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Effect of mannitol and sago starch on the qualities of frozen dough pizza from rice-pregelatinized cassava flour

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Abstract

Globally, the baking industry is creating gluten-free pizza, due to celiac disease which restricts the use of wheat flour. Cassava flour, rice flour, and sago starch are potentially substituted for wheat in the pizza dough. Gelatinization may alter the characteristics of native sago. Frozen pizza dough accelerates service. Mannitol preserves yeast by maintaining moisture during freezing storage, hence enhancing the quality and shelf life of dough. The purpose of this research was to determine the ideal formula by analyzing the physical properties of dough (development volume), pizza products (development volume, hardness, springiness and chewiness), and organoleptic products (appearance, smell, taste, texture, crumb uniformity and overall acceptance). This study utilized sago starch (native and extruded) and mannitol (0, 1 and 2%) for the dough, and stored it at -4°C for 6 days. Physical characterization and organoleptic evaluations suggested that formula 3 (adding native sago starch +2% mannitol), and formula 5 (adding extruded sago starch +1% mannitol) were the optimal pizza base compositions. Formula 3 was 85.11 gf in hardness, 2.15 mm in springiness, and 1.35 mJ in chewiness. Formula 5 exhibited a hardness of 85.94 gf, a springiness of 2.16 mm, and a chewiness of 1.40 mJ. On the basis of organoleptic evaluations of flavor, texture, and crumb consistency, panelists appreciated Formula 5. Due to the absence of gluten, the non-wheat pizza crust exhibits a more fractal and elliptical crumb microstructure.

1. Introduction

The bakery business is presently beginning to grow and expand globally by creating a variety of bread products, including well-known pizza. Pizza is a flatbread created from wheat flour, water, sugar, yeast, and olive oil or fat through the dough forming, fermentation, and baking processes (Dinson and Zubaidah, 2015). Nearly every nation has fast-food establishments that sell pizza with a variety of toppings (Asghar *et al*., 2012). These pizzas often use dough that has been frozen so that it may be prepared more quickly. This frozen dough technology was expanding quickly in the food industry (Omedi *et al*., 2019). The advantages of utilizing frozen dough for industry and restaurants are that it may save dough-making time, lower the number of trustworthy employees in each restaurant, and make fresh bakery items accessible every day (Terentyev and Labutina, 2022). In addition, frozen storage may lengthen the shelf life of dough (Omedi *et al*., 2019; Ding and Yang, 2021), enabling it to be transported to distant regions (Asghar *et al*., 2012).

Wheat gluten is often used to make pizza dough because it contains proteins that may produce gluten. The protein in wheat flour that is insoluble in water will absorb water and produce gluten when mixed, allowing the dough to expand as a result of fermentation. Gluten consumption by patients with celiac disease may trigger overactive immune responses and damage the small intestine of the patient (Shaaker, 2021). Celiac disease sufferers may enjoy pizza if non-wheat pizza dough is produced. The local flour that is potentially utilized in place of wheat flour is a mixture of cassava flour, rice flour, and sago starch. Cassava flour contributes to the

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high carbohydrate content in pizza dough, around 85.6% (Akubor and Gambo, 2020). Modified cassava flour could be used in bread product to modify and stabilize the texture of bread (Ratnaningsih *et al*., 2019; Akubor and Gambo, 2020). Rice flour is one of the native flours that has hypo-allergenic qualities or at least produces allergies (Asghar and Zia, 2016), thus it may be used to make pizza dough without wheat. The carbohydrate content of sago starch is greater than the carbohydrate content of wheat flour, which is 77.30% (Sumardiono *et al*., 2022). Gelatinized sago starch may alter starch properties including syneresis value and starch digestibility (Schmiele *et al*., 2019; Sumardiono *et al*., 2022). Extrusion may be used to modify sago starch because it offers various benefits, including high production and inexpensive cost (Schmiele *et al*., 2019).

Pizza dough's shelf life may be prolonged by freezing, despite the fact that its quality and physical properties may degrade during storage. Mannitol is a sugar alcohol that protects yeast in bread dough when it is frozen (Sahin *et al*., 2018). Mannitol may function as an osmoprotectant and has the capacity to bind water when protein and starch in frozen dough release water (Asghar *et al*., 2012). This form of polyol has the potential to enhance the quality and physical properties of pizza dough by decreasing the mobility of water during storage at freezing temperatures. Asghar *et al*. (2012) found that the addition of 2% mannitol (based on flour weight) may enhance physical features such as dough being softer, easier to expand, and more stable, as well as the panelist's perception of the overall sensory quality. Due to poor absorption and a little laxative impact, the sugar alternative has less calories than sucrose. Polyols have a lower glycemic response than sucrose or glucose since it is incompletely digested (Ding and Yang, 2021).

This study aims to investigate the effect of using different sago starches (native and extruded) and the addition of mannitol on the physical properties of dough, and non-wheat pizza crust products, as well as the sensory and chemical properties of non-wheat pizza crust products, and to determine the optimal formula for dough and non-wheat pizza crust products. This study is anticipated to examine the quality and characteristics of frozen dough and non-wheat pizza crust goods.

2. Materials and methods

2.1 Raw materials

The research utilized pizza-making materials, including pregelatinized cassava flour, rice flour, native sago starch, and extruded sago starch which obtained from ICAPRD in Bogor, Indonesia; sugar (Gulaku brand), yeast (Fermipan brand), margarine, milk powder (Dancow brand), xanthan gum, bread improver, and eggs which bought from local market in Bogor, Indonesia; water, mannitol (Qingdao Bright Moon Seaweed Group Co. Ltd.); and analyzing materials, including aquades, hexane (Merck), HCl (Merck), H_2SO_4, HgO, K_2SO_4, NaOH, H_2BO_3, KI, $Na_2S_2O_3$, ethanol, KOH, dinitrosalicylic acid (Sigma-Aldrich), alpha-amylase enzyme (Sigma-Aldrich), maltose standard (Merck), RS kit assay (Megazyme K-RStar).

