Functional Properties and Resistant Starch Content of Banana Flour and Its Application to Noodle Product

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Abstract: Banana flour (BF) were prepared by using unripe banana due to it contains mainly carbohydrate especially starch that is suited to use as the source of flour. For the functional properties of BF, the gelatinization temperature ranges were 72.93 to 79.41°C and enthalpy of gelatinization (ΔH) was 10.93 J/g. The pasting curves and viscosity parameters were including pasting temperature, peak viscosity, breakdown, setback and final viscosity were 82.10ºC, 3573.33 mPa.s, 1567.33 mPa.s, 1794.67 mPa.s and 3800.67 mPa.s, respectively. The flour paste samples showed shear thinning behavior of pseudo-plastic materials. BF was high in resistant starch (RS) which contained 55.33%. Fresh noodle that substituted with BF of 10%, 20%, 30% and 40% were investigated in their quality characteristics. While the substitution of BF increased, the RS content of noodles increased from 9.00% to 22.01%. However, the RS had affected the lightness and texture properties of noodle products.When the BF substitution increased at 10 to 40%, tensile strength and elasticity values were decreased from 35.50 to 26.84 g_f and 33.75 to 15.04 mm, respectively. The utilization of BF as an ingredient in food products exerts a beneficial effect that provides high resistant starch or low carbohydrate digestibility.

1 INTRODUCTION

The nutritional properties of bananas are known to provide health benefit because it is rich in fiber and rich source of minerals (Singh *et al.*, 2016). The interesting substantial type of starch in an unripe banana is resistant starch (RS). RS of banana has the potential to provide health benefits similar to dietary fiber that increased satiety, helps burn fat more quickly and low calorie content as well as promote a reduced glycemic response.

The alkaline noodle is one type of noodle that is responsible for 48% of flour consumption in South East Asia (Ho and Che, 2016). However, the noodle is the major carbohydrate based food that lacks many essential nutritional components. Therefore, the consumption of this noodle could lead to malnutrition that considers being high calories and leads to health problems (Ramli *et al.*, 2009). It would be desirable if the incorporation of unripe banana flour can reduce the rate of digestion in noodles due to its high resistant starch content. It could be beneficial in the management of health problems.

Therefore, the present study had two main objectives. Firstly, to determine the functional properties and resistant starch content of banana flour (BF). The second was to investigate the effects of wheat flour substitution with BF as a functional food on qualities of fresh noodle.

2 MATERIALS AND METHODS

2.1 Materials

Unripe bananas (*Musa sapientum* L., ABB group), were purchased from the local market in Hatyai, Songkhla, Thailand. The basic ingredients for alkaline noodle were purchased from the local supermarket. Resistant Starch Assay Kit was purchased from Megazyme, Ireland.

2.2 Banana Flour Preparation

Banana flour (BF) was prepared by adapted from Tiboonbun *et al*. (2011). BF was stored at 4°C in vacuum sealed aluminium foil containers.

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2.3 Functional Properties

2.3.1 Gelatinization Properties

Gelatinization properties were analyzed using by a Differential Scanning Calorimeter (DSC). The temperatures of the characteristic transitions at onset (T_o), peak (T_p) and completion (T_c) were recorded and the relative enthalpy (ΔH) of the transition were calculated.

2.3.2 Pasting Properties

The pasting properties were determined using Rapid Visco Analyzer (RVA). BF suspension (12% w/w, db) was poured into a RVA canister. The suspension was equilibrated at 50°C then heated from 50-95°C at a rate of 1.5°C/min, maintained at 95°C for 3 min. The paste was cooled to 50°C and held for 5 min. The parameters; pasting temperature, peak viscosity, breakdown, setback and final viscosity were recorded.

2.3.3 Flow Behaviour

Flow behavior was determined according to Noosuk *et al*., (2003) using the rheometer. 4% (w/w) BF was heated at 95°C for 15 min then flour paste was measured viscosity values and shear stress with shear rates between 10-1000 s^{-1} at 60°C. The consistency coefficient and flow behavior index also were calculated.

