

# APPLICATION OF BANANA STARCH AND BANANA FLOUR IN VARIOUS FOOD PRODUCT: A REVIEW

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## Abstract

Banana, a botanically berry, is an edible fruit produced by several kinds of large herbaceous flowering plants in the genus *Musa*. Banana has been known as an abundant fruit in Indonesia. Badan Pusat Statistik shows that in 2017, the production of banana in Indonesia was the highest among other fruits (7.16 million tons in 2017), showing a 2.22% increasing rate from the last year. Banana can be directly eaten when it is ripe, or can be processed first while it is unripe. Banana, while it is unripe, contains high carbohydrate with 17.2- 38% starch in it. This starch fraction, whether it is in native state or modified state, can be extracted and can be used for many purposes in food production means such as in producing cookies, pasta etc. Many studies has been accomplished to learn the characteristics of products that are made by substituting some of the flour using banana starch. Compared to the product that are made by using 100% wheat flour, products that are made by substituting some of the flour using banana starch have some differences in physical and chemical characteristics, digestibility, sensory properties and acceptability. This review article are meant to elaborate the uses of banana starch flour in food production and its effect to those products characteristics.

*Keyword : banana starch, banana flour, food product*

## 1. Introduction

Food processing is an effort that aims to change the shape of food, both agricultural and livestock crops, into the desired food products so that the food gets added value in terms of quality, acceptability and storage power. The food processing process can also provide a diverse diet for humans because by going through a processing process, a raw material can become several different products with different flavors, shapes, aromas and

colors. This can provide a variety of diets for consumers.

Food processing has been known since pre-historic times where the first food processing came from a hunting process which then social groups at that time used heat from fire or boiling water to make meat, roots and vegetables more suitable for consumption. The food processing process continues to develop until finally at the present time, the processing process becomes an obligation in industry and

trade as well as in ensuring food availability. Food processing has four objectives

1. To extend the period during which a food remains wholesome (the shelf-life) by preservation techniques that inhibit microbiological or biochemical changes and thus allow time for distribution, sales and home storage
2. To increase variety in the diet by providing a range of shapes, tastes, colours, aromas and textures in foods
3. To provide the nutrients required for health
4. To generate income for the manufacturing company and its shareholders (Fellows, 2000).

Starch, which is the main source of energy in most green plants, is a chemical compound that is very often used in food processing both as raw material and as a food additive. Starch can be used as a raw material in food products such as bread, biscuits, noodles, cookies, pasta and others while as food additives, starch can act as a filler, fat substitute, thickener and others.

The use of starch as the main ingredient in making products is an effort in the food processing process. This can change the shape of starch (flour) into a variety of products that can be consumed

by consumers. Sources of starch commonly used in various types of processing products made from starch are usually derived from wheat, corn and tubers. In addition to these ingredients, it was found that raw bananas can also be used as a potential source of starch

Banana (*Musa paradisiaca L.*) is a large grass species that can grow well in almost all tropical regions in Indonesia. Banana is a fruit that is widely produced in Indonesia, which according to the Central Bureau of Statistics (BPS), banana production has increased by 6.19 million tons in 2012 and on 2017, production of banana in Indonesia reached 7,162,685 ton. This figure far exceeds the production of other fruits such as mango, durian, oranges, papaya and pineapple.

According to research, starch derived from bananas is starch which is resistant to the attack of the  $\alpha$ -amylase enzyme found in the human digestive system. This is one of the hallmarks of banana starch compared to starch derived from cereals where the resistant starch (RS) can have a health effect on consumers so that it can make banana starch an added value for manufactured food products. Based on data from BPS and the fact that banana starch has a function on health, it can be seen that

banana starch can be used as an alternative raw material in making food products.

## 2. Characteristics of banana flour and banana starch

The composition of bananas undergoes a lot of drastic changes when it comes to maturity. According to (Von, 1950) there are eight stages towards maturity in bananas. These changes also occur in starch component which is the main component in raw bananas. The average starch content in the pre-climacteric stage has decreased from 70–80% to less than 1% in bananas that have experienced a climacteric end period. According to (Lii *et al.*, 1982; Fellows, 2000), changes in banana starch can be seen in table 1.

