Songklanakarin J. Sci. Technol.
45 (3), 407–414, May – Jun. 2023

http://www.sjst.psu.ac.th

Original Article

Effect of drying temperature on physicochemical properties and resistant starch in unripe banana flour obtained from Kluai Khai Pratabong (*Musa acuminata*, AAA Group) and its application in a soup product

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Received: 16 November 2022; Revised: 21 March 2023; Accepted: 21 April 2023

Abstract

Bananas are one of the lowest cost fruits, mostly grown in tropical/subtropical countries. They are a significant source of nutrients that aid in digestion, weight loss, and heart health. Unripe banana flour (UBF) is a complex carbohydrate source, with a high resistant starch (RS) content, and can be used as a functional ingredient. This study evaluated the effects of drying temperature (40, 50, or 60 °C) on RS content and physicochemical properties of UBF from Kluai Khai Pratabong. Application of UBF as a thickener in soup products was also assessed. The highest RS contents were found in flour samples dried at 40 ˚C or 50 ˚C (41% RS). Nonetheless, a minor difference in physicochemical properties of UBF was observed when it was dried at different temperatures. The optimization of the soup formula based on viscosity, RS content, and overall liking scores revealed that the optimum amounts of chicken broth (CB), boiled Nile tilapia (NF), and UBF in the soup product were 85.06 %, 9.97 %, and 4.97 %, respectively. Increasing the amount of UBF in soup products resulted in increased RS and fiber contents. As such, Kluai Khai Pratabong flour can be employed as a functional ingredient in health food products.

Keywords: resistant starch, unripe banana flour, physicochemical properties, Kluai Khai Pratabong, soup product

1. Introduction

Kluai Khai Pratabong belongs to the AAA group of *Musa acuminata* and it is one of the banana cultivars found in Thailand, especially in Phayao province. This cultivar has a unique taste when it is ripe, making it organoleptically different from other cultivars. Notably, its sour taste has enormously contributed to its unpopularity in terms of consumer preferences and in applications for food innovation by local communities. However, bananas are well-known sources of macro and micronutrients, including carbohydrates, vitamins B and C, potassium, and magnesium. Moreover, recent publications have documented that banana has a high content of resistant starch (RS), which provides health benefits (Escobar *et al.*, 2019; Hoffmann Sardá *et al.*, 2016; Vatanasuchart, Niyomwit, & Narasri 2012). Nowadays, consumers are becoming increasingly interested in health food products. RS has complex molecular structure with high resistance towards enzyme α-1,4 amylase digestion in the small intestine (Raigond, Ezekiel, & Raigond, 2015; Lopez-Rubio, Flanagan, Shrestha, Gidley, & Gilbert, 2008). The characteristics of RS are similar to soluble and insoluble

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dietary fibers in the gastrointestinal system, and play a significant role as health food ingredient (Hoffmann Sardá *et al.*, 2016). Increasing the amount of RS in food will improve the excretory system, similar to the functionality of dietary fiber (Escobar *et al.*, 2019). There are five different types of RS namely RS1 (physically entrapped, non-digestible starch in a non-digestible matrix), RS2 (native granular resistant starch in B- or C-polymorphs), RS3 (retrograded starch), RS4 (chemically modified resistant starch), and RS5 (single amylose helix complexed with lipids) (Roman & Martinez, 2019). However, only RS1 and RS2 can be found naturally in foodstuffs including milled grains, seeds, legumes, unripe banana, taro, and beans (Shen, Zhang, & Dong, 2016).

