moisture content of all flours ranged between 6.07–10.67% (wet weight basis). Eggs, milk, butter and refined palm olein cooking oil were purchased from a supermarket in Bangkok (Thailand). Potassium iodide was purchased from Ajax Finechem, (New Zealand) and iodine monochloride 98% was supplied from Loba Chemie Private Limited Co., Ltd. (India). All other chemicals used were analytical grade.

2.2 *Methods*

An overview of the experiments carried out in this study is shown in Figure 1 and the used methodologies are described as follows.

2.2.1 Granule size and morphology

The morphology of each flour was observed using a Nikon ECLIPSE EI light microscope (Tokyo, Japan). Flour suspensions were stained with 0.2% I_2/KI by suspending 0.05 mg of sample in 5 mL of iodine solutions and dropped on a microscope slide, spread uniformly for 30 s. A cover glass was placed on top, and the starch granules were observed under a light microscope at 40X. The images of starch granules were captured using a LANOPTIK MC500W-G1 (Guangzhou, China) microscope camera. Forty starch granules of each flour from three field replications were randomly recorded using a Nikon ECLIPSE EI light microscope (Tokyo, Japan) at 40X magnification, and the data were averaged.

2.2.2 Flour and flour blends preparation

Four different flour blends were prepared using the following RF:BF:JTF ratios (by weight): RF60 (60:30:10), RF50 (50:35:15), RF40 (40:40:20) and RF30 (30:45:25). All blends were mixed using a blender (Kenwood KM230, England) at a low speed for 20 min, and passed through a sieve (80 mm mesh size). The flour blends were packed in an aluminum sealed bag and kept at –5 °C until analysis.

2.2.3 Physical properties

A colorimeter (Color Quest XE, USA) was used to evaluate the color of each flour and flour blend. The

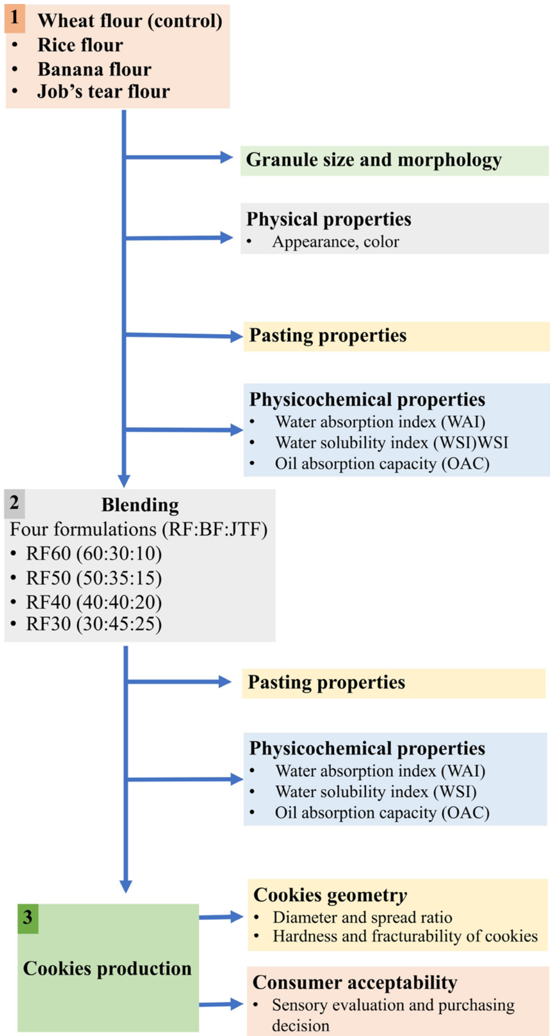

Figure 1: Overview of the experiments and analyses carried out in this study for the production of gluten-free cookies.

value $L*$ indicates blackness to whiteness on a 0 to 100 scale, while $a*$ and $b*$ are redness (+redness/ -greenness) and yellowness (+yellowness and -blueness), respectively. Five measurements were performed for each sample.