The research also used a double screw extruder (Berto BEX-DS-2256), pin disc mill 2850 rpm, Ro-Tap 100 mesh vibrating screen, hand mixer, scales, bread maker (Re-bread), freezer, final proofer (Heng Wei), oven (Memmert), and analytical equipment, including texture analyzer (CT3-4500 Brookfield), Rapid Visco Analyzer (S4 Newport Scientific Pty.), Scanning Electron Micrograph (Zeiss Evo MA 10), proximate analyzer, starch content, starch digestibility, and resistant starch test device.

2.2 Flour preparation and sago starch extrusion

Cassava flour was pregelatinized using a drum dryer at 70°C (Ratnaningsih *et al*., 2019) before being weighed and formulated. Rice flour and native sago starch were also weighed and formulated.

For the extruded sago starch making, the native sago starch was sifted through an 80-mesh sieve, then 30% of the starch weight was added with water. Starch and water were mixed for 3 min by hand mixer. Then the combination of sago starch-water was fed into a double screw extruder under the following condition: barrel I (feed) temperature of 90°C, barrel II (compression) temperature of 90°C, barrel III (metering) temperature of 70°C, and screw rotation speed of 151 rpm. After milling the sago extrudate using a pin disc mill, the extruded sago starch was sieved through a 100-mesh vibrating sieve.

2.3 Formulation of pizza dough and manufacturing pizza crust

The pizza formula used in this research referred to Asghar *et al*. (2012) for frozen pizza added with mannitol and sago starch with some modifications. The design of the non-wheat pizza formula is presented in Table 1.

Non-wheat pizza manufacturing from frozen dough following Asghar *et al*. (2012) with modification. The yeast was dissolved in warm water (35°C), and sugar was added. To activate the yeast, the solution was left to stand for 5-10 min until foam appeared. Then milk, eggs, and melted margarine were added to the solution, which was then mixed with Re-Bread. Pre-gelatinized cassava,

Table 1. Design of non-wheat pizza dough formula.

Ingredient	Total (g)					
	F1	F2	F3	F4	F5	F6
Pre-gelatinized cassava flour	100*	100*	100*	100*	100*	100*
Rice flour	80*	80*	80*	80*	80*	80*
Sago starch (native)	20*	20*	20*	--	--	--
Sago starch (extruded)	--	--	--	20*	20*	20*
Sugar	6*	6*	6*	6*	6*	6*
Yeast	3*	3*	3*	3*	3*	3*
Water	250	250*	250*	250*	250*	250*
Milk powder	25*	25*	25*	25*	25*	25*
Eggs	60*	60*	60*	60*	60*	60*
Bread improver	0.6*	0.6*	0.6*	0.6*	0.6*	0.6*
Liquid margarine	40*	40*	40*	40*	40*	40*
Xanthan gum	5*	5*	5*	5*	5*	5*
Mannitol	0**	1**	2**	0**	1**	2**

*Based on the percentage of total flour used.
**variable variables in experimental design.

rice flour, sago starch, mannitol, xanthan gum, and bread improver were added to the dough, and the mixing continued. The dough was then divided and weighed (65 g per pan), placed on the baking sheet, rested (30 mins, with cloth covered at room temperature), packed on the zip plastic bag, frozen (-18°C for 6 days), thawed (45 min, room temperature), proofed (35 min, 35°C, RH 85%), and roasted (30-40 mins, 190°C).

2.4 Determination of two best formula

The two best formulas in this experiment were decided based on the high values of dough development volume, product development volume, and springiness, but low hardness and chewability, and achieving high hedonic values in all dimensions.

2.5 Analysis procedure

2.5.1 Color analysis of sago starch

The colors of sago starch were assessed using a chromameter (Wang *et al*., 2020), as L* (lightness), a* (redness/greenness), and b* (yellowness/blueness) values. Then, Hue as displayed the eye-visible color group was defined as sum of wavelengths that a surface can reflect (Cazzaniga *et al*., 2021), and was determined using equation:

$$\text{Hue}(°) = \tan^{-1}\frac{a^*}{b^*}$$

Degree of whiteness was calculated by equation (Ratnaningsih *et al*., 2019):

$$\text{Degree of whiteness (\%)} = 100 - \sqrt{(100 - L^*)^2 + a^{*2} + b^{*2}}$$

2.5.2 Mixed flour pasting profile analysis

The method described by Vatanasuchart *et al.* (2012) *was followed.* The color 3 g of sample was mixed with 25 mL of distilled water (canister). The sample was spun for 1 min at 160 rpm (960 rpm for the first 8 s) and 50°C. The temperature was raised from 50 to 95 for 8.5 mins. 5 mins at 95°C (up to 13.5 min). After heating for 21 mins, the temperature was decreased to 50°C, and held for 2 min (until the 23rd min). Initial pasting temperature and time, peak viscosity, hot paste viscosity, breakdown viscosity, final viscosity, and setback viscosity were measured.

2.5.3 Dough expansion volume

Dough expansion volume was examined by following equation:

$$\text{Dough expansion volume} = \frac{B - A}{B} \times 100\%$$

Where A = volume of dough after mixing (cm^3) and B = volume of dough after proofing (cm^3).