Soup is a liquid dish cooked with meat or fish stock, seasonings, spices, and stuffings. Soup can be a main dish or an appetizer. While soup is quickly digested by the human body, and provides significant health benefits, addition of carbohydrates or fiber also has been shown to increase satiety (Mahmudatussa'adah, Setiawati, Sudewi, & Juwaedah, 2021). This indicates that incorporation of carbohydrates or fiber in soup products might improve quality dietary habits of individuals. Depending on the desired product, flour, grain cereals, potatoes, and other additives may be used as thickeners to improve the quality characteristics of a soup product. Furthermore, the functionality of flour as a color or flavor additive provides desirable characteristics and improves the quality of soup products. Thus, flour from unripe banana might be an excellent substance for use as a functional thickening agent in processed starchy foods, while providing resistant starch to slower digestion (Naivikul, & Arlai, 2022). Considering the nutritional profiles, unripe banana flour from Kluai Khai Pratabong can be a good source of RS in soup products. Vatanasuchart *et al.* (2012) previously studied the RS profiles in banana from different cultivars in Thailand and reported that the cumulative RS levels in Kluai Hom, Kluai Khai, Kluai Lebmuenang, and Kluai Namwa were 54.0, 51.8, 54.7, and 58.1 (g per100 g, dry basis), respectively. However, to the authors' knowledge, there is no prior published literature investigating the RS profiles and physicochemical properties of Kluai Khai Pratabong among the banana cultivars. Moreover, supplementation of unripe banana flour in soup products can be an option to increase utilization of the aforementioned banana cultivar. Accordingly, the aim of this study was to investigate the RS content and the physicochemical properties of unripe banana flour from Kluai Khai Pratabong. Furthermore, this study also investigates the optimization of soup products with unripe banana flour as a source of RS in an innovative sense.

2. Materials and Methods

2.1 Effect of drying temperature on the properties of unripe banana flour

Unripe bananas (Kluai Khai Pratabong), at their first stage of ripening were purchased from the local markets in Phayao, Thailand, and subjected to non-abrasive mechanical peeling by knife to remove inedible green portions. Thereafter, the peeled products were sliced to chips of 1 mm thickness and subsequently soaked in 1% citric acid solution. The banana chips were dried by tray drying in an oven at various temperatures, viz. 40 °C, 50 °C, or 60 °C for 6-8 h until the moisture content was below 13%. The samples were ground in a hammer mill and sieved through a 100-mesh sieve for use in further analyses.

2.2 Determination of unripe banana flour properties

2.2.1 RS content

RS content of the unripe banana flour was determined according to the Resistant Starch Assay Kit procedure (Megazyme International Ireland Ltd.Co., Wicklow, Ireland). Briefly, nonresistant starch was solubilized and hydrolyzed to glucose by the combined action of pancreatic α-amylase and amyloglucosidase (AMG) at 37 °C for 16 h. RS was recovered as a pellet by centrifugation and dissolved in 2M KOH by vigorously stirring under chilled conditions (in an ice–water bath). The resulting solution was neutralized with acetate buffer and the starch quantitatively hydrolyzed to glucose with AMG. Glucose content was measured with glucose oxidase–peroxidase reagent (GOPOD), for a measure of the RS content (AOAC method 2002.02).

2.2.2 Water absorption index (WAI)

WAI of the unripe banana flour was measured based on the methods previously described by Anyasi, Jideani, and Mchau (2015) with some modifications. Briefly, a 0.4 g sample (dry basis) of flour was added to 40 ml of water and mixed thoroughly using a vortex, to form a suspension. After incubation at room temperature for 30 min, the mixture was centrifuged at 3,000 x g for 10 min and the supernatant was discarded. The WAI was determined as the weight of sediment divided by the weight of dry sample solids.

2.2.3 Pasting properties

Pasting properties of the flour were determined using the Rapid Visco Analyzer (Newport Scientific Pty. Ltd., Australia). The sample (3 g, 14 g/100 g moisture basis) was mixed with 25 ml of distilled water in aluminum cans. The profile for analysis followed a prior description (AACC method 61-02). The data obtained from the RVA were processed by Thermocline software (Thermocline version 2.0, Newport Scientific).

2.2.4 Thermal characteristics

Thermal characteristics of the flour were analyzed using a differential scanning calorimeter (DSC) (Pyris 6, Perkin-Elmer instruments, USA) designed to distinguish endothermic and exothermic transformations of the flour as a function of temperature. According to a method adapted from Vatanasuchart *et al.* (2012), a 3-5 mg sample was weighed into aluminum pan and deionized water was added (flour to water ratio of 1:1) making a 30%-50% starch suspension. The sample pans were tightly sealed and allowed to equilibrate overnight at room temperature. Samples were heated from 25-150 °C at a rate 5 °C/min. A sealed empty pan was used as a reference. Onset temperature (To), peak temperature (Tp), conclusion temperature (Tc) and enthalpy (ΔH) were obtained from endothermic curves by using the software for Perkin-Elmer instruments.

