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Physicochemical, Functional and Sensory Characteristics of Prebiotic Bread Making from Banggai Yam Starch Modified with Sodium Trimethaphospate

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Abstract

Banggai yam starch is derived from the Banggai yam plant, an endemic species of Banggai Regency, Central Sulawesi Province, Indonesia. Locally, this starch is commonly processed into various foods such as chips and staple dishes. In addition to being a carbohydrate source, Banggai yam starch also contains protein, fat, and minerals. This study aimed to determine the optimal concentration of Banggai yam starch modified with Sodium Trimetaphosphate (STMP) on the physicochemical, functional, and sensory properties of prebiotic bread. The research employed a Completely Randomized Design (CRD) with one factor STMP modified Banggai yam starch concentration—at four levels (0%, 15%, 30%, and 40%) with four replications, resulting in 16 experimental units. The results showed that the modification significantly affected several parameters, including degree of development, oven spring, weight, oil holding capacity (OHC), water holding capacity (WHC), swelling power, and sensory attributes (texture, color, aroma, taste, and overall liking). The 40% concentration produced the best results, with a degree of development of 46.06%, oven spring of 0.78, weight of 36.26 g, WHC of 2.72 g/g, OHC of 2.85 g/g, moisture content of 9.28%, ash content of 0.79%, swelling power of 4.84 g/g, solubility of 10.52%, and sensory scores for color (5.3), texture (5.90), aroma (5.43), taste (5.78), and overall liking (5.62), indicating good panelist acceptance.

Keywords: Banggai Yam Starch; Sodium Trimetaphosphate (STMP); Physicochemical Properties; Functional Properties; Prebiotic Bread

1. Introduction

Banggai yam starch is a banggai yam starch from the Banggai Islands, with many varieties. Banggai yam starch is a source of carbohydrates, one of the components of which is starch. According [1] reported that the starch content of banggai yam starch flour ranges from 70.96-84.71% which has the potential as a new starch source. In general, D. alata group starch paste has high viscosity, stable gel characteristics, is resistant to heating and storage so it has the potential to be applied in the food industry as a thickener or gel former [2].

Banggai yam starch are white with a cylindrical shape and a tapered base (like the Butun variety), dark purple with a cylindrical shape and a tapered base (like the Pusus variety), yellowish with a round shape (like the Tau variety), a mixture of white and purple with a cylindrical shape and a tapered base (like the Paupau Ateno variety), and brownish with a cylindrical shape and a tapered base (like the Lembet variety). Another characteristic of banggai yam starches is that they produce a slimy liquid that causes itching when peeled and soaked in water [3]. People process this banggai

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yam starch into kolak (composite fruit), chips, cakes, or simply boil it as a main dish. A diet that consumes banggai yam starch as a main course is essentially a healthy diet and is worth maintaining and developing [4].

Dioscorea alata (Banggai yam) is a member of the Dioscoreaceae family, which has many species. Dioscorea has the potential to be a food source because it contains quite high levels of nutrients. The nutrients contained in Dioscorea are carbohydrates (15-25%), fat (0.05-0.20%), and protein (1-2.5%) [4]. The people of Banggai Islands consume banggai yam starchas a staple food, which is processed into payot which is processed by boiling, grating, wrapping in banana leaves and frying. Banggai yam starch is also commonly processed by the people of Banggai Islands Regency into baby porridge or cooked with coconut milk and salt which is called nalum. developed banggai yam starchporridge from the raw makulolong and raw pukus varieties. The people of Banggai Laut Regency also process banggai yam starch into chips [5].

2. Materials and Method

2.1. Materials

The materials used in this study were banggai yam starch of the Pusus variety obtained in the Banggai Islands, Sodium Trimethaphosphate (STMP), wheat flour, modified banggai yam starch, sugar, powder milk, yeast, water, eggs white, margarine and salt.

2.2. Research design

This study used a Completely Randomized Design for the analysis of the degree of development, oven spring, weight, WHC, OHC, water content, ash content, swelling power, solubility and a Randomized Block Design (RBD) for the analysis of sensory of color, texture, aroma, taste, preference with one factor, namely PUBM-STMP, each with a concentration of 0%, 15%, 30%, 40% w/w. Each treatment was repeated 4 times to obtain 16 experimental units. The formulation for making prebiotic bread can be seen in Table 1.