Flour and banana starch can be characterized based on their chemical and physical properties. Judging from its physical properties, XRD analysis, granule morphology, swelling volume, freeze-thaw stability, pasting properties and water absorbing capacity can be used as parameters.

### 2.1. XRD characteristic

The crystalline structure of starch can be detected by X-ray diffraction (XRD). Starches from different plant sources can be divided into A-, B-, and C-type sources according to their XRD patterns. Li *et al.* (2018), mined the comparison of physicochemical properties of starch found in banana meat and starch found in raw

**Table 1.** Characteristics of banana flour and banana starch.

Stage	Peel color	Starch (%)	Reducing sugar (%)	Sucrose (%)	Gelatinization temperature (°C)
1	Green	61.7	0.2	1.2	74–81
2	Green	58.6	1.3	6.0	75–80
3	Green/a trace of yellow	42.4	10.8	18.4	77–81
4	More green than yellow	39.8	11.5	21.4	75–78
5	More yellow than green	37.6	12.4	27.9	76–81
6	Yellow with a green tip	9.7	15.0	53.1	76–80
7	All yellow	6.3	31.2	51.9	76–83
8	Yellow few brown spots	3.3	33.8	52.0	79–83
9	Yellow/many brown spots	2.6	33.6	53.2	-

Based on these data, it can be seen that to extract large amounts of starch, raw bananas are the most appropriate ingredients.

banana peels. Its showed that crystalline structure for meat and banana peel had the same diffraction at 5.6 °, 15 °, 17 °, 22 °, and 24 ° 2θ which showed that banana starch had type B crystalline starch.

Cahyana *et al.* (2019), examined concerning the characteristics of XRD of natural and modified banana flour and showed that natural banana flour had an XRD pattern which showed a type B crystalline pattern characterized by small peaks at 5.51 °, peak strong at 15 ° and 16.95 ° with shoulder around 17.8 ° and broad peak at 22.98 ° 2 $\theta$  with relative crystallinity of 31.9%.

## 2.2. Granule morphology

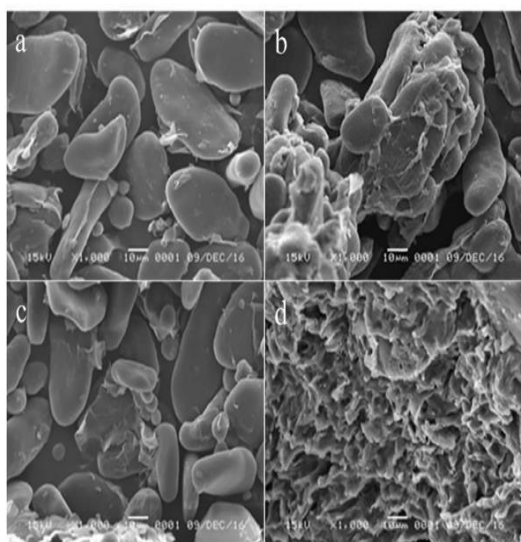
In general, banana starch has an irregular shape which when viewed under a microscope has an elongated oval shape with ridges. The main axis ranges from 6 to 80  $\mu\text{m}$ , mostly between 20 and 60  $\mu\text{m}$ . [6] examined the characteristics of starch from the Mysore variety banana which is still green and the result showed that it was beads with sizes and different shapes, wherein there is a predominance of the ellipsoidal shape with irregular diameters ranging between axes 10 and 100 micrometers and smooth surface. The particle size amounted area and perimeter averages of 277.67  $\mu\text{m}^2$  and 141.33 micrometers respectively. It was counted about 53 particles (Fontes *et al.*, 2017).