2.4 Resistant Starch Content (RS)

Resistant starch content (RS) were determined using the Megazyme RS assay kit (Wicklow, Ireland) by McCleary and Monaghan (2002).

2.5 Noodle Production

Fresh noodles were prepared using a method similar to Zhou *et al*. (2015) with modifications. The formulations consisting of 100% wheat flour and substitution wheat flour with 10%, 20%, 30% and 40% of banana flour. The noodle dough was passed through the noodle machine to form a dough sheet and then was slit into 2.5 mm width strands. Afterward, the noodle strands were pre-cooked in boiling water for 30 sec and cooled for further analysis.

2.6 Color Analysis

Color analysis was performed on a colorimeter by Hunter Lab Colorflex version 3.73, in triplicate, using the CIE standard (L*, a*, b*).

2.7 Texture Properties

The texture properties were determined using a texture analyser (TA-XT2i) as describe by Shan *et al.* (2013). The fresh noodle strand will be measured to the maximum tension force and the maximum distance.

2.8 Statistical Analysis

The data were expressed as the means ± standard deviation in triplicate. Data were analyzed by using one-way analysis of variance (ANOVA), followed by Duncan's multiple-range test to apply for the mean comparison when determines the significant differences at $p \leq 0.05$.

3 RESULTS AND DISCUSSION

3.1 Functional Properties and Resistant Starch (RS) Content of Banana Flour

3.1.1 Gelatinization Properties

The gelatinization properties of BF measured by DSC are presented in Figure 1. The gelatinization parameters including onset temperature (T_o), peak temperature (T_p), conclusion temperature (T_c) and enthalpy of gelatinization (ΔH) are presented in Table1. BF had 10.93 J/g of ΔH value. It could reflect the melting of the crystallites during gelatinization. Thus ΔH of BF indicated that relative the energy was required to break down the crystalline. Nimsung *et al.* (2007) found the ΔH (15.37 J/g) and gelatinization temperature (76.27ºC:T_o, 80.5ºC:T_p and 85.99ºC:T_c) of BF were higher than the results in this study.

3.1.2 Pasting Properties

The pasting profiles and viscosity parameters of BF analyzed by Rapid Visco Analyzer (RVA) are presented in Figure 2 and Table 1. The pasting profiles is a measure of the viscosity behavior of starch solution during the heating and cooling. Peak viscosity shows resistance to swelling within the granules. This value is depended on amylose and amylopectin ratio and swelling of granules. The final

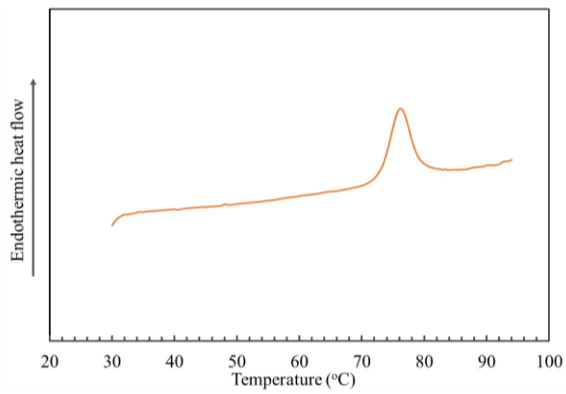

Figure 1: The DSC endotherms of banana flour.

Table 1: Functional properties of banana flour.