Table 1 The formulation for making prebiotic bread

Components	**Banggai yam starch Modified by STMP**			
	0%	15%	30%	40%
Wheat Flour (g)	100	85	70	60
Modified banggai yam starch (g)	0	15	30	40
Sugar (g)	20	20	20	20
Powder milk (g)	4	4	4	4
Yeast (g)	3	3	3	3
Water (ml)	52	52	52	52
Egg white (g)	10	10	10	10
Margarine (g)	15	15	15	15
Salt (g)	1,5	1,5	1,5	1,5

2.3. Preparation of banggai yam starch

The first step is to peel the banggai yam starch until clean. After peeling, the banggai yam starch is then washed with clean water. The cleaned banggai yam starch is then cut into small pieces to make it easier to process in the next step. After being cut into small pieces, the banggai yam starch is soaked in salt for 1 hour, then washed again to remove mucus and remaining salt. The next step is to crush it using a blender. This process is carried out to separate the starch contained in the banggai yam starch. The results of this crushing process are then squeezed to separate the starch. The squeezed starch is then left overnight in a closed container. After leaving it overnight, the water at the top of the container is carefully discarded, leaving only the starch sediment remaining. The starch sediment that has been obtained is then dried using an oven at a temperature of 105 °C. This drying process is carried out until the starch is completely dry and no longer contains a high moisture content. The resulting dry starch is then ground again using a blender to form a fine powder. The banggai yam starch powder that has been ground is then sieved using a 80 mesh sieve and then stored in a clean and dry container or jar to maintain its quality and cleanliness.

2.4. Phosphorylation of banggai yam starch

Phosphorylation of banggai yam starch using STMP with a method developed by [6] as much as 200 g of natural starch mixed with 450 ml of distilled water into a glass beaker, then stirred using a magnetic stirrer for one hour until evenly mixed. After that, 3% NaOH solution was added to the mixture and the pH was measured using a pH meter until it reached pH 10. When the pH of the mixture had reached 10, STMP of 12 g was added to the mixture and stirred again for 45 minutes. Next, 0.5 N HCl solution was added slowly until the pH of the mixture dropped to 4.5. After the pH reached 4.5, the modified starch was washed with distilled water three times. Then, 96% ethanol was added to the modified starch to help the water bonding. Finally, the modified starch is dried using an oven at a temperature of 55 °C until it is completely dry, then blended and sieved using a 80 mesh sieve, after which it is stored in a closed container to maintain its cleanliness.

2.5. The making of prebiotic bread

Making prebiotic bread based on the method from [7]. First, yeast and water are fermented in a glass, then stirred and covered and left for 5 minutes or until foam appears. After that, wheat flour, granulated sugar, and powdered milk are put into a baking pan, then mixed evenly. Next, the fermented yeast and water mixture together with eggs are put into the pan. Margarine and salt are then added to the dough, stirred until the dough is smooth or elastic (can be seen by pulling the dough and seeing whether it is white and elastic). After that, the dough is covered with a cloth or plastic and left for 45-60 minutes or until it doubles in size. The dough is then pressed to remove the gas that has formed and kneaded again until smooth. The smooth dough is then divided of 38 g each and rounded. The rounded dough is then placed in a gutter that has been smeared with margarine and left for another 30 minutes until it rises. Next, the risen dough is placed in an oven at 175-200°C for 25-30 minutes. Once cooked, the bread is removed from the oven and cooled. The prebiotic bread produced was analyzed for its physicochemical, functional, and sensory properties, including degree of development, oven spring, weight, WHC, OHC, moisture content, ash content, swelling power, solubility, and sensory attributes.

3. Results and Discussion

3.1. Degree of Development

The results of the analysis of variance showed that the concentration of STMP-modified banggai yam starch had a very significant effect on the degree of development of prebiotic bread. The average degree of development of prebiotic bread from different concentrations of STMP-modified banggai yam starch is presented in Table 2.

Table 2 Degree of development of prebiotic bread

Banggai yam starch Modified by STMP (%)	Degree of Development (%)	Notation
0	42.26	ab
15	37.13	a
30	44.01	b
40	46.06	b

Different letter notations after numbers in the same column indicate significant differences ($p \leq 0.05$).

Based on the further test at 5% level, it shows that the highest average degree of bread development is at a concentration of 40% with a value of (46.06%), while the lowest is at a concentration of 15% with a value of (37.68%). Banggai yam starch modified using STMP can affect the degree of bread development because the modification changes the functional properties of the starch, especially its ability to bind water and its swelling power, which are very important in the structure of bread dough. The right temperature and baking time will produce bread with optimal volume. Too high a temperature or too long a baking time can cause the bread crust to form too quickly, thus inhibiting development [8].

This is caused by differences in gluten content in different flour formulations. The higher gluten content in formulations with higher flour content can hold gas much better so that the bread rises more, gluten is able to make bread dough rise more because protein can make the dough elastic so it can hold gas and make the dough rise [9].