In addition, Fontes *et al.* (2017), revealed that the surface particles of banana starch and banana flour have

differences. Granules from banana flour have a rough surface while banana starch has a smooth surface. Differences in varieties can also cause different surface structures of starch granules and banana flour. Cavendish banana varieties and Awak bananas have the form of granules which are flat with impurities that are difficult to remove, thus preventing the enzyme from attacking the starch fractions of these two varieties. While the Dwarf Red variety has granules that tend to be oval in shape, long with smaller granule sizes. This facilitates the enzyme in attacking starch granules in the Red Dwarf variety banana so that the starch digestibility in this variety is higher (Bi *et al.*, 2017).

Differences in varieties can cause differences in the morphological properties of banana starch granules. Nimsung *et al.* (2007), suggested that the major radius of the NWS banana was around 40-45  $\mu\text{m}$ , the HTS 47-60  $\mu\text{m}$  variant and the 32-55  $\mu\text{m}$  KHS variety. Cahyana *et al.* (2019), showed in his research that green banana flour has the shape of a granule with a long and compact oval shape. The researcher also stated that there were changes that could be seen when modification efforts were made. Modified flour using heat-

moisture treatment (HMT) treatment resembled an amorphous mass with a cohesive structure and a less compact surface while DR-treated samples showed the presence of a similar cohesive structure with some holes on the surface. DR treatment resulted in much more aggregated granules with a more irregular granule surface than HMT treatment. These changes in morphology might cause a difference in enzymatic digestibility.



**Figure 1.** Flour which is the result of modified HMT has a more porous structure than the original banana flour. This affects the ability of the enzyme to hydrolyze starch in the digestive system.

### 3. Banana flour and starch in breadmaking

Bread, a staple food made mainly from flour and water, leavened by yeast and baked, is a very popular food throughout

history. Bread usually prepared by mixing wheat flour, which is high in gluten, with water and other ingredients such as fat and protein. Bread considered as high carbohydrate food with GI around  $74 \pm 2$  for whole meal bread. High GI can cause a rapid increase in glucose blood concentration.

According to Cahyana *et al.* (2019), unripe banana flour contains high amount of resistant starch (RS). This RS fraction of starch can be considered as a functional starch when added to food because RS can't be hydrolyzed by digestive enzyme and can pass human's digestive tract. This kind of starch considered to have many health benefits such as improved insulin sensitivity, lower blood sugar levels, reduced appetite and various benefits for digestion (Nugent, 2005). Considering health benefit of RS, some researchers tried to substitute some of the flour in bread-making using unripe banana flour.

#### 3.1. Chemical composition and digestibility

Noor *et al.* (2012), studied about composition, digestibility and application in bread-making of banana flour. They showed that banana flour has 73.36% starch and 14.52% dietary fiber as its highest constituents. There are two types

of starch in unripe banana called available starch (56.29%) and resistant starch (17.50%). They stated that in recent years, there has been a considerable interest in the possibility of improving control of diabetic patients by altering the glycemic impact of the carbohydrates ingested.

A tool for ranking foods with respect to their potential blood glucose raising is the glycemic index (GI) concept which leads to the preferred selection on “slow carbohydrate”. This team showed that there is significant difference in chemical composition between banana flour bread (BF) and control. It can be seen on Table 2.

**Table 2.** Chemical composition between banana flour bread (BF) and control.

Sample	BF bread	Control bread
Moisture	26.6 ± 0.87 <sup>a</sup>	13.7 ± 0.07 <sup>b</sup>
Ash <sup>b</sup>	3.3 ± 0.01 <sup>a</sup>	2.0 ± 0.0 <sup>b</sup>
Protein <sup>b,c</sup>	9.8 ± 0.02 <sup>a</sup>	4.1 ± 0.07 <sup>b</sup>
Lipod <sup>b</sup>	14.2 ± 0.96 <sup>a</sup>	18.4 ± 0.06 <sup>b</sup>
Total Starch <sup>b</sup>	63.1 ± 0.41 <sup>a</sup>	59.4 ± 0.16 <sup>b</sup>
As <sup>b</sup>	54.9 ± 0.15 <sup>a</sup>	59.1 ± 0.63 <sup>b</sup>
RS <sup>b</sup>	6.7 ± 0.07 <sup>a</sup>	1.0 ± 0.06 <sup>b</sup>
Dietary fiber <sup>b</sup>	5.1 ± 0.11 <sup>a</sup>	2.3 ± 0.09 <sup>b</sup>
Insoluble indigestible fraction <sup>b</sup>	22.3 ± 0.83 <sup>a</sup>	12.4 ± 0.55 <sup>b</sup>
Soluble indigestible fraction <sup>b</sup>	3.8 ± 0.19 <sup>a</sup>	5.9 ± 0.25 <sup>b</sup>
Total indigestible fraction	26.1 ± 0.92 <sup>a</sup>	18.4 ± 0.073 <sup>b</sup>