2.3 Application of unripe banana flour in soup products

The optimization of soup formula by mixture design was conducted. The three main ingredients chicken broth (CB, 80-90%), boiled Nile tilapia (NF, 5-10%), and unripe banana flour (UBF, 1-5%) were manipulated in the experimental design performed by Minitab software. The experimental design consisted of 9 formulations from simplex centroid mixture design. Each formula had the same 5% level of steamed taro, 0.7% soy sauce, 0.2% pepper, 0.2% salt, 0.1% sugar, and 0.5% olive oil. All the ingredients were weighed following the formulations. The ingredients were mixed and blended using a blender. The mixed ingredients were then boiled until the temperature reached 95 °C and thereafter continuously for 5 minutes. The soup samples were cooled down and packaged in polyethylene bags that were kept at 4 °C until analysis. The experiments were replicated independently for three runs.

2.4 Physicochemical analysis of soup product

2..4.1 The viscosity

The viscosity of soup samples was analyzed by using Brookfield viscometer Model DV-//+Pro (Brookfield engineering laboratory, Inc., USA), using S64 spindle at 100 rpm for 15 seconds. The temperature of the soup samples was maintained at 40 °C during the entire measurement.

2.4.2 RS content

The RS content of the soup samples was determined using the Megazyme Resistant Starch kit (Megazyme International Ltd., Ireland) as described in a previous section (AOAC method 2002.02.).

2.4.3 Proximate analysis

Moisture, protein, fat, fiber, ash, and carbohydrate contents of the soup products were evaluated using standard methods (AOAC, 2000).

2.5 Sensory evaluation

Sensory evaluation of the soup samples was conducted by using an acceptance test method. Fifty untrained panelists with ages 55 and above were included in the sensory test since the soup was developed targeting this age group. The panelists were informed about voluntary withdrawal from the test if they had a previous history of allergies related to the ingredients used in the soup formulation. They were asked to evaluate the 5 attributes appearance, color, flavor, taste, and overall liking of the samples, using a 7-point hedonic scale where 1 represents dislike very much, 2 dislike moderately, 3 dislike slightly, 4 neither like nor dislike, 5 like slightly, 6 like moderately, and 7 like very much.

2.6 Statistical analysis

All experiments were conducted in three replications and results are presented as means ± SD. The data obtained in drying process study and physicochemical properties of soup products were analyzed by one-way analysis of variance (ANOVA) using SPSS 25.0 software (IBM, New York, U.S.). Differences among the mean values of samples were determined by Duncan's multiple range test (DMRT) at 95% level of significance. Furthermore, the data obtained from the optimization of soup recipe experiments were analyzed by using Minitab software.

3. Results and Discussion

3.1 Effect of drying temperature on the physico-chemical properties of unripe banana flour

3.1.1 RS content

The drying temperature influenced the RS amount in unripe banana flour. As illustrated in Table 1, unripe banana flour subjected to drying at 40 °C and 50 °C showed the highest RS contents of about 41%. However, drying at a further elevated temperature (60 °C) resulted in a reduced RS (p<0.05) of 27.18%. The X-Ray diffraction patterns of banana flour showed B-type crystallinity. An increased drying temperature resulted in the disruption of the starch crystallinity. A significant correlation between RS content and the effect of temperature was observed (r > 0.91, p = 0.05), which confirmed that destroying the granular crystalline structure of starch was associated with a decreased amount of RS (Khoozani, Bekhit, & Birch, 2019). Tribess *et al.* (2009) also reported that the drying conditions were significantly influencing RS content of banana flour, probably due to the higher drying temperature, time, and consequently partial disorganization of the crystalline structure of starch. Such conditions also play an important role in starch gelatinization and retrogradation. In a previous study conducted by Rosado *et al.* (2020), banana (*Musa acuminata* (AAA Group) dried in an oven at a constant temperature of 55 °C for 24 h showed RS content of 22.8%. Additionally, Bi *et al.* (2019) conducted similar studies at different ripening stages of a banana cultivar belonging to *Musa* ABB group (Pisang Awak subgroup) and reported various RS contents from drying at 45 °C for 10 h. The RS contents of banana at different ripening stages (1, 3, 5, and 7) were 81.15, 67.06, 42.67, and 31.61%, respectively. Similarly, the RS contents of other banana cultivars grown in Thailand, including Kluai Hom (54.0) Kluai Khai (51.8) Kluai Lebmuenang (54.7) and Kluai Namwa (58.1) were investigated on a g per 100g dry basis at the green stage of ripening (Vatanasuchart *et al.*,2012). The results suggest that the banana cultivar under investigation, the ripening stage, as well as the drying conditions, affect RS content in banana flour.