3.2. Oven spring

Oven spring analysis is used to determine how the bread develops in the first minute in the oven. This is important because the bread is considered successful if it develops well, and vice versa. The results of the oven spring analysis of STMP prebiotic bread can be seen in Table 3.

Table 3 Oven spring of prebiotic bread

Banggai yam starch Modified by STMP (%)	Oven spring	Notation
0	0.47	a
15	0.49	ab
30	0.66	b
40	0.78	c

Different letter notations after numbers in the same column indicate significant differences (p≤0.05).

Based on the further test at 5% level, the highest average oven spring was 0.78 at a modified STMP concentration of 40% Banggai yam starch, while the 0% treatment obtained the lowest average value of the other concentrations, namely 0.47.

This modification process involves the formation of new covalent bonds between starch molecules, namely between the hydroxyl (-OH) groups on different starch chains and the phosphate groups of STMP. This reaction produces phosphate starch or cross-linked starch [10]. Gluten functions to retain gas to obtain the desired volume and texture in the dough system [8].

3.3. Weight

The results of the analysis of variance showed that the concentration of STMP-modified banggai yam starch had a very significant effect on the weight of prebiotic bread. The average weight of prebiotic bread from different STMP-modified banggai yam starch concentrations is presented in Table 4.

Tabel 4 Weght of prebiotic bread

Banggai yam starch Modified by STMP (%)	Weight (g)	Notation
0	35.73	ab
15	35.51	a
30	36.05	ab
40	36.26	b

Different letter notations after numbers in the same column indicate significant differences (p≤0.05).

Based on the results known in Table 4, it shows that the highest weight of prebiotic bread is 36.26 g at a modified banggai yam starch concentration of 40%, while at a modified banggai yam starch concentration of 15% it has the lowest value compared to other treatments, namely 35.51 g.

Formulation changes, such as substituting wheat flour with other flours (e.g., plantain flour, pumpkin flour, or sorghum flour), will affect the weight and volume of the bread. For example, replacing wheat flour with other flours with lower gluten content can result in denser bread, so the weight may be higher while the volume is smaller, ultimately reducing the specific volume [11].

According to [12], the reduction in gluten content in white bread dough causes the dough to be more hydraulic, resulting in stronger interactions between starch granules. The texture of white bread is closely related to the crystallization of the amylopectin fraction which occurs slowly after the bread is baked.

3.4. Water holding capacity

The results of the analysis of variance showed that the concentration of STMP-modified banggai yam starch significantly affected the water-holding capacity of the bread. The average water-holding capacity of the prebiotic bread is presented in Table 5. Based on the further test of BNJ at 5% level in Table 5, the highest WHC of bread was 2.86 g/g at a modified banggai yam starch concentration of 30%, while at a concentration of 0% without substitution, the modified banggai yam starch STMP had the lowest value, namely 1.96 g/g.

Tabel 5 Water holding capacity of prebiotic bread

Banggai yam starch Modified by STMP (%)	WHC (g/g)	Notation
0	1,96	a
15	2,67	b
30	2,86	b
40	2,72	b

Different letter notations after numbers in the same column indicate significant differences ($p \le 0.05$).

Phosphate compounds are water emulsifiers or can only absorb water, so this is what causes their high WHC. Emulsifiers can be used in the baking industry, broadly speaking, they can be divided into two categories, dough strengtheners that interact primarily with gluten and improve the volume of bread, and reduce crumbs that will become stale during storage [13]. According to [12], water absorption is an important parameter for dry products because it is prone to damage in food products. Bread that has good water absorption will also be good when it enters the body, good water retention capacity supports the formation of an optimal and flexible dough structure.

3.5. Oil holding capacity

The results of the analysis of variance showed that the concentration of STMP-modified banggai yam starch had no significant effect on the oil retention capacity of the bread. The average water retention capacity of the prebiotic bread is presented in Table 6. Based on the results known in Table 6, it shows that the highest oil holding capacity is 3.15 g/g in the treatment of modified banggai yam starch concentration of 40%. Meanwhile, the treatment of 15% banggai yam starch concentration has the lowest value, namely 2.70 g/g.

Tabel 6 Oil holding capacity of prebiotic bread

Banggai yam starch Modified by STMP (%)	OHC (g/g)	Notation
0	1,96	a
15	2,67	a
30	2,86	a
40	2,72	a

Different letter notations after numbers in the same column indicate significant differences ($p \le 0.05$).