As seen on Table 2, BF bread has higher total indigestible fraction than control. This result shows that using banana flour in bread-making may be an

alternative for people with special caloric requirements. They also showed that BF bread has lower hydrolysis index (HI) and predicted glycemic index (pGI). This condition is caused by the present of resistant starch, dietary fiber and insoluble fractions in BF (Juarez-Gracia *et al.*, 2006).

**Table 3.** BF bread has lower hydrolysis index (HI) and predicted glycemic index (pGI).

Sample	HI (%) <sup>a</sup>	pGI (%) <sup>b</sup>
BF bread	65.1 ± 2.4 <sup>a</sup>	64.3
Control bread	81.9 ± 3.2 <sup>b</sup>	78.8
White bread reference	100 <sup>c</sup>	94

They also showed that DPPH scavenging activity of bread produced by substituting a part of flour using unripe banana flour is significantly higher than the control one. This shows high antioxidative effect of unripe banana flour.

### 3.2. Physical characteristics

Substituting wheat flour with banana flour can also increase water holding capacity of flour mixture. Noor *et al.* (2012), showed that by substituting 30% of wheat flour using banana flour can increase WHC up to 161 ± 0.02% compared to 100% wheat flour (WHC = 84±0.01%). This higher WHC value on

flour mixture using banana flour indicated high fiber content in banana flour because fiber can entrap more water. The high WHC of fibre rich flour is attributed to the higher number of hydroxyl groups found in the fibre structure, which tends to allow more water interactions through hydrogen bonding. This statement is in agreement with their total dietary fiber (TDF) analysis result. Control bread, which use 100% wheat flour, has  $2.24 \pm 0.11\%$  TDF while bread produced by substituting 30% of wheat flour using banana flour has  $5.65 \pm 1.31\%$  TDF (Noor *et al.*, 2012).

In term of physical quality, steamed white bread that use 30% banana flour has lower specific volume (3.67 mL/g) compared to 100% wheat bread (4.20 mL/g). This decrement in specific volume could be caused by the lack of gluten in bread that used 30% banana flour compared to control that used 100% wheat flour. This change can also be due to interaction between fiber and gluten as reported by Wang *et al.* (2002), who reported that by adding fiber from carob, pea and inulin decreased specific loaf volume of bread compared to the standard bread (861 mL for carob, 733 mL for inulin, 719 mL for pea fiber and 906 mL for control bread). The significant decrease

in loaf volume was attributed to lower gas retention as opposed to unsatisfactory production of gas (Jaroslaw, 2015).

In 2012, Ase *et al.* (2012), studied how unripe apple and unripe banana flour affecting the quality of bread. They showed that bread containing unripe banana flour (*Musa acuminata*) has lower specific loaf volume than control bread (Not using fruit flour) but has higher SLV than bread using unripe apple flour.

### 3.3. Sensory evaluation aspects

In term of sensory evaluation, Noor Aziah *et al* reported that by substituting 30% of wheat flour using banana flour did not affect aroma and taste of steam white bread significantly. They also reported that there is no significant difference in overall acceptability of steam bread that was made by substituting 30% of wheat flour using banana flour so it has high potential in marketability as a bread product with added functional value.

In terms of color, Juarez-Gracia *et al.* (2006) reported that bread using unripe banana flour has darker color than control bread ( $L^* = 38.67$ ) and has browner crust and crumb color. They also reported that sensory wise, bread using unripe banana flour is still acceptable (Ase *et al.*, 2012).