Table 1. Resistant Starch content and Water Absorption Index of unripe banana flour

Drying temperature (°C)	RS (%)	WAI (g/g)
40	41.00 ± 0.26[a]	4.39 ± 0.22[a]
50	40.94 ± 0.42[a]	4.81 ± 0.19[a]
60	27.18 ± 1.35[b]	4.65 ± 0.23[a]

Values in the same column with the same superscript are not significantly different (p > 0.05).

3.1.2 Water absorption index (WAI)

Water absorption is a measurement of a raw material's ability to absorb water to achieve a desirable consistency that aids in obtaining food products of good quality. Water absorption index is linked to the amount of starch in the substance. The WAI of unripe banana flour was investigated, and the results are shown in Table 1. WAI of banana flour ranging from 4.38 - 4.43 g/g was not significantly affected ($p > 0.05$) despite the different drying temperatures used to produce the flour. This can be explained with reference to thermomechanical treatment, hydrophilic characteristics of the starch due to gelatinization, intramolecular and intermolecular connections, and the exposed hydroxyl groups that can form hydrogen bonds with water (Campuzano, Rosell, & Cornejo, 2018; Marta, Cahyana, Bintang, Soeherman, & Djali, 2022). However, the gelatinization temperature of unripe banana flour in this study was 73.98 °C to 75.49 °C, which are higher than the drying temperature used. Thus, drying at 40 °C to 60 °C had not damaged the flour structure of any of the samples; hence WAI did not significantly differ between the treatments.

3.1.3 Pasting properties

As regards the pasting properties, the apparent viscosity during heating and cooling was investigated. The pasting properties of unripe banana flour at different drying temperatures are shown in Table 2. The drying temperature did not significantly affect the final viscosity or pasting temperature of unripe banana flour ($p > 0.05$). At 40 °C drying temperature, peak viscosity and breakdown profiles showed significantly lower magnitudes compared to samples dried at 50 and 60 °C, while setback properties showed the highest value (39.62 RVU) in samples dried at 60 °C. Rodríguez-Damian, De La Rosa-Millán, Agama-Acevedo, Osorio-Díaz, and Bello-Pérez (2013) reported that pasting properties of banana flour vary depending on heat-moisture treatment and cooking time. This is attributable to the associations among the chains in the amorphous region and changes in crystallinity of the granules during hydrothermal treatment, which cause changes in the pasting properties of the starch (Subroto, Indiarto, Marta, & Shalihah, 2018). In this study, the drying process was initiated at a temperature below the pasting temperature of banana flour. The gelatinization stage had not occurred, and the starch granules were still compact, resulting in only minor differences in the pasting properties between the samples. A previous study also observed insignificant alterations in the shape, crystallinity, and properties of unripe banana flour at air-drying conditions compared to extrusion (Naivikul & Arlai, 2022), which apparently explains the results obtained in this study. However, the WAI and pasting properties of flour could be related to the particle porosity of flour, the amylose content, the amount of insoluble dietary fibers, or protein (Khoozani *et al.* 2019).