2.2.4 Pasting properties

Pasting properties of each flour and flour blend were measured using a Rapid Visco Analyzer (RVA-4, Perten Scientific, Springfield, IL, USA) based on the method of [19] with some modifications. Three grams of sample were placed into the RVA canister, followed by the addition of 25 mL of distilled water. The pasting profile of the sample was monitored during the heating and cooling stages. Suspensions were equilibrated at 50 ºC for 1 min, then heated to 95 ºC for 7.30 min, and maintained at 95 ºC for 5 min. Finally, the paste was cooled to 50 ºC within 7.30 min and held at 50 ºC for 2 min.

2.2.5 Physico-chemical properties of flour and flour blends

Water absorption index (WAI) and water solubility index (WSI)

Ten milliliters of distilled water were added to 100 mg of the sample at room temperature (25 ºC ± 2). The suspension was stirred using a vortex mixer for 5 min and centrifuged at 3,500 g (4 ºC ± 2) for 15 min. The supernatant was separated and dried at 102 ºC to constant weight. WAI and WSI were calculated according to Equations (1) and (2), respectively [20], where 'W' is the weight of dry solids in the original sample (g), 'W_g' is the weight of sediment (g), and 'W_s' is the weight of dissolved solids in the supernatant (g).

$$\text{Water absorption index (WAI)} = \frac{W_g}{W} \quad (1)$$

$$\text{Water solubility index (WSI)} = \frac{W_s}{W} \quad (2)$$

Oil absorption capacity (OAC)

One milliliter of refined cooking palm oil was added to 100 mg of the sample and mixed for 30 min. The suspension was separated using a centrifuge at 3,000 g at 4 ºC for 10 min. The supernatant was carefully removed with a pipette, and OAC was calculated and expressed as g oil/ g sample according to Equation (3), where Wr is the residue weight and Wi is the sample weight (g oil/g sample).

$$\text{Oil absorption (OAC)} = \frac{W_r}{W_i} \quad (3)$$

2.2.6 Preparation of cookies

Cookies were prepared following the AACC method 10-50D [21] with some modifications. The ingredients used for the preparation of the cookie are listed in Table 1. The ingredients used to prepare cookies products included wheat flour as a control formula (35.50%). For gluten-free cookies, the flour blends RF60, RF50, RF40, and RF30 were used to substitute wheat flour. Shortening, butter, sugar, sodium bicarbonate, salt, water, and dextrose 0.09 g/mL were mixed using an electric mixer (Kenwood KM230, England) at a low speed for 3 min. Egg and flour were added and mixed well for 2 min at the same speed. The cookie dough was baked at 120 ºC for 30 min in an electric oven (Sharp EO70K, Japan). Baked cookies were cooled down to room temperature around 25 ºC ± 2 for 30 min and kept in a glass bottle until further analysis and sensory evaluation.

Table 1: Ingredients used for the preparation of cookies with wheat flour as the main ingredient (control formula)

Ingredients	(wt%)	Ingredients	(wt%)
Wheat flour	35.50	Water	20.50
Sugar	12.62	Milk	3.15
Sodium bicarbonate	0.78	Egg	4.41
Salt	0.33	Dextrose 0.09 g/mL	5.20
Rice bran oil shortening	15.15	Butter	2.36

2.2.7 Quality measurement of the cookies

Diameter and spread ratio

The physical characteristics of cookies, including diameter (width and thickness) and spread ratio, were evaluated according to [22]. Cookies (n = 3) were selected randomly and weighed using a calibrated analytical balance. The heights of the samples were averaged and taken as the final thickness of the cookie. The spread ratio of the cookies was measured according to Equation (4).

$$\text{Spread ratio} = \frac{\text{Diameter (cm)}}{\text{Thickness (cm)}} \quad (4)$$

Hardness and fracturability of cookies

Hardness and fracturability of cookies were determined using a texture analyzer (TA.XT2 plus, Stable Microsystems, Surrey, U.K) in a compression mode with a sharp-blade cutting probe. Pre-test, test, and post-test speeds were 1, 2, and 10.0 mm/s, respectively. The hardness, calculated as the maximum force (N) at the point of break and the fracturability, termed as the displacement at rupture (N), were measured with four samples for each treatment [23].