According to [11], oil absorption is influenced by the presence of protein in starch granules. Protein can form complexes that provide binding sites for oil to the starch. The addition of high protein flour is thought to produce soft and fluffy bread. Fiber can form a denser matrix, thus inhibiting the movement of oil into the product. The addition of fiber, both soluble and insoluble, is often used to reduce oil absorption. Fiber can form a denser matrix, thus inhibiting the movement of oil into the product.

3.6. Moisture content

The results of the analysis of variance showed that the concentration of STMP-modified banggai yam starch did not significantly affect the moisture content of prebiotic bread. The average moisture content of prebiotic bread is presented in Table 7. Based on the results listed in Table 7, the highest water content of the bread was 9.42% at a modified banggai yam starch concentration of 15%, while at a modified banggai yam starch concentration of 0% it had the lowest value, namely 8.68%.

Tabel 7 Moisture content of prebiotic bread

Banggai yam starch Modified by STMP (%)	Moisture content (%)	Notation
0	8.68	a
15	9.42	a
30	9.27	a
40	9.28	a

Different letter notations after numbers in the same column indicate significant differences (p≤0.05).

STMP-modified starch can interact with other components in the dough, such as protein, fat, or sugar, forming a stronger complex. This complex can reduce the availability of hydroxyl groups in the starch to bind water. Changes in pH due to the addition of other ingredients or the fermentation process can affect the starch's ability to bind water [14]. Water Sufficient water content will make the dough more elastic and easier to work with. However, if the water content is too low, the dough will be stiff and difficult to rise. Conversely, too high a water content can make the dough too sticky and difficult to handle [15].

3.7. Ash content

The results of the analysis of variance showed that the concentration of STMP-modified banggai yam starch did not significantly affect the ash content of prebiotic bread. The average ash content of STMP-modified banggai yam starch prebiotic bread is presented in Table 8. Based on the results shown in Table 8, the highest ash content of bread is 1.12% at a modified banggai yam starch concentration of 15%, while at a modified banggai yam starch concentration of 40%, the ash content value is the lowest, namely 0.79%.

Table 8 Ash content of prebiotic bread

Banggai yam starch Modified by STMP (%)	Ash content (%)	Notation
0	1.03	a
15	1.12	a
30	0.92	a
40	0.79	a

Different letter notations after numbers in the same column indicate significant differences (p≤0.05).

Flour with a higher ash content usually indicates that the flour is less refined and contains more fine bran particles and endosperm adjacent to the bran. Bran is the main source of minerals in grains. Therefore, ash content is widely used as an index of flour purity and its extraction rate during milling [16].

3.8. Swelling power

Table 9 Swelling power of prebiotic bread

Banggai yam starch Modified by STMP (%)	Swelling power (g/g	Notation
0	3.4	a
15	4.62	b
30	5.13	b
40	4.84	b

Different letter notations after numbers in the same column indicate significant differences (p≤0.05).

The results of the analysis of variance showed that the concentration of STMP-modified banggai yam starch significantly affected the rising power of prebiotic bread. The average prebiotic rising power is presented in Table 9. Based on the results known in Table 9, the highest bread expansion power is 5.13 g/g at a modified banggai yam starch concentration of 30%, while at a modified banggai yam starch concentration of 0% it has the lowest value, namely 3.4 g/g.

Once the granules are completely filled with water, hydrogen bonds between the amylose and amylopectin chains will attempt to maintain the integrity of the starch granules, and a swelling process will begin, starting from the core of the starch granule. The linear structure of amylose is able to form a stronger internal network, so that the swelling ability and solubility of starch are more limited [17].

3.9. Solubility

The results of the analysis of variance showed that the concentration of STMP-modified banggai yam starch did not significantly affect the solubility of prebiotic bread. The average solubility of STMP-modified banggai yam starch prebiotic bread is presented in Table 10. Based on the results known in Table 10, the highest bread expansion power is 10.52% at a modified banggai yam starch concentration of 40%, while at a modified banggai yam starch concentration of 30% STMP, the lowest value is 8.61%.

Table 10 Solubility of prebiotic bread

Banggai yam starch Modified by STMP (%)	Solubility (%)	Notation
0	10.18	a
15	9.60	a
30	8.61	a
40	10.52	a

Different letter notations after numbers in the same column indicate significant differences (p≤0.05).

Starch is grouped based on its swelling capacity, namely starch with high swelling (>30%), moderate/limited (16-20%), and very limited (<16%). Based on this grouping, the modified Banggai yam starch prebiotic bread has a very limited swelling capacity and solubility. Bread with a medium resistant starch content (replacing high amylose flour at 10% and 20%), good initial quality and a slower dehydration rate. The matrix counteracts the negative effects of starch retrogradation on bread texture [18].

