Functional cake characteristics of modified arrowroot starch (MAS) with the gelatinization-retrograde method

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Abstract. Healthy food consumption is a critical issue which enhances the functional food production demand. This research aimed to identify the optimum modified arrowroot starch for the best functional cake characteristics. Completely Randomized Design with one factor (arrowroot starch: wheat flour proportion) which consisted five levels (0:100; 25:75; 50:50; 75:25 and 100:0) was applied. The first step was MAS production (gelatinization-retrograde method) then applied to functional cake followed by proximate, resistant starch, expansion volume index and texture analysis. The result showed that 100% MAS was the best treatment with the highest carbohydrate and resistant starch (25.85% and 59.28%), and the lowest ash content, hardness, and expansion volume index (1.8%, 104.95N/mm² and 45.32%). It can be concluded that functional cake characteristic becomes better and resistant starch (RS) level become higher with MAS application.

1. Introduction
Nowadays, people have a lot of activity but less healthy food consumption. Functional food isn’t medicine but it’s aimed to reduce diseases risk factors and enhance health performance. A functional food can be found as cake, bread, or beverages.

A cake is typically famous and acceptable dessert, because it’s simple, consumable, and served with attractive physical form, color, and various flavor. A cake is typically baked and divided based on cooking technique and ingredients. Various research were done for improving cake characteristics alike texture and organoleptic improvement with potato flour [1], sorghum flour heat-moisture effect to functional cake [2], cake glycemic index [3], the effect of oil palm to the cake [4], dough formula effect to the cake microstructure [5], sponge cake shelf life extension by active packaging as an alternative chemical preservative to direct addition, and pastry glycemic index of arrowroot starch with red bean flour [6].

Arrowroot starch is alternative flour which can be used for producing functional food like cake. The arrowroot starch research has been done, such as butyrate synthesis [7], butyrate hypoglycemic,
functional pastry microscopic and organoleptic of MAS [8], arrowroot starch physicochemical properties [9], functional properties of arrowroot starch in cassava and sweet potato composite starches [10], physical modification effect on granule morphology, pasting behavior, and arrowroot starch functional properties [11], heat-moisture treatment effect on the physicochemical, structural, and rheological arrowroot starch [12]. Meanwhile, the research of gelatinization-retrograde method which applied to modified arrowroot starch is less, even though it’s possible to increase the resistant starch [13-14].

Resistant starch (RS) is starch molecules which resist digestion and has a lot of benefits for metabolic health. It can be fermented in the colon by the gut flora become short chain fatty acids (SCFA), especially acetate, propionate, and butyrate [15]. Resistant starch can be hypercholesterolemia and hypoglycemic, so it will be helpful for degenerative patients’ alike diabetes or coronary heart [16] and it’s well known that the food with high resistant starch means low glycemic index [17].

The functional cake perfection with high resistant starch alike arrowroot starch is an interesting topic to be analyzed and discussed. Therefore, the current study aimed to analyze the arrowroot starch effect to the functional cake characteristics.

2. Materials and Methods

Arrowroot tubers (10 months) were collected from Wagir-Subdistrict, Malang, East Java, Indonesia. Then the analysis specimens are a standard glucose solution, distilled water, alcohol, Nelson reagents, Arsenomolydate reagents, Na$_2$S$_2$O$_3$, HCl, H$_2$SO$_4$, NaOH, K$_2$SO$_4$, Na$_2$SO$_4$-HgO, boric acid saturated solution, ethanol, acetic acid, methyl red or methylene blue, and iodine. This research started with arrowroot starch extraction then followed with modification of arrowroot starch by using the gelatinization-retrograde method. The second stage was functional cake production from modified arrowroot starch and wheat flour (0: 100; 25:75; 50:50; 75:25; and 100: 0%).

2.1. Modified Arrowroot Starch Production

Arrowroot starch was suspended in distillate water (20% b/v), heated and mixed at 70°C for 10 minutes up to homogenous. After that, the suspended arrowroot starch gave high heat treatment 121°C for 60 minutes in an autoclave, and it was cooled for 1 hour in room temperature (24°C), then it was retrograded for 24 hours at 4°C in the freezer. The starch was dried in a cabinet dryer at 50°C for 28 hours, grounded used grinder and strained (80 mesh). Then MAS was packed used plastics polypropylene.

2.2. Functional Cake Production and Analysis Method

The functional cake production used several additional materials such as egg, margarine, sugar, and cake emulsifier. The cake microscopy was well documented by Scanning Electron Microscope (SEM) [18], while the chemical characteristics including RS content [19], water content, ash content, protein, fat, and carbohydrate were recorded by Different Method [19]. Texture analysis was analyzed by Texture Profile Analyzer type EZ-Test Model SM-SOON-168 [5].