#### 4. Banana flour in pasta

Pasta is a type of food typically made from an unleavened dough of durum wheat flour (semolina) mixed with water or eggs, and formed into sheets or various shapes, then cooked by boiling or baking. Rice

texture, and taste of the cooked product (Zheng *et al.*, 2016).

##### 4.1. Cooking characteristics

Adding banana starch into pasta formulation increased the cooking loss and

**Table 4.** The cooking quality of the pasta.

Formulation	Cooking loss	Properties	Refs.
100% Semolina flour	$4.37 \pm 0.17\%$	-	Ovando-Martinez <i>et al.</i> (2009)
Semolina : BF	$5.28 \pm 0.16\%$		
85 : 15	$6.08 \pm 0.19\%$		
70 : 30	$6.17 \pm 0.33\%$		
55 : 45			
		<i>Cooking weight</i>	Hernandez-Nava <i>et al.</i> (2009)
100% Semolina flour	$6.25 \pm 0.02 \%$	$29.66 \pm 0.29$ g	
Semolina : BF	$6.36 \pm 0.03\%$	$29.91 \pm 0.19$ g	
95 : 5	$6.43 \pm 0.08\%$	$30.36 \pm 0.45$ g	
90 : 10	$7.13 \pm 0.13\%$	$30.97 \pm 0.35$ g	
85 : 15	$7.40 \pm 0.11\%$	$31.82 \pm 0.33$ g	
80 : 20			Zandonadi <i>et al.</i> (2012)
		<i>Cooking times</i>	
Standard Pasta	$4.48 \pm 1.22\%/mL$	6 minutes	
Modif. Pasta (60.6% wheat flour, 47% BF)	$12.75 \pm 1.98\%/mL$	8 minutes	

flour, or legumes such as beans or lentils, are sometimes used in place of wheat flour to yield a different taste and texture, or as a gluten-free alternative. Pasta is a staple food of Italian cuisine

Pasta products play an important role in human nutrition. They can be easily prepared, handled, cooked, and stored. The most important consumer attribute is the cooking quality of the pasta, which includes cooking time, water absorption,

cooking weight of pasta but decreased its firmness compared to the 100% semolina pasta. The loss in firmness in the spaghetti may be a direct effect of the possible increase in amylose loss during the cooking of spaghetti.

Ovando-Martinez *et al.* (2009), studied the cooking characteristics, specifically cooking loss, from pasta made from unripe banana starch. They reported that there is significant different in cooking loss between control and pasta with unripe



banana flour. The cooking loss increased with the rose of banana flour concentration. The cooking loss for control, 15% banana flour pasta, 30% banana flour pasta and 45% banana flour pasta are 4.73%, 5.28%, 6.08% and 6.17% respectively. Rayas-Duarte *et al.* (1996), stated that addition of non-gluten ingredient into pasta dough can lead into the dilution of gluten that can cause the leaching of more solid from pasta into the cooking water due to the weaker gluten network. Cooking loss of solids tests the amount of residue in the cooking water. Low cooking loss indicated high noodle cooking quality (Zhang *et al.*, 2007).

Hernandez-Nava *et al.* (2009), also studied the effect of banana starch addition to the cooking quality of pasta. They reported that by adding banana starch into pasta formulation increased the cooking loss and cooking weight of pasta but decreased its firmness compared to the 100% semolina pasta. The loss in firmness in the spaghetti may be a direct effect of the possible increase in amylose loss during the cooking of spaghetti.

Zandonadi *et al.* (2012), studied the cooking characteristics of pasta made using green banana flour. They showed that green banana pasta has higher water

absorption ( $401.73 \pm 18.86$  %) compared to the standard pasta ( $263.23 \pm 11.88$  %). They stated that this higher water absorption on green banana flour pasta can be caused by longer cooking time to completely gelatinized the green banana flour pasta. The modified pasta also has less firmness but higher stickiness compared to standard pasta. Green banana flour pasta also has higher solid loss ( $12.75 \pm 1.98$  %/mL) compared to standard gluten-free pasta ( $4.48 \pm 1.22$  %/mL). This higher solid loss due to the longer cooking time of green banana flour pasta.