2.5.4 Product development volume

Product development volume was determined by following equation:

$$\text{Product development volume} = \frac{B - A}{B} \times 100\%$$

Where A = volume of dough after mixing (cm^3) and B = volume of product after baking (cm^3).

2.5.6 Texture analysis

Pizza textures were studied using texture analyzer (Pro CT V1.2 Brokfield Inc.). Pizza texture investigation employed a 38.1 mm TA4/1000 plunger and a TA-BT-KIT base plunger. Non-wheat pizza samples were sliced lengthwise and cubed to 20×20×20 mm^3. Texture profile analysis produced a curve showing the connection between strength and time and data program. Hardness (gf), springiness (mm), and chewiness (mJ) were measured.

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2.5.7 Sensory analysis

The sensory test was a hedonic rating test on samples of non-wheat pizza, for appearance, aroma, taste, texture, crumb uniformity, and overall acceptance using a seven-point scale: 1. extremely dislike, 2. dislike, 3. somewhat dislike, 4. moderate, 5. somewhat like, 6. like, 7. like a lot. The 70 untrained panelists were employed. Pizza samples were coded randomly, and panelists were examined the samples from left to right.

2.5.8 Proximate analysis

Moisture, ash, protein, and fat content were examined using AOAC methods (AOAC, 2016). The moisture content was determined using oven drying procedure (AOAC procedure 925.10). Dry ashing technique according to AOAC 923.03 was used to evaluate the ash content. Protein content was measured using Kjeldahl method (AOAC 991.20), using 6.25 conversion factor. Fat content was assessed using Soxhlet technique following AOAC 922.06 procedure. Carbohydrate was measured using by-difference technique.

2.5.9 Starch content and starch digestibility in vitro analysis

Total starch content was measured using the Luff-Schroll methods following AOAC 1995 method (Vatanasuchart *et al*., 2012). Starch digestibility in vitro was investigated following Vatanasuchart *et al*. (2012) procedure. 1 g sample was dissolved in 100 mL of distilled water, heated to 90°C, and cooled. Approximately 2 mL of solution was mixed with 3 mL distilled water and 5 mL pH 7 phosphate buffer. Each sample had a blank clone. 15 mins at 37°C were spent incubating closed tubes. Sample solution got 5 mL of α-amylase enzyme solution (1 mg/mL in phosphate buffer pH 7), whereas blank solution received phosphate buffer pH 7, 30 mins incubation. 1 mL of incubation mixture was added to 2 mL of DNS (dinitrosalicylic acid), boiled for 12 mins, then chill. 10 mL of distilled water increased absorbance to 520 nm. In vitro starch digestibility was assessed by comparing the maltose content of the sample to pure maltose starch.

2.5.10 Resistant starch analysis

The resistant starch was measured using Megazyme Resistant Starch Assay Kit (K-RSTAR) using AOAC method (Zailani *et al*., 2022). The samples were treated with a pancreatic α-amylase mixture for 16 hrs in a shaking incubator (200 strokes/min, 37°C). The mixture was rinsed with ethanol and centrifuged to remove the non-resistant starch fraction. In an ice bath with agitation, the pellet was then treated with potassium hydroxide (2 M). The mixture was then treated with sodium acetate buffer (1.2 M, pH 3.8) and α-amylase solution (3000 rpm, 10 min) before being heated at 50°C for 20 mins. The resistant starch concentration was then determined using glucose oxidase/peroxidase (GOPOD) solution and a UV-Vis spectrophotometer at absorbance 510 nm. The standard and blank were D-glucose and sodium acetate buffer (0.1 M, pH 4.5), respectively.

2.5.11 Microstructure analysis

Pizza crumb microstructure was examined using scanning electron microscopy (Zeiss EVO MA10) (Torbica *et al*., 2019). Pizza was cut into 4×4×4 mm^3 cubes. The perimeter and center were cube-cuttable. The samples were freeze-dried for 12 hrs, then gold-coated for one minute at 20 mA before being put in a vacuum chamber. Fired with kV electrons. The filament was spun till saturation. The snapshot was 25x magnified.

2.6 Statistical analysis

The data were analyzed using two-way ANOVA consisting two factors, type of sago starch (native and extruded) and concentration of mannitol (0, 1 and 2%), followed by Duncan's multiple range tests at $p<0.05$ level.

3. Results and discussion

3.1 Color of sago starch and pasting profile of mixed-flour

3.1.1 Color of native and extruded sago starch

Visual appearance of native and extruded sago starch can be seen in Figure 1. Native sago starch showed a lightness value (L*) of 98.71 and a degree of whiteness of 93.66 (Table 2). The value of lightness and whiteness of native sago starch was greater than extruded sago starch because extruded sago starch had gone through a preheating process so that it has a slightly brownish color. The hue value showed the position of the sample color on the color chart obtained from the conversion of a* and b* values on the chromameter. The hue value of sago starch ranged from 81 to 82 (Table 2), which was in the yellow–red range (54°-90°).

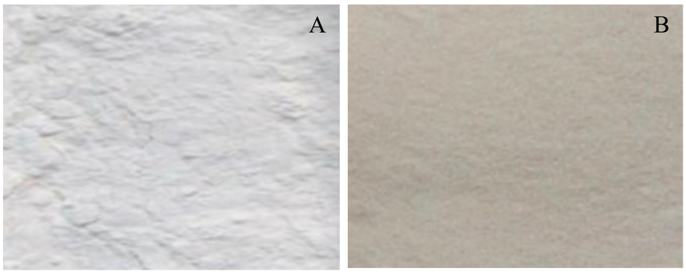

Figure 1. The visual appearance of (A) native sago starch and (B) extruded sago starch.