2.2.1. Resistant starch analysis. The method which applied for resistant starch analysis was AOAC: 991.43. Total dietary fiber kit (Product code: 112979, Merck Millipore, Darmstadt, Germany) and digest enzyme alike amylose, protease and amyloglucosidase were used. Then the digestive was added alcohol and filtered. Afterward, the resistant starch residues were washed, dried and weighted.

2.2.2. Cake microscopy analysis. Analysis of starch granules was carried out using the Hitachi type 3000 SEM (Scanning Electron Microscope) brand. Samples in the form of powder were sprinkled thinly and evenly in the conductive double side tape that had been affixed to the specimen holder. Handle where the sample is drawn, and the specimen holder is placed in the space provided, then the handle is closed again. Then the EVAC / AIR button is pressed to make the chamber vacuum, until the WATER LED lights are constantly blue. The SEM software icon on the computer is clicked, the start icon is
clicked to start the sample observation. Filaments in SEM will emit electrons that will hit the sample. Then the electrons are reflected by the sample towards the detector, then processed and displayed on the monitor. The results of the analysis and observation are stored on the hard drive. When the observation on the sample has been completed, the stop button is clicked.

2.2.3. Texture. Texture analysis was closely related to the mechanical evaluation characteristics, which depended on the control forced. The deformation curves were the last result that explained the material response. The cake texture included hardness and broken potency was analyzed used Texture Profile Analyzer type EZ - Test Model SM-SOON-168.

2.2.4. Statistical analysis. The quantitative data were subjected to analysis of variance (ANOVA) and followed by Duncan's test ($\alpha = 0.05$) using the program SPSS 10.0 for Windows.

3. Results and Discussion

3.1. Cake Chemicals Properties

The result showed that arrowroot starch and wheat flour formula’s gave significantly effect (p< 0.05) on water content, protein, fat, ash, carbohydrate (Table 1) and resistant starch (Figure 1). Based on ISO standards, the cake meets the standards of water content. Treatment A (0% MAS and 100 %WF) showed the highest level of water content (31.60 %) compared to others. This is probably caused by the cakes are produced by 100% wheat flour, and it has a larger cavity and more porous than others, therefore it affects the water stored enhancement. In addition, the water content of wheat flour is higher than arrowroot starch and water absorption ability of wheat flour is higher too (56-58%) [20]. Water content is important because it indicates total water that could be absorbed and storage time, afterward it is usually better to choose the flour which can absorb the largest water in cake production.

| Treatment (MAS:WF) | Water  | Protein | Fat   | Ash   | Carbohydrate |
|--------------------|--------|---------|-------|-------|--------------|
| A (0: 100)         | 31.60 b| 2.48 c  | 6.61 d| 3.29 b| 56.32 a      |
| B (25: 75)         | 30.59 b| 2.36 b  | 6.50 c| 3.85 d| 56.70 a      |
| C (50: 50)         | 30.03 a| 2.31 b  | 6.20 a| 3.52 c| 57.94 b      |
| D (75: 25)         | 30.16 a| 2.27 b  | 6.30 b| 3.24 b| 58.03 b      |
| E (100: 0)         | 30.19 b| 2.02 a  | 6.31 b| 1.80 a| 59.28 c      |

Remark: the letters (a-d) in each column shows significant difference at Duncan’s test ($\alpha = 5\%$).

Treatment A is known to have the highest protein content, which is 2.48%. This result is caused by the protein content of wheat flour was higher than modified arrowroot starch. Moreover, it is consistent that wheat flour contains gluten which is a blob and elastic when wheat flour unmixed in water. The largest protein contribution was given by 16.5% egg yolk, 10.9% egg white, and 10-11% wheat flour. It also indicates that the process of arrowroot starch modification does not affect the cake protein content [21].

Based on ANOVA results, it was known the significant effect of arrowroot starch and wheat flour formula’s which against cake fat contents. It was clearly showed that treatment A (6.61 %) had the highest fat content. This is caused by arrowroot starch fat content (0.80%) was lower than wheat flour (1.11%), and the addition of additives such as liquid margarine which can’t be dissolved properly [6]. Fat content is a necessary factor that affects the cake quality, because of it able to reduce the bitter taste and mildew potency, and further is able to increase consumer acceptability [22].
Figure 1. Resistant starch content of functional cake.