They studied about how green banana flour used in gluten-free pasta. The recipe for whole wheat pasta they used is 60.6% whole wheat flour, 39.4% whole egg and for green banana pasta they used Green banana flour (47.0%), egg whites (31.5%), water (16.4%), guar gum (2.5%), and xanthan gum (2.5%). The using of egg white instead of whole egg in modified was very important because it can reduce lipid content and increase protein value since excluding gluten causing a loss of an important protein fraction that can affect sensory and technological characteristics of pasta products. Egg whites has a strong influence on the quality of gluten-free pasta products due to its high protein

content, which can be coagulated at low heat. The use of egg whites in the green banana flour pasta was important because they present good coagulation, easy access, and low cost. Besides the egg whites, the gums were also included to promote similar gluten characteristics because egg whites do not substitute gluten completely

#### 4.2. Chemical composition

In terms of chemical composition the modified pasta has a very low fat content. It loss more than 98% fat content compared to standard pasta. This reduction in fat can be an important matter for someone with celiac disease (CD) who are undergoing treatment since gluten-free products tend to have high level of lipids due to the removal of gluten. Green banana flour pasta, when compared to the gluten-free pasta made from rice flour and quinoa that are commercially available in Brazil, has lower calories (83 kcal for green banana flour pasta and 138.74 kcal for commercial pasta). This lower calories attributed by the higher content of resistant starch in green banana flour compared to wheat flour (Zandonadi *et al.*, 2012).

#### 4.3. Sensory quality and acceptability

Zandonadi *et al.* (2012), showed that green banana pasta has high acceptability since this modified pasta showed no significant difference in terms of appearance, aroma, flavor and overall quality. In fact, modified pasta is more acceptable by panelists with CD. They also observed that the modified pasta was better accepted than the standard pasta in aroma, flavor, texture, and overall quality, which indicates that this product can possibly be commercialized both to CD patients and non-CD individuals. The modified sample had greater sensory quality (84.5% for celiac individuals and 61.2% for non-celiac) than standard samples (53.6% for non-celiac individuals), according to all the analyses performed.

Agama-Acevado *et al.* (2009), studied the using of unripe banana flour in pasta. They reported that in terms of quality, pasta with unripe banana flour has slightly low lightness value, lower diameter. They concluded that the acceptability of unripe banana flour pasta is higher than their control pasta

**Table 5.** Color of spaghetti with banana flour.

Spaghetti	L*	a*	b*
Control	86.79 ± 0.8 <sup>a</sup>	1.33 ± 0.2 <sup>a</sup>	13.82 ± 0.4 <sup>a</sup>
15%	83.90 ± 0.6 <sup>b</sup>	1.54 ± 0.1 <sup>a</sup>	10.33 ± 0.6 <sup>b</sup>
30%	81.24 ± 0.5 <sup>c</sup>	1.08 ± 0.2 <sup>b</sup>	8.92 ± 0.3 <sup>c</sup>
45%	80.79 ± 0.8 <sup>c</sup>	0.97 ± 0.2 <sup>b</sup>	9.60 ± 0.4 <sup>c</sup>

Table 5 shows that the higher the concentration of unripe banana flour, the lower the lightness value are. This decrease in lightness is due to the production of pigments during the reaction of polyphenol oxidase (PPO) upon the phenolic compounds.

In terms of texture, adding unripe banana flour didn't give significant difference to hardness of cooked pasta but it gives significant difference to their adhesiveness. The addition of banana flour produced an increase in adhesiveness of the spaghetti, and the effect was higher when the banana flour amount rose in the pasta. In general, the elasticity and chewiness did not change with the addition of banana flour, although an appreciable increase in the chewiness was observed with the addition of banana flour in the composite (Agama-Acevedo *et al.*, 2009).