3.10. Sensory properties

The results of the analysis of variance showed that the concentration of STMP-modified yam starch significantly affected the sensory characteristics of color, texture, aroma, taste, and the preference for prebiotic bread. The average sensory values of prebiotic bread are presented in Table 11. Based on the results known in Table 11, the highest level of preference for bread color was 6.29 at a modified banggai yam starch concentration of 0%, while at a modified banggai yam starch concentration of 40%, the lowest value was 5.3. The highest level of preference for bread texture was 6.13 at a modified banggai yam starch concentration of 15%, while at a modified banggai yam starch concentration of 30% it had the lowest value, namely 5.75. The highest level of preference for bread aroma was 6.35 at a modified banggai yam starch concentration of 15%, while at a modified banggai yam starch concentration of 40% it had the lowest value, namely 5.43. The highest bread taste was 6.43 at a modified banggai yam starch concentration of 15%, while at a modified banggai yam starch concentration of 30% it had the lowest value, namely 5.73, and for the overall preference of the bread, the highest was 6.40 at a modified banggai yam starch concentration of 15%, while at a modified banggai yam starch concentration of 30%, the lowest value was 5.58.

Table 11 Sensory properties of prebiotic bread

Banggai yam starch modified by STMP (%)	Color	Texture	Aroma	Taste	Overall accepted
0	6.29^{c}	5.76^{a}	6.31^{c}	5.80^{ab}	6.28^{b}
15	6.28^{c}	6.13^{b}	6.35^{c}	6.43^{b}	6.40^{b}
30	5.55^{b}	5.75^{a}	5.74^{b}	5.73^{a}	5.58^{a}
40	5.3^{a}	5.90^{ab}	5.43^{a}	5.78^{ab}	5.62^{a}

Different letter notations after numbers in the same column indicate significant differences (p≤0.05).

Color is a visualization of a product that is immediately seen first compared to other variables. Color directly influences the perception of the elis. If the data is not normally distributed, a Friedman test is performed followed by a multiple comparison test and a BNJ test at the 5% level [19]. The elastic and expandable physical properties of gluten allow the dough to retain the leavening gas and allow the dough to puff up like a balloon. This process can create fine cavities in the bread and a soft, elastic texture. Good flour is characterized by its ability to absorb large amounts of water to achieve a dough consistency with a soft texture and large volume. The type of flour intended for bread making is hard wheat. Hard wheat flour has a protein content of 12-13% [20].

According to research [21], the distinctive aroma of bread is influenced by yeast which changes sugar into carbon dioxide gas and aromatic compounds, thus creating the distinctive aroma of bread. Changes in aroma are often also associated with changes in other physicochemical parameters of bread, such as moisture content, texture, or color. Prebiotic fibers can affect water absorption, gluten network structure, and crust formation, which can indirectly affect the retention or release of volatile compounds during baking [22]. The thing that needs to be considered when modifying starch is to ensure that all the tools used are sterile according to standart operation procedural. Banggai yam starc contains oxalic acid which will cause a bitter taste in bread. Mistakes in modifying starch will cause the bread to become bitter. The activity of baker's yeast in dough is influenced by several factors, including protease, lipase, invertase, and maltase enzymes, water content, temperature, pH, sugar, and salt. Protease enzymes can reduce the strength of the gluten network, making the dough easier to work with [20].

Organoleptic testing became a scientific field after assessment procedures were standardized, rationalized, and linked to objective assessments, allowing for more systematic data analysis. Organoleptic testing is widely used to assess quality in the food and agricultural industries. Sometimes, these assessments can yield very accurate results. In some cases, sensory assessments even exceed the accuracy of the most sensitive instruments [23].

4. Conclusion

The modification of Banggai yam starch with Sodium Trimetaphosphate (STMP) significantly influenced the physicochemical, functional, and sensory properties of prebiotic bread. Among the tested concentrations (0%, 15%, 30%, and 40%), the 40% concentration produced the best overall results. At this concentration, the bread exhibited optimal degree of development (46.06%), oven spring (0.78), weight (36.26 g), water holding capacity (2.72 g/g), oil holding capacity (2.85 g/g), moisture content (9.28%), ash content (0.79%), swelling power (4.84 g/g), and solubility (10.52%). The sensory evaluation also showed acceptable scores for color (5.3), texture (5.90), aroma (5.43), taste (5.78), and overall liking (5.62). Therefore, it can be concluded that 40% STMP-modified Banggai yam starch is the optimal concentration for improving the physicochemical, functional, and sensory qualities of prebiotic bread, making it acceptable to consumers.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest in our manuscript.

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