2.2.8 Sensory evaluation of cookies

Sensory evaluation was performed by thirty untrained panelists (15 females and 15 males, 20–30 years) from the Faculty of Applied Science, King Mongkut's University of Technology North Bangkok. The hedonic 9 points-scale test was used to evaluate consumer acceptability of the cookies in terms of color, aroma, crispness, texture, mouthfeel, taste and overall acceptability, in which 1 = disliked extremely and 9 = liked extremely. The code 3-digit numbers were used for random labeling orders. The samples with random codes were served in a plastic dish covered with aluminum foil at 25 ºC ± 2. During the evaluation, untrained panelists were instructed to drink some water and take a break for a few minutes before the next samples were served. For buying decisions, the panelists have evaluated the purchasing decision "willing to buy" of each cookie when considering it as healthy cookies [11].

2.2.9 Statistical analysis

All experiments were performed in triplicate. Statistical analysis was carried out using the software SPSS 17 for Windows (SPSS Inc., Chicago, III, USA). Results were subjected to one-way ANOVA, and a comparison of means was made by Duncan's multiple range test (DMRT) for a significance level of ($p < 0.05$).

3 Results and Discussion

3.1 *Starch morphology and granule size*

Starch morphology and granule size are presented in Figure 2. Results were different according to the plant source. Starch granules of WF (15.45–56.65 µm) and BF (10.30–66.95 µm) were larger than the starch granules of JTF (10.30–30.90 µm) and RF (5.15–10.30 µm). In terms of morphology, WF starch exhibited oval and spherical shapes while BF starch, for example, showed irregular and elongated oval shapes. Devi *et al.*, [24] found two types of granules in wheat starch, which included A-type starch granules, which had lenticular shape with a larger diameter of 18.80–21.50 µm, and B-type starch granules, which displayed spherical shape with a smaller diameter of 3.93–5.10 µm. Marta *et al.*, [25] reported that banana starch has dense

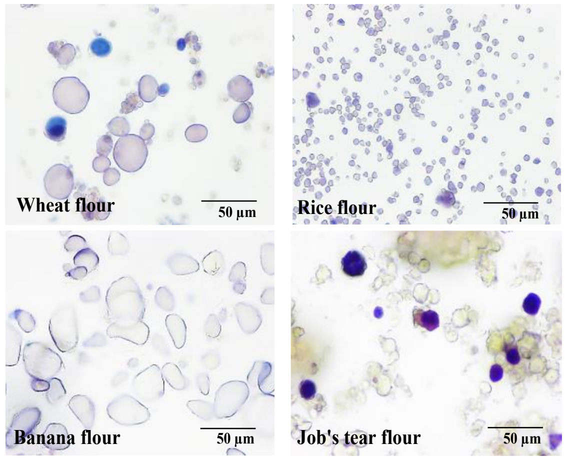

Figure 2: Light micrographs of wheat flour, rice flour, banana flour, and job's tears flour. Magnification: 40-folds.

surfaces with a small thin layer that consisted of non-starch components. The authors also reported that the granule size of banana starch was larger than that of cereal starches such as rice starch and sorghum starch. Dechkunchorn and Thongngam [17] reported that JTF starch granule looked similar to corn and sorghum starch granules. In contrast, rice starch granules were very small, with even size distribution and tended to be polyhedral in shape [26].

3.2 *Physical properties*

The color of each flour presented in Table 2 revealed that $L*$ and $b*$ values of all flours were not statistically different ($p < 0.05$). $L*$ value of all flours ranged between 81.00 and 83.66 (very light) while, $b*$ value was around 7.33 and 11.00. BF exhibited the highest $a*$ value of 3.00, while WF and RF presented lower $a*$ values, equal to 1.00. JTF had the $L*$, $a*$, and $b*$ values of 81.00, 1.66, and 11.00, respectively. Similar results were reported by [17] who observed $L*$, $a*$ and $b*$ values of JTF of 82.52, 0.35, and 7.63, respectively. Pongjanta *et al.* [27] reported $L*$ value of twelve rice flour grown in upper Northern Thailand ranged from 88.92–89.12. In addition, the color of the four flour blends, RF60, RF50, RF40, and RF30 was also very similar for $L*$ value (79.33–80.00) and $b*$ value (10.00–12.33), with a very slight difference in $a*$ value (1.00 to 4.00) only.