#### 4.4. Functionality and digestibility.

Zheng *et al.* (2016), studied the structural properties and digestion of green banana flour as a functional ingredient in pasta. They found that pasta formulations which contains green banana flour has a lower rates of digestion compared to wheat

pasta formulations. They stated that although green banana flour known as the source of resistant starch, in low-moisture product such like pasta, the properties of high enzyme resistance of unripe banana flour can be partially retained. Zhang *et al.* (2007) and Dhital *et al.* (2015) "The enzymic susceptibility of starch in processed foods are affected by the ability of enzymes to access the substrate (physical barrier) as well as the surface and internal structural features of substrates limiting the binding and sub-sequent catalysis (micro- and macro structural barrier)"(Zheng *et al.*, 2016).

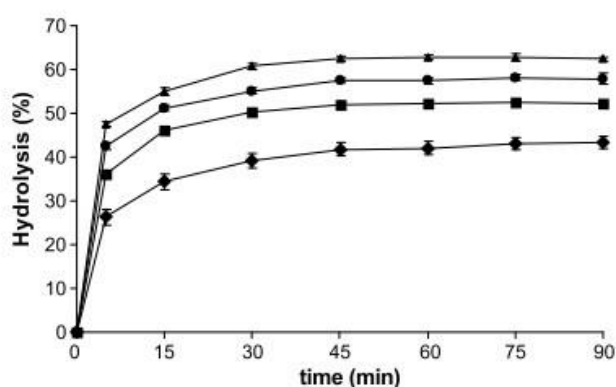
The same result also showed by <sup>[16]</sup> In pasta that were using banana flour as the partial ingredient, the indigestible fraction is much higher than the 100% semolina pasta (Table 6). RS content in pasta containing unripe banana flour is also higher than semolina pasta. This can lead to the development of functional pasta as RS has several functionality as stated before.

**Table 6.** The indigestible fraction semolina pasta.

Sample	RS	Indigestible fraction	
		Insoluble	Soluble
Control	1.11 ± 0.02	10.78 ± 0.57	5.12 ± 0.30
15% BF	2.84 ± 0.04	14.45 ± 0.48	4.19 ± 0.31
30% BF	6.45 ± 0.16	17.51 ± 0.54	3.87 ± 0.49
45% BF	12.42 ± 0.16	26.18 ± 0.26	3.37 ± 0.22

Source: <sup>[9]</sup>

In terms of in vitro hydrolysis, pasta with banana flour show a slower rate of digestibility (Figure 2). Control spaghetti showed the highest enzymatic hydrolysis rate, and this rate decreased when banana flour in the composite spaghetti increased. At 15 min of reaction, the hydrolysis percentage increased very quickly for all the samples studied. Thereafter, hydrolysis increased slowly and after 30 min of reaction a plateau was reached.



**Figure 2.** Average in vitro starch hydrolysis curves of cooked spaghetti. (▲) control, (●) 15% BF, (■) 30% BF and (◆) 45% BF.

As shown in figure 2, the control pasta underwent approximately 55% of hydrolysis at 15 min while pasta with

banana flour underwent slower hydrolysis than control (35% hydrolyzed at 15 min for pasta with 45% BF). This pattern is in agreement with RS content in pasta containing banana flour.

### 5. Banana flour and starch in cookies making

Cookies is a small cakes that is baked. It contains basically the same ingredient as cake except in moisture and fat content. Cookies has low amount of water and high amount of fat. In United Kingdom, cookies are called biscuits. In cookies-making, gluten formation is not that important so we can use either high-protein flour or low-protein flour. High-protein flour usually gives thin and crisp cookies and low-protein flour can give a puffy, soft cookies (Brown, 2011).