3.1.4 Thermal properties

The results on thermal properties of unripe banana flour are shown in Table 3. While the samples were heated, the unripe banana flour showed morphological and structural changes. Onset temperature (T_o) and peak temperature (T_p) varied from 70.97 °C to 72.11°C, and from 73.98 °C to 75.49 °C, respectively, depending on the drying temperature, while conclusion temperatures (T_c) did not significantly differ ($p>0.05$). The findings apparently agree with Khoozani *et al.* (2019) who reported T_o, T_p, and T_c of whole green banana flour subjected to oven air-drying at 50 °C as 73.45, 75.9, and 85.51 °C, respectively. The enthalpies of unripe banana flour, 5.61 and 5.87 J/g obtained from 40 °C and 50 °C drying temperatures, respectively, were not significantly different ($p > 0.05$). Nonetheless, enthalpy of flour dried at 60 °C showed a lower magnitude at 5.29 J/g compared to when lower temperatures are used. The enthalpy is defined as the amount of energy required to break the molecular interactions within the starch structure during gelatinization (Tribess *et al.*, 2009). As a result, flour produced at 60 °C had a lower RS content compared to flour produced at 40 °C and 50 °C. It is possible that the differences in enthalpies in this study were related to RS contents in the flour samples. A variety of factors, including amylose content, crystalline structure type and

Table 2. Pasting properties of unripe banana flour

Drying temperature (°C)	Peak viscosity (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Pasting temperature (°C)
40	423.60 ± 11.88^{b}	202.17 ± 12.50^{c}	269.59 ± 7.31^{a}	33.26 ± 1.27^{b}	77.98 ± 0.84^{a}
50	464.12 ± 23.64^{a}	237.16 ± 20.14^{ab}	271.78 ± 10.08^{a}	30.60 ± 0.96^{b}	76.98 ± 0.38^{a}
60	482.25 ± 15.94^{a}	269.48 ± 14.12^{a}	259.29 ± 3.51^{ab}	39.62 ± 8.66^{a}	75.23 ± 0.69^{a}

Values in the same column with the same superscript are not significantly different ($p > 0.05$).

Table 3. Thermal properties of unripe banana flour

Drying temperature (°C)	T_o (°C)	T_p (°C)	T_c (°C)	ΔH (J/g)
40	72.11 ± 0.64^{a}	75.49 ± 0.18^{a}	82.69 ± 0.89^{a}	5.61 ± 0.14^{a}
50	71.13 ± 0.19^{ab}	74.68 ± 0.26^{ab}	82.10 ± 0.97^{a}	5.87 ± 0.23^{a}
60	70.97 ± 0.26^{b}	73.98 ± 0.11^{b}	81.96 ± 0.91^{a}	5.29 ± 0.75^{b}

T_o: onset temperature, T_p: peak temperature, T_c: conclusion temperature, and ΔH: enthalpy. Values in the same column with the same superscript are not significantly different ($p > 0.05$).

arrangement, and interactions with other elements in the starch might have affected the bond strength in starch structure. The digestibility is known to be related to crystalline polymorphic forms, and it is reported that the A type X-ray diffraction is associated with higher susceptibility to amylolysis than the B-type pattern (Bi *et al.*, 2017; Srichuwong, Sunarti, Mishima, Isono, & Hisamatsu, 2005). The major pattern of the RS in green banana flour corresponds to B-type crystallinity, which is structurally tight and orderly in a way that makes it highly resistant to enzymatic hydrolysis (Jaiturong *et al.*, 2020; Khoza, Kayitesi, & Dlamini, 2021).

3.2 Application of unripe banana flour in soup products

3.2.1 Physicochemical analysis of soup products

The physicochemical properties of soup samples are shown in Table 4. Viscosity is one of the most important quality characteristics of a soup product. The viscosities of soup products in this study ranged from 24 to 2,375.33 centipoise. Viscosity increased significantly with an increased level of unripe banana flour and decreased with amount of chicken broth. The current study does agree with Naivikul & Arlai, (2022), who reported similar observations upon 100% substitution with unripe banana flour. Abdalla & Ahmed (2019) reported high ($p \leq 0.05$) increase in viscosity of fresh yoghurt when banana flour content was increased. Similarly, Detchewa, Prasajak, Sriwichai, and Moongngarm (2021) revealed that the addition of unripe banana flour increased the viscous properties of gluten-free rice cookies. RS content in all formulations of soup products showed significant differences ($p \leq 0.05$) ranging from 0.29% to 1.68%. Formulations 2, 4, 7, and 9 were not significantly different ($p > 0.05$) and showed the highest RS content in soup products with a range of 1.38% to 1.68%. Increasing the amount of unripe banana flour resulted in high levels of RS content in soup products. This indicates that unripe banana flour is a good source of RS (Detchewa et. al., 2021; Escobar *et al.*, 2019; Khoozani *et al.*, 2019; Vatanasuchart *et al.*, 2012) as increasing its amount would result in elevated RS content.