Table 2: Starch granule size, color, and moisture content of each flour used in the experiments

Sample	Appearance	Color		
		L^{*ns}	a^{*}	b^{*ns}
Wheat flour		81.66 ± 1.15	1.00 ± 0.00c	7.33 ± 0.57
Rice flour		83.66 ± 2.30	1.00 ± 0.00c	9.66 ± 0.57
Banana flour		83.66 ± 0.57	3.00 ± 1.00a	10.33 ± 0.57
Job's tear flour		81.00 ± 1.00	1.66 ± 1.15b	11.00 ± 3.60

*Means ± SD in the same column followed by the same letter are not significantly different at $p < 0.05$.
^{*ns} : Not significantly different ($p > 0.05$)

3.3 *Pasting properties of flours and flour blends*

Pasting properties of flour or starch play an important role in their industrial application as a thickener, binder or any other use [28]. The pasting properties of each flour and flour blend are presented in Figure 3. The viscosity of each flour paste is dependent on the rigidity of starch granules, which in turn affects the granule swelling and the amount of amylose leaching out in the solution [28]. Peak viscosity is an indicator of the easiness with which the starch granule is disintegrated and is often correlated with final product quality [28]. WF presented the highest peak viscosity of 180.00 RVU, followed by RF (140.15 RVU), JTF (105.50 RVU), and BF (63.50 RVU). The results indicated that WF and RF starch granules had a more rigid structure than the starch from JTF and BF. The gluten protein in wheat flour also affected the peak viscosity. These results were in agreement with Weiser and Kieffer [29] who reported that the resistance of gluten was correlated with the quantity of glutenin present in wheat flour. WF and RF had higher amylose content when compared to BF and JTF [28], which resulted in higher final viscosity (220.00 RVU and 248.50 RVU), holding strength (118 RVU and 100 RVU) and set back to trough (102 RVU and 100 RVU), respectively. Set back to trough resulted from retrogradation of the starch paste, which affects the final texture such as firmness, hardness, and cohesiveness of the products. Both JTF and BF showed very low set back.

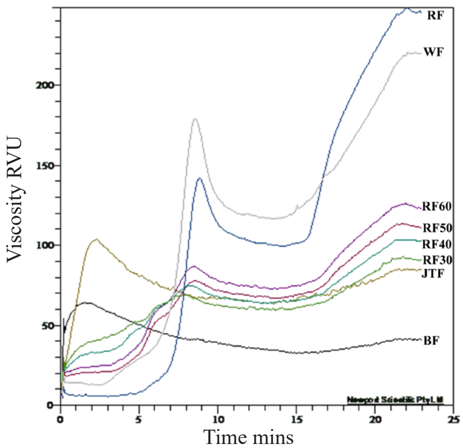

Figure 3: Pasting profile of flours and flour blends: wheat flour (WF), rice flour (RF), banana flour (BF) and job's tears flour (JTF), and flour blends of RF:BF:JTF at 60:30:10 (RF60), 50:35:15 (RF50), 40:40:20 (RF40), and 30:45:25 (RF30).

Pasting temperature is the temperature at the beginning of the heating process when the viscosity starts to increase. The smallest size and rigidity of the rice starch structure led to the highest pasting temperature of rice starch, 65.76 ºC, followed by the starch from WF (62.09 ºC), JTF (50.15 ºC), and BF (50.15 ºC). Other authors reported that RF has higher amylose levels when compared to BF and JTF [28].