Functional properties	Value
Gelatinization properties	
- Onset temperature (T_o, ºC)	72.93 ± 0.06
- Peak temperature (T_p, ºC)	76.17 ± 0.00
- Conclusion temperature (T_c, ºC)	79.41 ± 0.16
- Enthalpy of gelatinization (ΔH, J/g)	10.93 ± 0.00
Pasting properties	
- Pasting temperature (ºC)	82.10 ± 0.65
- Peak viscosity (mPa.s)	3573.33 ± 31.94
- Breakdown (mPa.s)	1567.33 ± 35.73
- Setback (mPa.s)	1794.67 ± 38.18
- Final Viscosity (mPa.s)	3800.67 ± 39.11
Flow behavior	
- Consistency coefficient (k, $Pa.s^n$)	3.54 ± 0.36
- Flow behavior index (n)	0.29 ± 0.01
- Area	1563.33 ± 240.58

Each value is mean of triplicate ± SD.

viscosity was related to recrystallization of gelatinized starch. The pattern of pasting profile in this study was similar to the result of Vatanasuchart *et al*. (2012) and Babu *et al*. (2014).

3.1.3 Flow Behaviour

The relationship between apparent viscosity and shear rate for BF, in shear rates range 10-1000 s^{-1} are showed in Figure 3a. The sample curves exhibited similar shear thinning behavior of pseudo-plastic materials because the viscosity decreased when shear rate increased. The parameter values, consistency coefficient (k) and flow behavior index (n) were shown in Table 1. Moreover, Figure 3b showed that both of BF occurred hysteresis loops, indicating that it was the time-dependent non-newtonian flow behavior of thixotropy as shown in Table 1.

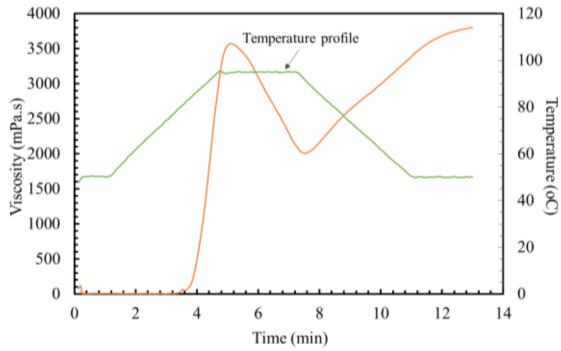

Figure 2: Pasting profiles of banana flour at the concentration of 12% w/w (db).

3.1.4 Resistant Starch Content (RS)

The resistant starch (RS) content of BF was 55.33%. Goñi *et al*. (1996) classified classes of RS which very high RS had RS content more than 15%. Therefore this result indicated that BF containing very high RS content. Several studies had reported that starch of unripe banana is RS type 2 which consists of native starch granular (Tiboonbun *et al*., 2011).

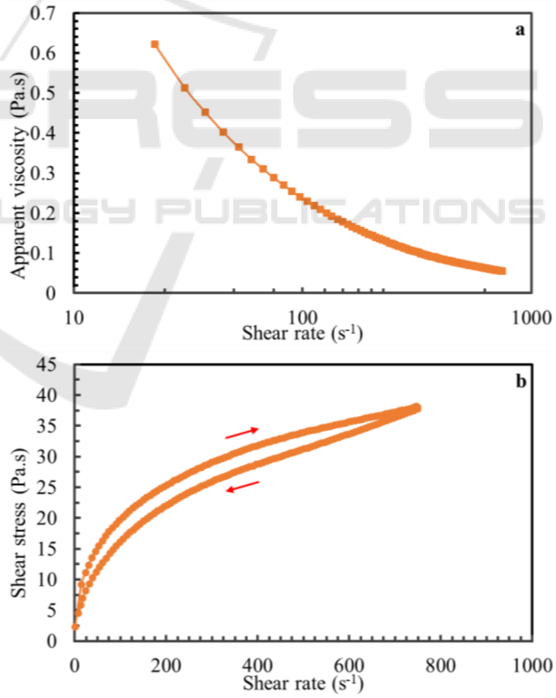

Figure 3: Flow curve of relationship between (a) apparent viscosity and shear rate (b) shear stress and shear rate of banana flour at 60°C over the shear rates range 10-1000 s^{-1}.

Table 2: Quality characteristics and resistant starch content (RS) of fresh noodles substituted with banana flour.