3.2.2 The proximate compositions of soup products

The proximate compositions of soup products are also shown in Table 4. Moisture contents in the soup products ranged from 85.86% to 91.68%. The highest crude protein contents (3.12-3.19%) were found in formulations 1 and 3, while formulations 4 and 9 showed the lowest protein contents (0.72%). High crude lipid content was observed in formulation 6 (2.83%), while the lowest amount was observed in formulations 1 and 2 (0.16%). Crude fiber contents ranged from 0.65% (formulation 1) to 4.78% (formulation 2). No significant differences in ashes (0.90% to 0.99%) were found between formulations 2, 4, 7, and 9. In terms of carbohydrates, the highest amount was found in formulation 8 (8.77%), with 6 showing the lowest carbohydrate content (2.78%). The proximate compositions of soup products depend on the concentration of ingredients in the formula. For instance, increasing the amount of unripe banana flour resulted in high crude fiber and RS contents in the soup products. The results apparently agreed with previous studies who reported high fiber and RS content in bread (Roman & Martinez, 2019), gluten free rice cookies (Detchewa *et al.*, 2021), and high fiber cookies (Syafii & Fajriana, 2021) as regards effects of increasing the amount of unripe banana flour

3.2.3 Sensory evaluation

The different formulations of soup products were evaluated for the 5 attributes appearance, color, flavor, taste, and overall liking (Table 5). The appearance was not significantly different ($p > 0.05$) between formulations 2, 4, and 7, with a score ranging from 4.93-5.48, corresponding to 'like slightly' on the 7-point hedonic scale. Color scores of formulations 2, 7, and 8 were the highest with no significant differences ($p > 0.05$) existing between them. In terms of flavor, the panelist mostly chose formulation 2 (score of 5.60). Regarding taste attributes, the results indicated that formulation 2 was moderately ranked (highest score of 6.04) on the hedonic scale. For overall liking, the highest scores were found for formulations 2 and 7, with scores of 5.72 and 5.16, respectively. Based on the results of sensory evaluation, it is recommended that a soup formulation with high levels of unripe banana flour and low levels chicken broth and boiled Nile tilapia would be a better formulation for optimizing soup products.

3.2.4 The optimization of soup formula by mixture design

Overlaid contour plots were used to optimize the soup formula with help of the Minitab program. based on