The blending of RF with an increased amount of JTF and BF resulted in a decrease in pasting temperature, peak viscosity, final viscosity and set back of the flour blends. Many pasting profiles of flour blends have been reported such as flour blends of taro flour, rice flour and pigeon pea flour [28], flour blend from rice flour and chickpea flour for application in bread products [30]. Kahraman *et al.*, [30] also reported that the incorporation of chickpea flour and rice flour caused an increase in the viscous and elastic moduli of rice-based doughs, resulting in a good quality of the bread dough. To the best of our knowledge, there is no study reporting the pasting profile of blends of RF, BF and JTF.

3.4 *Physicochemical properties of flour and flour blends*

WAI, WSI, OAC of each flour evaluated in the present study are shown in Figure 4. JTF exhibited the highest WAI of 5.51 g/g, followed by BF (3.92), RF (0.62), and WF at 0.26 g/g. The source, structure and size of the starch, as well as the chemical composition of each flour may influence the water absorption into the starch granules [16]. The highest protein content (around 13.28%) in JTF could be another factor that increased the water absorption of JTF [31]. Although WF had high protein (around 11.35%), it showed the lowest WAI [32]. The protein in wheat is classified into four groups based on solubility in different solutions including, albumins in distilled water, globulins in dilute salt solutions, prolamins in 70% aqueous ethanol, and glutelins in dilute acid [33]. WAI was also dependent on specific characteristics such as type and morphology of the starch in each flour. Rice flour presented the highest WSI of 2.73 g/g, followed by WF (2.64 g/g), BF (1.31 g/g), and JTF (0.75 g/g). Water solubility indicates the ability of the solids to dissolve or disperse in an aqueous solution. The solubility is associated

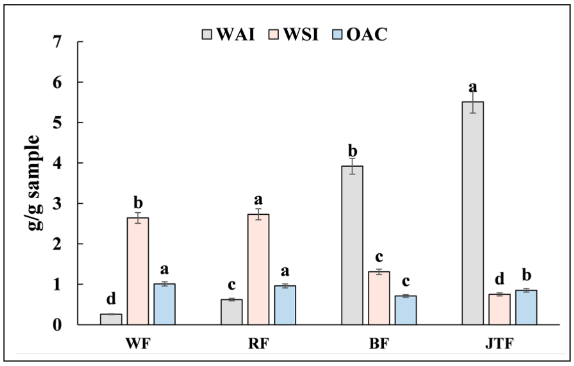

Figure 4: Physicochemical properties of wheat flour (WF), rice flour (RF), banana flour (BF) and job's tears flour (JTF): WAI: water absorption index (g/g), WSI: water solubility index (g/g), OAC: oil absorption capacity (g oil/g). The bars and error bars represent the means and standard deviation. Different letters (a, b, c, d) for the same property mean a statistically significant difference at $p < 0.05$.

with the hydrophilicity and easiness of disruption of the starch granules [34]. Amylose constitutes the larger percentage of the amorphous component of the starch granules where water penetration into the granule is more pronounced. The high solubility of the starches could be attributed to their high amylose content [35]. Bonding forces within granules could also affect their solubility behavior [28].

The OAC of WF and RF was not significantly different (1.01 g/g and 0.96 g/g, respectively), while JTF and BF showed a slightly lower OAC (0.85 g/g and 0.71 g/g, respectively). Similar results on OAC of these four flours were reported by [32]. The mechanism of oil absorption may be explained as a physical entrapment of oil related to the non-polar side chains of proteins. Both protein content and the starch type contribute to the oil-retaining properties of food materials [36].

The blending of RF with an increased ratio of BF and JTF led to mixed properties, with an increase of WAI, a decrease of WSI, and a non-significant difference in OAC as presented in Figure 5. The water and oil absorption into the ingredients, mainly the starch and protein used for cookies, would affect the properties of the baked products, especially their texture.