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Table 2. Color values of native and extruded sago starch.

Parameters	Native sago starch	Extruded sago starch
Lightness value (L*)	98.71^{a}	97.85^{b}
Hue value (°)	82.04^{a}	81.94^{a}
Degree of whiteness (%)	93.66^{a}	89.31^{b}

Values with different superscripts are statistically significantly different ($p<0.05$).

3.1.2 Pasting profile of mixed-flour

The mixed flour in the pizza formula consists of mixture flour I (rice flour + pregelatinized cassava flour + native sago starch), and mixture flour II (rice flour + pregelatinized cassava flour + extruded sago starch). The pasting profile results can be seen in Table 3 and Figure 2.

Table 3. Pasting profile of mixed flour (pregelatinized cassava flour + rice flour + sago starch).

Parameters	Flour type	
	Mixed flour I	Mixed flour II
Starting time of pasting (mins)	2.80	1.78
Initial pasting temperature (°C)	71.80	14.90
Peak viscosity (cP)	2285.50	1229.00
Hot paste viscosity (cP)	1573.00	998.00
Final viscosity (cP)	2185.30	1354.00
Breakdown viscosity (cP)	712.50	231.00
Setback viscosity (cP)	100.20	125.00

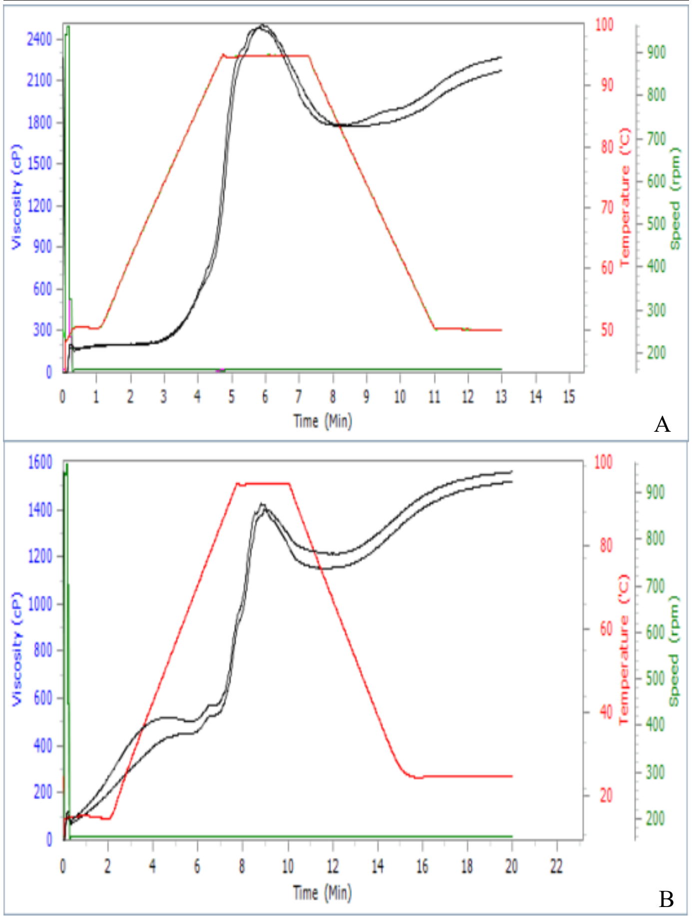

Figure 2. Pasting profile of (A) mixture flour I, and (B) mixture flour II analyzed using Rapid Visco Analyzer.

The results of the RVA analysis showed that the mixture flour I has a higher pasting time and initial temperature value than the mixture flour II was 2.80 mins and 71.80°C. The initial time of pasting indicated the ease with which the starch will form a paste. The lower initial time and temperature of pasting flour mixture II was caused by the addition of extruded sago starch which had undergone a previous gelatinization process. The gelatinization process begins with the expansion of starch granules because water penetrates into the granules and was trapped in the amylose and amylopectin structures. The initial gelatinization process experienced by flour will make hydrogen bonds attracted to the negative charge of oxygen atoms from other hydroxyl groups so that hydrogen bonds are weakened (Wang *et al.*, 2021). The molecular hydrogen bonds of the weak starch granule structure can affect the starch granule to expand faster, so that the temperature of the formation of paste in the flour mixture II was lower (Schmiele *et al.*, 2019).

Mixed flour I had higher peak and hot paste viscosity values of 2285.50 cP and 1573.00 cP, respectively. The peak viscosity value indicated the ability of starch granules to maintain swelling during heating (Li *et al.*, 2022). The decrease in peak viscosity in mixed II flour can be caused by the swollen granules becoming very brittle and breaking when they start to swell. Amylose was forced to straighten out thereby reducing the shear force between the liquid suspensions and causing a decrease in viscosity (Matsumoto *et al.*, 2022). The peak viscosity value was influenced by various factors, including amylose content, fat content, and granule size (Wang *et al.*, 2021).

Breakdown viscosity was a viscosity value that indicate the stability of starch paste against heating and stirring. Mixed flour I and mixture flour II had breakdown viscosity values of 712.50 cP and 231.00 cP, respectively. A high breakdown viscosity value indicated that starch was more heat resistant during processing (Wang *et al.*, 2021). The setback viscosity showed a tendency of retrogradation and potential for gelling. If the value of setback viscosity was larger, the propensity of starch in retrogradation will also be stronger (Li *et al.*, 2022). Setback viscosity was the difference between 50°C viscosity and maximum viscosity during heating. Mixed flour II had a setback viscosity value of 125.00 cP, so the final product tended to be drier after storage because amylose molecules had a tendency to re-bond to each other.