Table 4. The physicochemical and proximate properties of soup products

Formula	CB:NF:UBF	Viscosity (centipoise)	Resistant starch (%)	Moisture (%)	Crude protein (%)	Crude lipid (%)	Crude fiber (%)	Ash (%)	Carbohydrates (%)
1	89:10:1	42.00 ± 12.32^{e}	0.78 ± 0.08^{c}	91.68 ± 0.45^{a}	3.19 ± 0.58^{a}	0.19 ± 0.04^{e}	0.65 ± 0.17^{d}	0.66 ± 0.007^{cde}	3.63 ± 0.86^{c}
2	85:10:5	2375.33 ± 110.64^{a}	1.52 ± 0.09^{ab}	85.86 ± 0.21^{de}	2.23 ± 0.14^{bc}	0.16 ± 0.07^{e}	4.78 ± 0.28^{a}	0.96 ± 0.027^{b}	6.01 ± 0.61^{b}
3	90:9:1	26.00 ± 3.46^{f}	0.81 ± 0.17^{c}	89.78 ± 0.63^{b}	3.12 ± 0.19^{a}	1.59 ± 0.11^{b}	1.58 ± 0.10^{c}	0.63 ± 0.008^{de}	3.30 ± 0.35^{d}
4	90:5:5	1041.93 ± 61.66^{bc}	1.68 ± 0.27^{a}	87.01 ± 0.33^{c}	0.78 ± 0.26^{f}	0.80 ± 0.17^{d}	3.47 ± 0.14^{b}	0.90 ± 0.02^{b}	7.04 ± 0.22^{ab}
5	88.5:8.5:3	2251.67 ± 251.74^{a}	1.04 ± 0.16^{b}	89.70 ± 0.32^{b}	1.25 ± 0.49^{ef}	1.02 ± 0.07^{c}	0.94 ± 0.18^{cd}	0.71 ± 0.013^{cd}	6.38 ± 0.37^{b}
6	88.75:9.25:2	140.00 ± 18.33^{d}	0.54 ± 0.10^{cd}	91.51 ± 0.25^{a}	1.45 ± 0.39^{de}	2.83 ± 0.24^{a}	0.68 ± 0.14^{d}	0.75 ± 0.12^{c}	2.78 ± 0.88^{d}
7	86.75:9.25:4	1093.93 ± 129.67^{bc}	1.38 ± 0.23^{ab}	86.92 ± 0.22^{d}	1.69 ± 0.31^{de}	1.07 ± 0.20^{c}	3.54 ± 0.18^{b}	0.90 ± 0.04^{b}	5.88 ± 0.55^{b}
8	89.25:8.75:2	24.00 ± 3.46^{f}	0.29 ± 0.01^{d}	86.24 ± 0.20^{d}	1.86 ± 0.35^{cd}	1.10 ± 0.07^{c}	0.87 ± 0.19^{cd}	1.16 ± 0.017^{a}	8.77 ± 0.57^{a}
9	89.25:6.75:4	1390.3 ± 132.3^{b}	1.56 ± 0.19^{ab}	88.13 ± 0.62^{bc}	0.72 ± 0.18^{f}	1.12 ± 0.10^{c}	3.06 ± 0.21^{b}	0.99 ± 0.057^{b}	5.98 ± 0.88^{b}

CB: chicken broth, NF: boiled Nile tilapia, UBF: unripe banana flour
Different letters with the same column for each characteristic are significantly different ($p \leq 0.05$)

Table 5. Sensory evaluation parameters of soup products

Formula	CB:NF:UBF	Appearance	Color	Flavor	Taste	Overall liking
1	89:10:1	3.58 ± 0.85 ^{cd}	4.82 ± 1.21^{b}	3.26 ± 1.01^{de}	3.68 ± 1.11^{e}	3.98 ± 0.98^{e}
2	85:10:5	5.48 ± 1.47^{a}	5.48 ± 1.36^{a}	5.60 ± 1.41^{a}	6.04 ± 1.19^{a}	5.72 ± 1.39^{a}
3	90:9:1	3.68 ± 0.74^{c}	4.72 ± 1.12^{bc}	3.82 ± 0.98^{d}	3.42 ± 0.85^{e}	3.61 ± 0.74^{ef}
4	90:5:5	5.08 ± 1.32^{ab}	4.98 ± 1.32^{b}	4.76 ± 1.33^{b}	5.06 ± 1.33^{bc}	5.04 ± 1.29^{b}
5	88.5:8.5:3	4.95 ± 1.13^{b}	4.22 ± 1.01^{c}	4.00 ± 0.85^{c}	4.21 ± 0.97^{d}	4.67 ± 0.93^{cd}
6	88.75:9.25:2	3.98 ± 0.93^{c}	4.43 ± 1.13^{c}	4.09 ± 0.99^{c}	4.51 ± 0.94^{d}	4.20 ± 0.82^{d}
7	86.75:9.25:4	5.20 ± 1.20^{a}	5.06 ± 1.32^{ab}	4.96 ± 1.40^{b}	5.22 ± 1.36^{b}	5.16 ± 1.28^{ab}
8	89.25:8.75:2	4.93 ± 1.19^{b}	5.01 ± 1.18^{ab}	4.02 ± 0.96^{c}	3.98 ± 1.10^{d}	4.02 ± 1.13^{de}
9	89.25:6.75:4	4.90 ± 1.42^{b}	4.82 ± 1.27^{b}	4.66 ± 1.50^{bc}	4.84 ± 1.45^{c}	4.88 ± 1.47^{c}