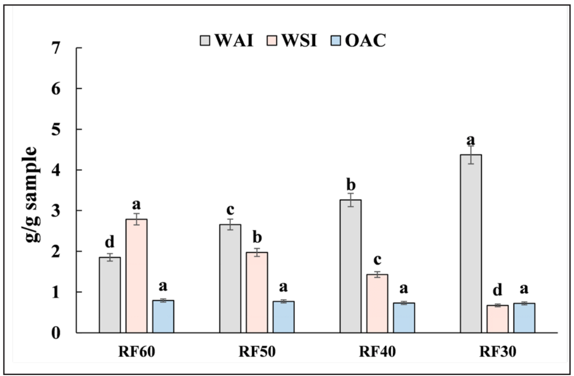

Figure 5: Physicochemical properties of flour blends from different ratios; RF:BF:JTF at 60:30:10 (RF60), 50:35:15 (RF50), 40:40:20 (RF40), and 30:45:25 (RF30). WF: wheat flour, RF: rice flour, BF: banana flour, and JTF: job's tears flour. WAI: water absorption index (g/g), WSI: water solubility index (g/g), OAC: oil absorption capacity (g oil/g). The bars and error bars represent the means and standard deviation. Different letters (a, b, c, d) for the same property mean a statistically significant difference at $p < 0.05$.

3.5 *Quality measurement of the cookies*

3.5.1 Diameter and spread ratio

The dimensions of cookies before and after baking and the spread ratio are shown in Table 3. Spread ratio is a physical attribute of baked cookies which depends upon the composition of the flour used. It is an important characteristic to determine the quality of cookies. Usually, products with a higher spread ratio value are more desirable [37]. Carbon dioxide released from the reaction of sodium bicarbonate caused bubbles in the cookies dough during baking and expanded the volume or width of the baked products. The thickness or high of cookies after baking was related to the viscosity of the cookie dough and the viscosity of each flour. The width of cookies dough made from WF, before baking, was significantly lower than the width of the cookies dough made from all rice flour blends. However, the use of WF (control) could expand the width of cookies around 55% (from 2.68 cm to 4.16 cm), with a spread ratio of 4.85 after baking. In fact, the numbers of disulfide bonds and sulfhydryl groups of the proteins, which are generated from the crosslinks between free SH groups and available SH groups in (gliadin and glutenin chains), could generate the strength of cookies dough. The arrangement of the gluten network is generated and leads to a greater extent of cookies dimension. Wheat gluten formed during the mixing of cookies could entrap the gas bubbles better than the flours without gluten [38].

Consequently, using RF instead of WF resulted in less expanded cookies after baking. However, there was a tendency for the flour blends of RF, BF, and JTF that, increasing the ratio of BF and JTF resulted in more expanded width and thickness of the baked cookies. This might be due to the fact that the highest protein content in JTF could help a better entrapment of the gas bubbles, resulting in more expanded width. The thickness of the cookie dough from WF was lower than the dough from RF60, RF50, RF40, but not significantly different from RF30 before baking. The viscosity of the cookie dough solution is known to decrease with the increase of the temperature used for baking. The reduced viscosity leads to increased gravitational flow leading to a higher spread ratio of cookies [39]. In addition, loss of water during the baking also leads to a reduced thickness of the baked products.

3.5.2 Appearance and texture of cookies product

The appearance, color and texture of the baked cookies are presented in Table 4. Cookies made from WF

Table 3: Geometry, width (cm) and thickness (cm) and spread ratio of the cookies before and after baking

Sample	RF: BF: JTF	Width (cm)		Thickness (cm)		Spread Ratio
		Before Baking	After Baking	Before Baking	After Baking	
WF (control)	-	2.68 ± 0.44^{d}	4.16 ± 0.34^{a}	1.68 ± 0.23^{b}	0.87 ± 0.11^{c}	4.85 ± 0.81^{a}
RF60	60:30:10	2.87 ± 0.10^{c}	3.38 ± 0.21^{c}	1.85 ± 0.05^{a}	1.08 ± 0.04^{c}	3.12 ± 0.20^{b}
RF50	50:35:15	3.11 ± 0.01^{ab}	3.72 ± 0.06^{b}	1.85 ± 0.10^{a}	1.64 ± 0.10^{a}	2.27 ± 0.13^{c}
RF40	40:40:20	3.30 ± 0.15^{a}	3.44 ± 0.15^{c}	1.88 ± 0.06^{a}	1.21 ± 0.09^{b}	2.83 ± 0.10^{ab}
RF30	30:45:25	3.38 ± 0.24^{a}	3.69 ± 0.138^{b}	1.62 ± 0.04^{b}	1.35 ± 0.02^{b}	2.72 ± 0.12^{ab}