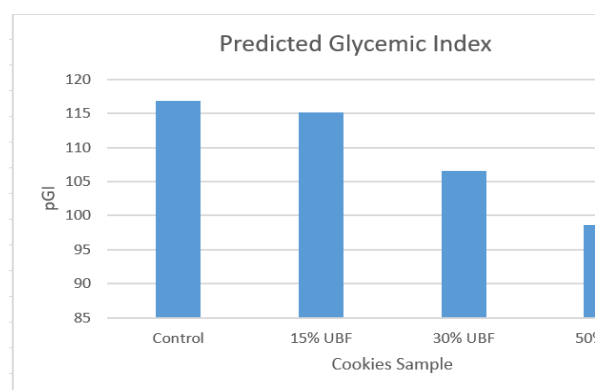
As mentioned before, banana starch and flour has functional aspect due to its high RS content. Substituting several part of flour in cookies-making using banana starch and banana flour can add some functionality in it as stated by Erez and Ayago-ayerdi (2004). These authors stated that cookies that are made by replacing corn starch using banana starch has higher content in RS. The “Pasta seca” cookies with corn flour has  $0.92 \pm 0.1\%$  RS while

cookies with banana starch has  $4.9 \pm 0.5\%$  RS fraction.

This high RS fraction in cookies with banana flour has an influence to its digestibility. The same authors also reported that cookies that used banana starch has slower digestibility than cookies using corn starch. These result showed that by replacing corn starch using banana flour can reduce digestibility in cookies and it can have a functionality to human health (Erez and Ayago-ayerdi, 2004).

Aparico *et al.* (2007), also studied how banana starch affect digestibility on cookies. These authors using 44.9 g of wheat flour as control and developed cookies with four kinds of formulations using resistant starch-rich powder (RSRP) in different levels. The first formulation is using 15.7 g wheat flour and 29.2 RSRP (35:65). The second one is 11.2 g of wheat flour and 33.7 RSRP (25:75). The third one using 6.7 g wheat flour and 38.2 g RSRP (15:85) and the fourth one using 4.5 g wheat flour and 40.4 g RSRP flour (10:90). As for the chemical composition, cookies with RSRP has higher total indigestible fraction (TDF) than control ( $23.4 \pm 0.73\%$  for RSRP cookies and  $16.8 \pm 0.92\%$  for control). This result is in agreement with many study that are stated

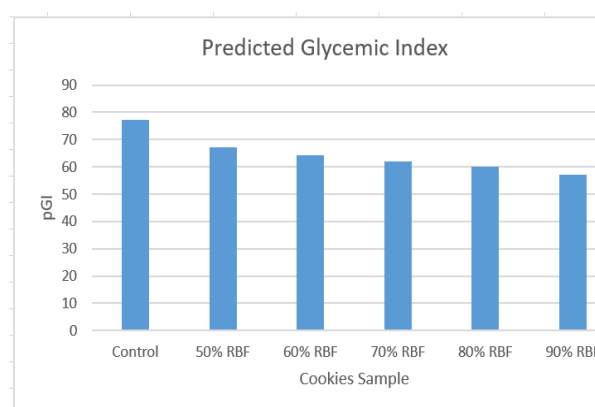
that banana starch contains high indigestible fraction called RS and this higher TDF content has a correlation to the digestibility of the cookies itself. The digestibility can be measured using hydrolysis index (HI) and predicted glycemic index (pGI). Control cookies has HI about  $80.54 \pm 2.64$  and pGI 77.62 while cookies with RSRP has HI around  $60.71 \pm 2.28$  and pGI 60.53. This result shows that cookies with banana starch that is rich in RS is less susceptible to  $\alpha$ -amylase enzyme and can be considered as a product with moderate GI. Agama-Acevedo *et al.* (2012), studied starch digestibility and glycemic index of cookies partially substituted with unripe banana flour.



**Figure 3.** Predicted glycemic index of cookies (Juarez-Gracia *et al.*, 2006)

They reported that cookies with unripe banana flour has lower pGI as shown in figure 3. According to figure 3 it can be known that pGI is decreased as the concentration of unripe banana flour

increased (Agama-Acevedo *et al.*, 2012). This result is also in agreement with study done by Cahyana and Restiani (2018). They stated that cookies with added modified banana flour in it has lower glycemic index as shown in Figure 4.



**Figure 4.** Glycemic index for cookies partially substituted with retrograded banana flour (RBF)(Wang *et al.*, 2002)

## 6. Conclusion

Compared to the product that are made by using 100% wheat flour, products that are made by substituting some of the flour using banana starch have some differences in physical and chemical characteristics, digestibility, sensory properties and acceptability.

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