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3.2 Dough expansion volume, product development volume, texture profile, and sensory values of non-wheat pizza

3.2.1 Dough expansion volume

The addition of native and extruded sago starch and mannitol concentration affected dough expansion ($p<0.05$), but their interaction did not. This means that native and extruded sago starch were independent of mannitol content.

Extruded sago starch increased dough expansion volume by 195.79%, compared to native sago starch, 156.54%, shown in Figure 3. Extruded sago starch had a decreased pasting viscosity due to its broken starch structure (Wang *et al*., 2021). Less viscosity in starch helped dough expand (Li *et al*., 2022). Lower viscosity dough was easier to press with fermented CO_2. Xanthan gum, one of ingredient, also affected dough volume. Xanthan gum form a thin layer with starch to mimic gluten in non-wheat bread (Asghar and Zia, 2016). The more xanthan gum bond to starch, the harder it is to press the dough with CO_2.

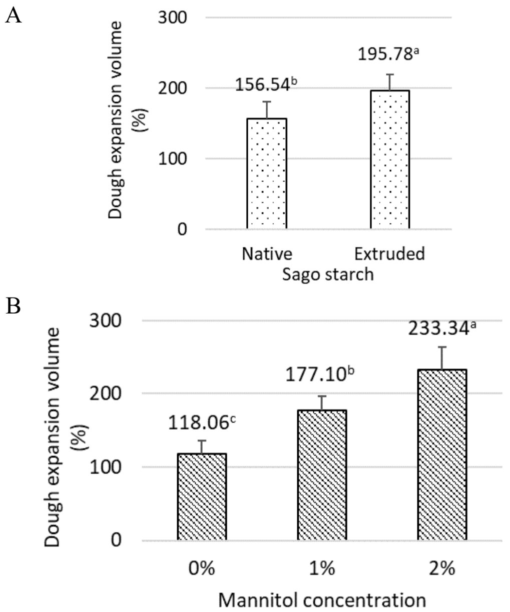

Figure 3. Dough expansion volume (%) of non-wheat pizza in different: (A) types of sago starch, and (B) mannitol concentration. Bars with different notations are statistically significantly different ($p<0.05$).

Higher mannitol concentrations enhanced dough expansion ($p<0.05$). The dough expanded 177.10% and 233.33% with 1% and 2% mannitol, respectively. Mannitol may preserve yeast when dough was frozen by binding water to retain yeast cell volume and minimizing excessive osmosis. This allowed the dough to expand more during proofing (final fermentation) since more yeast survived the freezing process (Asghar *et al*., 2012). Asghar *et al*. (2012) found that adding 1% and 2% mannitol to frozen wheat pizza dough increased dough stability, expansion time, and water binding.

3.2.2 Product development volume

Non-wheat pizza crust development followed dough expansion. More dough implies more baked product produced. Figure 4 shows the influence of native and extruded sago starch on the non-wheat pizza crust development volume, and the effect of mannitol on non-wheat pizza crust development volume. Addition of sago starch (native and extruded) and mannitol concentration had a significant influence on product development volume ($p<0.05$), but did not the interactions. It means that native and extruded sago starch levels were independent of mannitol content.

Pizza crust product using extruded sago starch had a higher product development volume, 250.62%, Figure 4. It corresponded to dough expansion volume. With extruded sago starch added to dough, product development volume increased. Armanto and Nurasih (2008) found that when sour cassava viscosity decreased, bread production rose. Application of mannitol increased product volume ($p<0.05$). Higher mannitol concentration increased product volume because more yeast survived (Asghar *et al*., 2012). Developing product required additional CO_2 gas. Non-wheat pizza crust with 1%, and 2% mannitol exhibited higher product development volume. It was in line with Asghar *et al*. (2012) that 1–2% mannitol application to frozen dough increased its volume.

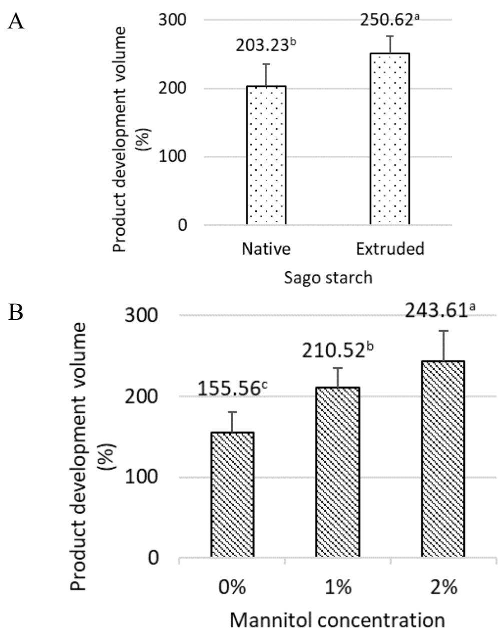

Figure 4. Product development volume (%) of non-wheat pizza in different: (A) types of sago starch, and (B) mannitol concentration. Bars with different notations are statistically significantly different ($p<0.05$).