Wheat flour (WF), rice flour (RF), banana flour (BF) and job's tears flour (JTF)
Means ± SD in the same column followed by the same letter represent results not significantly different at $p < 0.05$.

exhibited the highest L^* (lightness) compared to the products made from all rice flour blends. In addition, L^* and b^* values of the products tended to decrease with an increase in BF and JTF ratio. The cookies from RF60 presented the highest L^* value of 57.85, while the use of RF30 yielded products with the lowest L^* of 45.49. The dark color of cookies could be generated from the Maillard reaction between amino acids and reducing sugars in the raw materials used. It might be possible that the high protein composition in JTF led to an increase in Maillard reaction products during thermal processing [40], [41].

Textural properties are one of the major factors contributing to eating quality and consumer buying decision for cookies products. Hardness and fracturability are the most imperative textural characteristics for cookies, and are generally affected by the raw materials used [42]. Hardness is the maximum force required to break the product, while fracturability refers to the easiness of the product to break or crispiness [42]. Cookies made with WF as a control formulation presented hardness and fracturability of 2,052 N and 1,634 N, respectively. Using the ratio of RF: BF: JTF at 30:45:25 by weight (RF30) resulted in the highest hardness of 29,813 N. Moreover, the fracturability of RF30 could not be determined as the texture of the produced cookies was very hard and sticky. Increasing the ratio of JTF and BF in the blend tended to increase the hardness and fracturability of the product. On the other hand, the use high amount of rice flour (RF60), especially the RF:BF:JTF ratio of 60:30:10 by weight, resulted in the lowest hardness (1,157 N) and tractability (253 N). Using RF60 instead of WF yielded the cookies with much lower hardness and fracturability due to the lack of gluten in RF. The higher WAI of BF and JTF might compete the water absorption into RF, resulting in less water distribution in the dough ingredients. Uneven and some breakage on the cookies surface from RF30 might be the results of this uneven water absorption to each starch granules. Moreover, the hardness of the cookies is influenced by the water and starch protein interactions [43].

Table 4: Appearance and, color of the flour blends and the cookies obtained after baking

Sample	RF: BF: JTF	Flour Blend	Cookies Products					
			Appearance	Color			Hardness (N)	Fracturability (N)
				L^*	a^*	b^*		
WF (control)	-			68.57 ± 6.65[a]	10.67 ± 3.37[b]	32.62 ± 0.96[a]	2,052 ± 20[c]	1,634 ± 69[b]
RF60	60:30:10			57.85 ± 0.50[b]	12.07 ± 0.84[a]	29.61 ± 0.62[b]	1,157 ± 89[e]	253 ± 79[d]
RF50	50:35:15			51.83 ± 1.42[c]	7.35 ± 0.37[d]	24.52 ± 0.65[c]	1,744 ± 230[d]	799 ± 100[c]
RF40	40:40:20			48.53 ± 2.61[d]	10.49 ± 1.49[ab]	25.30 ± 2.42[c]	4,356 ± 900[b]	1,732 ± 371[a]
RF30	30:45:25			45.49 ± 0.46[e]	9.19 ± 0.86[c]	21.94 ± 1.02[d]	29,813 ± 2,467[a]	NA*

Wheat flour (WF), rice flour (RF), banana flour (BF) and job's tears flour (JTF)
Means ± SD in the same column followed by the same letter represent results not significantly different at $p < 0.05$.
NA*: Not available, could not be determined as the texture of cookies was very hard and sticky.