Sample	Quality characteristics					Resistant starch (%)
	Color			Texture		
	L*	a*	b*	Tensile strength (g_f)	Elasticity distance (mm)	
0%BF	68.36 ± 0.05^{a}	0.74 ± 0.02^{e}	25.18 ± 0.08^{a}	52.97 ± 1.80^{a}	44.60 ± 1.97^{a}	5.25 ± 0.14^{e}
10%BF	57.99 ± 0.01^{b}	3.69 ± 0.02^{d}	21.26 ± 0.06^{b}	35.50 ± 1.73^{b}	33.75 ± 1.39^{b}	9.00 ± 0.12^{d}
20%BF	50.33 ± 0.03^{c}	4.34 ± 0.04^{c}	18.56 ± 0.08^{c}	33.62 ± 1.00^{c}	27.27 ± 1.56^{c}	12.62 ± 0.15^{c}
30%BF	47.53 ± 0.09^{d}	4.41 ± 0.04^{b}	17.07 ± 0.06^{d}	29.89 ± 1.62^{d}	22.98 ± 1.18^{d}	17.01 ± 0.48^{b}
40%BF	40.23 ± 0.03^{e}	5.01 ± 0.03^{a}	14.94 ± 0.05^{e}	26.84 ± 1.56^{e}	15.04 ± 1.23^{e}	22.01 ± 0.27^{a}

Each value is mean of triplicate ± SD.; $^{a-e}$ = Mean values in a column with different lowercase superscript letters are significantly different at $p \leq 0.05$.; BF10 = 10% Banana flour, BF20 = 20% Banana flour, BF30 = 30% Banana flour, BF40 = 40% Banana flour.

3.2 Application of Banana Flour to Noodle Product

3.2.1 Color Characteristics of Noodle Substituted with Banana Flour

The color characteristics of BF-substituted noodles are shown in Table 2. The values were found significantly decreased ($p \leq 0.05$) in noodles replaced with 10%, 20%, 30% and 40% of BF. The results indicated that as the levels of BF substitution increased, the color of the noodles grew darker which affected a reduce L* and b* values and an increase a* value. These results were similar to those reported by Tiboonbun *et al*. (2011) and Vernaza *et al*. (2011).

3.2.2 Texture Properties of Noodle Substituted with Banana Flour

The results of texture analysis, tensile strength and elasticity distance of noodles substituted with BF (Table 2). Increasing level of BF substitutions significantly decreased ($p \leq 0.05$) the texture values. That was noodle from substituting BF for wheat flour had lower tensile strength and elasticity distance than the 0% BF noodles. This decrease might be explained by the percent reducing of the wheat gluten, causing the elasticity was decreased (Sirichokworrakit *et al*., 2015 and Ritthiruangdej *et al*., 2011).

3.2.3 Resistant Starch of Noodle Substituted with Banana Flour

Results of RS are shown in Table 2. A significant increase in RS content was observed in the BF noodle substitution. The 40% BF noodle had the highest RS content (22.01%), whereas 0% BF noodle had the lowest RS content (5.25%). As a result, these noodles high resistant to hydrolysis by enzyme activities due to the crystalline granular structure of BF. A similar pattern was previously reported for rice noodle from unripe banana flour by Tiboonbun *et al*. (2011).

4 CONCLUSIONS

The pasting curves of banana flour (BF) obtained by RVA showed pasting temperature, breakdown, and setback were 82.10ºC, 1567.33 mPa.s and 1794.67 mPa.s, respectively. The flour paste samples showed shear thinning behavior of pseudo-plastic materials. Banana flour is high in resistant starch type 2 (RS2) which contains 55.33%. For the alkaline noodle, while the substitution of BF increased, RS content of noodles was increased. In addition, the RS had affected the lightness and texture properties of noodle products that decreased tensile strength and elasticity value. Utilization of BF as an ingredient in food products exerts a beneficial effect that provides high nutritional quality containing resistant starch or low carbohydrate digestibility.

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