3.2.3 Texture profile

Pizza crust should be soft, the higher pizza hardness required more energy to digest. Figure 5 exhibited the hardness impact of native and extruded sago starch with

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mannitol inclusion. Application of native and extruded sago starch and mannitol concentration had a significant influence on product hardness ($p<0.05$), as did their interaction. The levels of distinct sago starch components (native and extruded) relied on the mannitol concentration factor. Non-wheat pizza crust with extruded sago starch had a lower hardness of 84.22-126.17 gf, whereas non-wheat pizza crust with native sago starch had a greater hardness of 85.11-230.67 gf (Figure 5). Development volume affected product hardness. As dough and product volume increased, product hardness decreased, requiring less energy to press. Failure to stretch the dough may increase gas-filled holes and hardness (Terentyev and Labutina, 2022). Adding native sago starch to pizza crust product with xanthan gum bound additional starch to the dough. More xanthan gum-bound starch stiffens the coating (Asghar and Zia, 2016). 1% and 2% mannitol may promote dough expansion, reducing product hardness (Sahin *et al*., 2018). Capacity of mannitol to prevent yeast from over-osmosing during freezing may increase CO_2 production and dough compression. The non-wheat pizza crust with mannitol and native sago starch had a hardness value of 85.11 gf-149.28 gf, while mannitol and extruded sago starch had a hardness value of 84.22-85.94 gf.

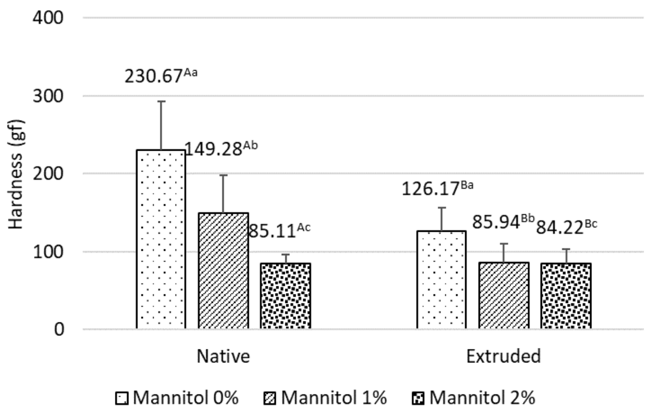

Figure 5. Hardness (gf) of the non-wheat pizza crust. Values with different uppercase superscripts are statistically significantly different ($p<0.05$) between the type of sago starch while values with different lowercase superscripts are statistically significantly different ($p<0.05$) between the mannitol concentration.

Pizza crust springiness was its ability to return to its original position after compression (Ding and Yang, 2021). Higher elasticity improved pizza crust texture. Figure 6 shows how sago and mannitol affect product elasticity. The addition of different types of sago starch (native and extruded) and the concentration of mannitol significantly affected the springiness ($p<0.05$), as did their interaction. This showed that the two factors were dependent, so the level of native and extruded sago starch depended on mannitol concentration. Springiness opposed hardness. Hardness decreased springiness. Pizza crust ranged from 1.55 to 2.15 mm with native sago starch, and 1.66 to 2.46 mm with extruded sago starch, Figure 6. Pizza crust with extruded sago starch had a higher elasticity value because the dough expanded more easily and the product was softer, so it easily returned to its initial position after first compression (Matsumoto *et al*., 2021). Addition of 1% and 2% mannitol increased product springiness ($p<0.05$). Extruded sago starch and 2% mannitol provided pizza crust the highest springiness 2.46 mm, while native sago starch and no mannitol provided the lowest springiness 1.55 mm. Without mannitol in the dough, the yeast could not survive the freezing process, reducing expansion and elasticity (Sahin *et al*., 2018).

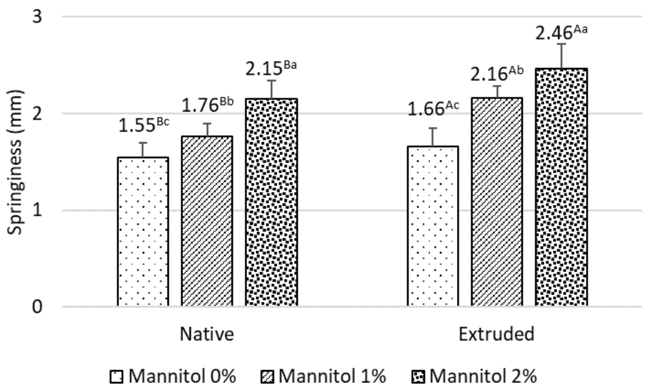

Figure 6. Springiness (mm) of the non-wheat pizza crust. Values with different uppercase superscripts are statistically significantly different ($p<0.05$) between the type of sago starch while values with different lowercase superscripts are statistically significantly different ($p<0.05$) between the mannitol concentration.

Chewing power was a textural analysis measure that reflects the energy needed to chew a product before swallowing (Sahin *et al*., 2018; Ding and Yang, 2021). Figure 7 demonstrates how sago starch and mannitol affect chewability. The addition of native and extruded sago starch and mannitol concentration had a substantial influenced on chewing power, as did their interaction. These two elements affect non-wheat pizza crust chewing strength. This illustrated that the two components were dependent, hence the amount of native and extruded sago starch relied on mannitol concentration. Non-wheat pizza crust with native sago starch had a chewability value of 1.35 mJ to 3.0 mJ, whereas non-wheat pizza skin with extruded sago starch had a chewability value of 1.33 mJ to 1.88 mJ, Figure 7. Lower starch viscosity may enhance expansion, reducing chewing strength (Ding and Yang, 2021). Hardness directly affected chewing power. Chewing power decreased with the hardness. More mannitol reduced chewing energy by softening the product. Adding 1% and 2% mannitol significantly increased chewability ($p<0.05$). Extruded sago starch and 2% mannitol had the lowest chewability of 1.33 mJ, whereas native sago starch with no mannitol had the maximum chewability of 3.0 mJ.