Table 5: Sensory evaluation of cookies product by 9 points-hedonic scale

Sample	RF: BF: JTF	Color	Aroma	Crispness	Texture	Mouthfeel	Taste	Overall Acceptability
WF (control)	-	6.66 ± 1.56^{a}	7.66 ± 1.24^{a}	6.86 ± 1.35^{a}	6.93 ± 1.38^{a}	6.50 ± 1.35^{a}	6.83 ± 1.57^{a}	7.20 ± 1.24^{a}
RF60	60:30:10	5.10 ±1.53^{ab}	5.66 ± 1.82^{c}	6.53 ± 1.81^{ab}	6.06 ± 1.98^{b}	5.66 ± 1.80^{b}	5.46 ± 1.69^{b}	5.79 ± 1.80^{b}
RF50	50:35:15	5.66 ± 1.49^{ab}	6.03 ± 1.67^{b}	6.43 ± 1.54^{ab}	5.76 ± 1.61^{c}	5.03 ± 1.58^{bc}	5.30 ± 1.34^{b}	5.76 ± 1.30^{b}
RF40	40:40:20	4.40 ± 1.52^{c}	4.39 ± 1.57^{d}	5.50 ± 1.79^{b}	4.86 ± 1.81^{d}	4.60 ± 1.69^{c}	4.90 ± 1.86^{c}	4.76 ± 1.50^{c}
RF30	30:45:25	4.26 ± 2.03^{d}	4.23 ± 1.85^{d}	1.76 ± 1.19^{c}	1.70 ± 1.02^{e}	1.96 ± 1.24^{d}	2.46 ± 1.52^{d}	2.33 ± 1.42^{d}

Wheat flour (WF), rice flour (RF), banana flour (BF) and job's tears flour (JTF). Means ± SD in the same column followed by the same letter represent results not significantly different at $p < 0.05$.

3.6 *Sensory evaluation of cookies and perches decision*

The sensory evaluation (Table 5) revealed that the cookies from WF obtained the highest scores for most of the attributes tested, with overall acceptability of 7.20. The substitution of WF by RF60, and RF50 yielded cookies products with comparable sensory acceptability in terms of color and crispiness, but slightly inferior in texture, mouthfeel, and taste, with overall acceptability of 5.79 and 5.76, respectively. The increase of BF and JTF in RF40 and RF30 resulted in products with lower consumer acceptability in all sensory attributes. According to the panelists, cookies made with WF, which was set as the control, presented qualities closed to commercial cookies available in the market. Considering the texture of the cookies, the sensory analysis revealed that these attributes were well related to hardness and fracturability measured as described above (Table 3). The higher protein content in JTF could lead to much harder texture of the cookies. The texture of the cookies from RF30 exhibited a texture around ten times harder than the cookies made from wheat flour (control). The addition of higher BF and JTF also resulted in a dark brown color which could be the result of the Maillard reaction from reducing sugar and amino acids in the flour mix. However, when consumers considered the products as healthy cookies, the purchasing decision for cookies from RF60 obtained the score as high as 80% (n = 24), while the product from WF obtained 36.67% (n = 11) only.

4 Conclusions

Three flours that are gluten-free and still have nutritive value and functional ingredients, rice flour, banana flour, and job's tear flour were used to replace wheat flour in the preparation of cookies products. In addition, cookies were also prepared using rice flour blended with the other two flours at different ratios. The results showed the flour blend containing rice flour: banana flour: job's tear flour at the ratio of 60:30:10 (RF60) by weight resulted in cookies product with a slightly lower overall acceptability (5.79 ± 1.80) compared to the products made from wheat flour (7.20 ± 1.24). However, the products from RF60 obtained a much higher "willing to buy" at 80% compared to the control (36.67%) when considering as gluten-free healthy cookies. This study demonstrated the high potential for rice flour, banana flour, and job's tear flour to be used for the preparation of gluten-free cookies products.

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Author Contributions

S.S.: Methodology, Software, Data Curation, Writing - Original Draft; B.T.: Project administration, Supervision; V.R.: Conceptualization, Supervision, Writing - Review and Editing; J.L.: Project administration; S.I.M.: Supervision, Writing - Review and Editing; D.U.: Project administration, Supervision. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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