The highest carbohydrate (59.28%) and resistant starch (25.85%) were treatment E (100% MAS, 0% WF) and it was given significantly effects (p<0.05). While, the lowest carbohydrate and resistant starch were treatment A (0% MAS, 100% WF). It means, increasing modified arrowroot starch (MAS) application enhance the resistant starch and carbohydrate content. This caused by in gelatinization process, the starch granules absorbed water maximally and busted. Then amylose will burst bond that effect to the starch granules structure irregularity, increasing starch suspend viscosity, and birefringent disappearance. Further, the cooling process also makes the kinetic energy declines which less to combine the amylose molecules again. Therefore, the several amylose molecules will merge with amylopectin molecules in the outside of granules, thus swollen starch granules will be microcrystal and suspended. This modification structure (gelatinization-retrograde methods) is profitable because it produces higher resistant starch than original starch. So that, whenever produce the cake with this raw material (MAS) will enhance the resistant starch of cake too. The food product with high resistant starch content tends to be hypoglycemic and hypocholesterolemic [8].

These results were consistent with the research of heat-moisture treatment of rice will increase the resistant starch. In this case, it caused by heat-moisture treatment can produce starch fraction which resists to the enzyme hydrolysis as consequences of double helices formation and compartmentalization of amylose–amylose, amylopectin–amylopectin and amylose-amylopectin chains [13] [23].

3.2. Cake Expansion Volume Index and Texture
The arrowroot starch and wheat flour formula’s gave significantly affect (Duncan’s test α = 5%) to the expansion volume index (Figure 2) and texture of cake (Table 2). The highest expansion volume index was A treatment (0% MAS: 100% WF) and tend to decrease with enhancing modified arrowroot starch application. The protein content of wheat flour is higher (10-11%) than arrowroot starch, is the main reason. In other hands, the cake production process also affected by gluten composition in wheat flour. The arrowroot starch didn’t support the increasing expansion volume index because it’s only consisted 3.34% [9].

Wheat flour has the capability to create the great dough that able to detain the gas production in the form of air, vapor, and CO₂. As the result, the spoons structure will be created on the food product (cake). The high gluten level is the main component that responds to this case. Gluten has high elasticity, so it able to swell the dough and conduct the big product but floaty. Therefore, for producing the crumb, great structure and tight volume of cake, it is needed correct method that able to create stable dough with a small air bubble. This vesicle act as the center, that will swell when there is CO₂ which produced by baking powder during the cooking or baking process [24-25]. The gluten quality and quantity also gave a contribution to the expansion volume index. Gas retention, crumb structure of cake level, and cake volume were depended to the gluten in flour and gluten production mechanism during cooking.
process especially in mixing dough [25-26]. The aeration also gave the significantly affect to the dough viscosity [2]. In other hands, the expansion volume index also affected by heat treatment. According to the previous research, heat treatment could increase the dough viscosity, and it decreased the gravity specific level. As the result, there was a lot of vesicles that trapped inside the dough and automatically expansion volume increase significantly [5].

Table 2. Cake physicals properties.

| Treatment          | Texture (N/mm²) |
|--------------------|-----------------|
| A (0% MAS:100% WF) | 190.45 c        |
| B (25% MAS:75% WF) | 193.28 c        |
| C (50% MAS:50% WF) | 126.21 b        |
| D (75% MAS:25% WF) | 120.93 b        |
| E (100% MAS:0% WF) | 104.95 a        |

Remark: the letters (a-c) shows significant difference at Duncan’s test (α = 5%).

Figure 2. Expansion volume index (%).

The texture scale explains the hardness level of cake. The hardness scale is about 104.95-193.28 N/mm² and it was a significant difference (p<0.05) (Table 2). The increasing modified arrowroot starch application decreased the hardness level. The lowest hardness level was cake with 100% arrowroot starch treatment (104.95 N/mm²) while the highest hardness level was cake with 100% wheat flour treatment (193.28 N/mm²). This result was consistent with the previous research, the addition of modified starch (5%) was able to decrease the hardness level and cake adhesion [27]. The decreasing of hardness level is caused by intramolecular interaction of starch molecules and supporting materials were decline. However, there was an analysis that explained cake hardness level had a negative correlation with expansion volume index, in other words, cake with small expansion volume had tight crumb structure [5]. A cake which created from pre gelatinization starch had a harder texture because it had lower porosity level [4].

4. Conclusion
The best result is cake with 100% MAS treatment with the highest resistant starch and carbohydrate level but has low fat, protein, ash, water, expansion volume index, and hardness. It means, modified arrowroot starch with a gelatinization-retrograde method is able to improve the cake chemical and physical properties by increasing resistant starch component. Therefore, modified arrowroot starch is
useful for enhancing functional food production. Furthermore, it needs to analyze the effect to the glycemic index, digestion, hypoglycemic, and hypocholesterolemia.

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