Scoring was performed using the 7-point hedonic scale where 1 represents dislike very much, 2 dislike moderately, 3 dislike slightly, 4 neither like nor dislike, 5 like slightly, 6 like moderately, and 7 like very much. CB: chicken broth, NF: boiled Nile tilapia, UBF: unripe banana flour. Different letters in the same column indicate significant difference between formulations ($p \leq 0.05$).

viscosity, RS content, and overall liking scores. The results are illustrated in Figure 1. The feasible region (white area) was the optimum formulation area. Response optimizer was analyzed to predict the optimum levels of chicken broth, boiled Nile tilapia, and unripe banana flour in the soup product and the results were 85.06 %, 9.97 %, and 4.97 %, respectively as shown in Figure 2. Generally, unripe banana flour provided a significant improvement in viscosity, RS content and the sensory scores of soup samples, suggesting that the soup formula may include at least 3% unripe banana flour. Moreover, the chicken broth and boiled Nile tilapia should be used for about 85% and 9%, respectively, in a soup formulation for acceptable soup sample. The findings of this study revealed that soup products with unripe banana flour can be a good source of RS and fiber. Furthermore, unripe banana flour influenced the physicochemical properties of the final product and can be incorporated in optimization protocols for soup products.

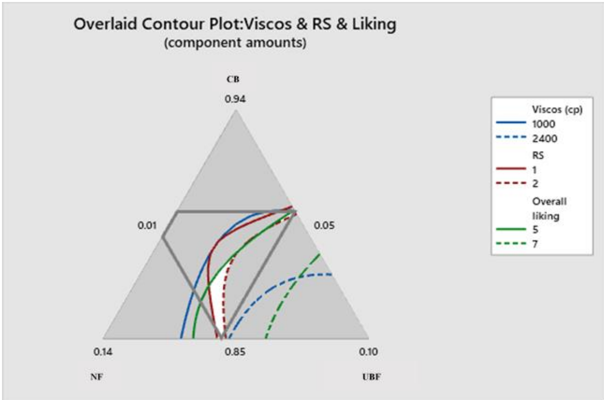

Figure 1. Overlaid contour plots of viscosity, RS content, and overall liking scores. The white region is the optimum area for soup optimization.

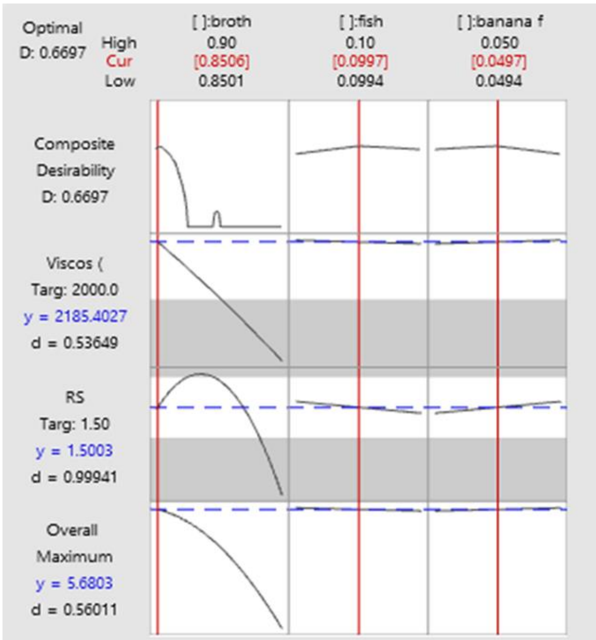

Figure 2. The optimization of soup formulation. The red vertical lines represent correct response optimizer for soup formula.

4. Conclusions

To sum up, the study revealed that drying at 40 ˚C or 50 ˚C produced the highest RS content in unripe banana flour. Flour samples investigated at different drying temperatures showed minor differences in physicochemical characteristics. Furthermore, the study also showed that mixture design can be used to optimize soup formulation to provide acceptable product. Additionally, incorporation of unripe banana flour not only improves the characteristic of the soup products but also increases the nutritional profiles that are acceptable by the consumers. Thus, unripe banana flour from Kluai Khai Pratabong can be used as a functional ingredient in health food products.

Acknowledgements

The authors acknowledge the financial support from the University of Phayao, Thailand.

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