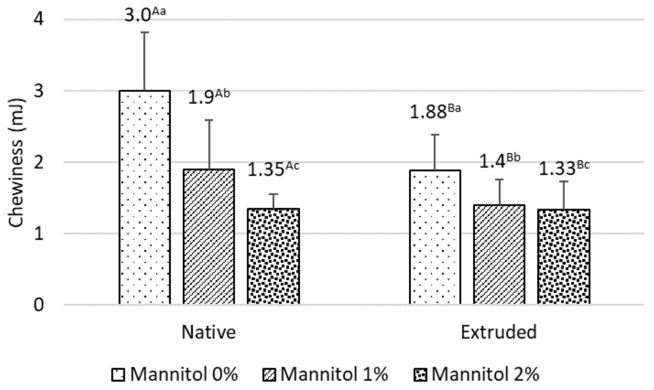

Figure 7. Chewiness (mJ) of the non-wheat pizza crust. Values with different uppercase superscripts are statistically significantly different ($p<0.05$) between the type of sago starch while values with different lowercase superscripts are statistically significantly different ($p<0.05$) between the mannitol concentration.

3.2.4 Sensory parameter

Appearance, aroma, taste, texture, crumb homogeneity, and overall acceptability of non-wheat pizza crust were rated, can be seen in Table 4. Pizza crust looked 4.47 to 5.24. (ordinary to somewhat like). Appearance affected consumer decisions. Cassava, rice, and extruded sago pizza crusts scored 5.24. Several sago starches, but not mannitol or their interaction, modified the product's color. Heating reducing sugars and amine groups on proteins gave pizza crust its brownish yellow color.

Non-wheat pizza crust smells like flour, margarine, yeast, and baking conditions. Aroma's hedonic range is 4.21 to 4.84. (normal). Sago starches and mannitol had little influence on pizza crust smell. Cassava flour makes over 50% of non-wheat pizza crust, therefore its scent dominates.

Taste influenced product selection. Taste hedonic range was 3.26-4.84. Sago starch and mannitol affected pizza crust flavor, but they didn't interact. Without mannitol, pizza dough ferments harshly from cassava flour, rice flour, and sago starch. Mannitol may hide the flavor of non-wheat pizza crusts, boosting their appeal.

Texture rated 3.44 to 4.67. Various sago starches and sago starch plus mannitol affected the texture of pizza crust ($p<0.05$). A non-wheat pizza dough is firm yet chewy. Panelists like reduced stiffness and chewiness since it requires less chewing energy. Because non-wheat flour absorbs more moisture than wheat flour, the crust was mushy. Consistent porosity in non-wheat pizza dough were key. The crumb homogeneity was 4.13 to 4.63. Adding sago starches and mannitol to non-wheat pizza crust didn't affect crumb uniformity.

Mouthfeel, non-wheat pizza crust with extruded sago starch is superior than pizza crust with native sago starch (3.70 to 4.99). Panelists enjoy crusty pizza. Extruded sago starch sped up retrogradation, making pizza crust crispier and less mushy.

3.3 Characteristics of the two best formulas

The investigation indicated that pizza crust containing pregelatinized cassava flour, rice flour, and extruded sago starch had superior qualities. The best dough and product features are formula 3 (pregelatinized cassava flour, rice flour, native sago starch +2% mannitol) and formula 5 (pregelatinized cassava flour, rice flour, extruded sago starch +1% mannitol).

3.3.1 Proximate, starch, resistant starch level, and digestibility of starch (in vitro)

Table 5 shows the chemical properties of the two best formulae. Non-wheat pizza with native sago starch +2% mannitol application has a greater moisture content than pizza with extruded sago starch +1% mannitol, because it was not readily retrograded (Ye *et al*., 2018). It made syneresis difficult to happen. The ash content of non-wheat pizza with native sago starch +2% mannitol was higher than pizza with extruded sago starch +1% mannitol. It related with flour and starch which used on the formulation. Commercial starch was derived from cereals and tubers that contain small amounts of

Table 4. Sensory characteristics of non-wheat pizza crust.

Type of sago starch	Mannitol (%)	Score*					
		Color	Aroma	Taste	Texture	Crumb uniformity	Overall acceptance
Native sago starch	0	4.47^{Ba}	4.21^{Aa}	3.26^{Bb}	3.44^{Ba}	4.13^{Aa}	3.70^{Bb}
	1	4.66^{Ba}	4.64^{Aa}	4.24^{Ba}	3.76^{Ba}	4.23^{Aa}	4.30^{Ba}
	2	4.97^{Ba}	4.84^{Aa}	4.69^{Ba}	3.97^{Ba}	4.37^{Aa}	4.67^{Ba}
Extruded sago starch	0	5.24^{Aa}	4.74^{Aa}	4.03^{Ab}	4.43^{Aa}	4.47^{Aa}	4.43^{Ab}
	1	5.00^{Aa}	4.79^{Aa}	4.84^{Aa}	4.67^{Aa}	4.63^{Aa}	4.99^{Aa}
	2	5.11^{Aa}	4.60^{Aa}	4.81^{Aa}	4.13^{Aa}	4.39^{Aa}	4.68^{Aa}

Values with different uppercase superscripts are statistically significantly different ($p<0.05$) between the type of sago starch while values with different lowercase superscripts are statistically significantly different ($p<0.05$) between the mannitol concentration.

inorganic salts which come from the inner material or from water during processing (Peris *et al*., 2019). The fat content of pizza was about 8%, it came from margarine, eggs, and powdered milk. Fat plays a role in forming a soft texture on pizza crumbs, helping the development of the physical structure of the crumb, and providing a savory taste (Kumar, 2018; Peris *et al*., 2019). The margarine application provided the function of shortening the structure formed by a mass of protein and hydrocolloids, so the pizza could be porous which means softer (Kumar, 2018; Peris *et al*., 2019). The protein in non-wheat pizza was around 6% which came from eggs, milk powder, and flour. The low protein content was because pregelatinized cassava flour, rice flour, and sago starch have low protein content. The results of the calculation of carbohydrates were around 49 to 55%, which came from pregelatinized cassava flour, rice flour, and sago starch that contained above 70% of carbohydrates. Other sources were sugar and powdered milk.

Table 5. Moisture, ash, fat, protein, carbohydrate, starch, resistant starch level, and digestibility of starch in vitro of the best formula for non-wheat pizza products.

Parameter	Native sago starch + 2% mannitol	Extruded sago starch + 1% mannitol
Moisture (% w/w)	35.40±0.35	29.70±0.25
Ash (% w/w)	0.87±0.02	0.64±0.02
Fat (% w/w)	8.33±0.03	8.13±0.16
Protein (% w/w)	6.31±0.06	6.41±0.14
Carbohydrate (% w/w)	49.09±0.38	55.11±0.07
Starch (% w/w)	36.25±0.34	45.37±0.22
Resistant starch (% db)	8.54±1.85	10.94±0.52
Digestibility of starch (% w/w)	60.64±1.39	52.12±0.65

Starch is the largest part in tuber and cereals, and serves as a substrate for yeast to ferment and produce CO_2 and alcohol. Starch interacted with proteins to absorb water in the formation of dough. At the time of roasting, the water contained in the protein will move to starch which in the roasting process undergoes gelatinization. The gelatinization process caused the baked pizza dough to have a firm structure. The results of the starch analysis showed that the pizza crust had a high starch content, which was around 36 to 45%. This starch included all glucose contained in the product so that the product with extruded sago starch +1% mannitol addition has a higher starch content.

The digestibility of starch in vitro illustrated the ease of starch being hydrolyzed by human digestive enzymes (Li, 2018). Native sago starch +2% mannitol pizza exhibited higher starch digestibility than extruded sago starch +1% mannitol pizza. It was altered by the resistant starch content of the pizza (Li, 2018).

Non-wheat pizza with extruded sago starch +1% mannitol had a greater resistant starch than pizza with native sago starch +2% mannitol. It is in line with Ye *et al*. (2018), because sago starch underwent gelatinization inside extruder, and underwent retrogradation during freezing. Resistant starch came from the retrograded starch (Wang *et al*., 2021).

3.3.2 Microstructure of crumb

The crust (outer layer) and crumb (inner) of non-wheat pizza include air-filled spaces. Figure 8 depicts the microstructure of non-wheat pizza. The crumb was not consistent or spread equally. In general, pizza crust made with native sago starch +2% mannitol has bigger holes than pizza crust made with extruded sago starch + 1% mannitol. It is related to mannitol, which might maintain the yeast so that more air was created after fermentation and the dough could expand more effectively. The pores in both formulations were fractal and somewhat oval in shape. Extruded sago starch +1% mannitol created more oval holes because the dough was able to survive the gas production from yeast fermentation. Due to the absence of gluten in the pizza crust, the cell walls become more rigid and prone to injury (Sharma and Gujral, 2019). The fractal structure of non-wheat products may be due to a layer of xanthan gum and starch that was incapable of retaining gas, leading to the formation of enormous, irregularly shaped holes (Asghar and Zia, 2016).

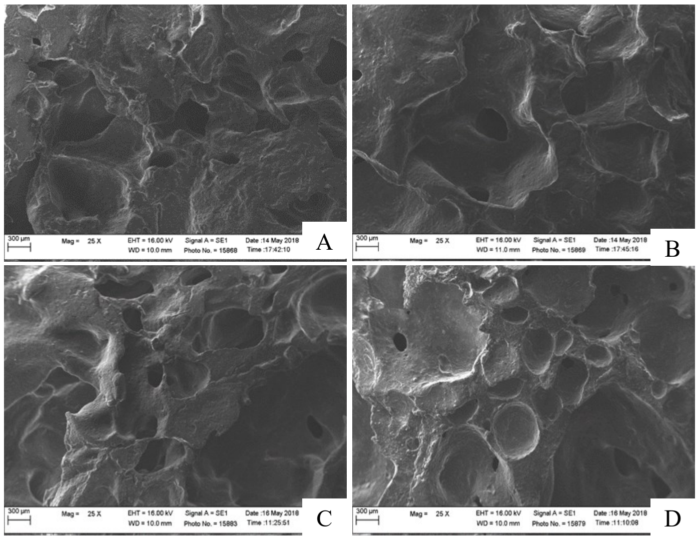

Figure 8. Crumb microstructure of non-wheat pizza with the native sago starch +2% mannitol application (A) on the edge, (B) in the center, and with the extruded sago starch +1% mannitol application (C) on the edge, (D) in the center.

4. Conclusion

Non-wheat flour made from pre-gelatinized cassava and rice flour, added with sago starch (native or extruded) and mannitol had the potential to be developed into frozen dough and pizza crust product. Native and extruded sago starch and mannitol had a substantial influence on product hardness, springiness, and

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chewiness, but not dough expansion or product development volume. Best formula was pre-gelatinized cassava flour, rice flour, native sago starch +2% mannitol, and pre-gelatinized cassava flour, rice flour, extruded sago starch +1% mannitol. Both formulae had low hardness, high flexibility, low chewiness value, and excellent acceptability.

Conflict of interest

The authors declare no conflict of interest.

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