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Original Paper

Characterization of Bubble Pearls from a Mixture of Tapioca and Glucomannan

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***Abstract*— Boba is a drink originating from Taiwan that has become popular in the Indonesian beverage industry in recent years. This drink consists of a mixture of tea with fruit or milk flavors, with the addition of tapioca-based black chewy textured balls called bubble pearls/boba. Bubble pearls made from tapioca are known to have low nutrition and fiber, so it is necessary to improve their functional characteristics by utilizing local commodities, one of which is porang. Porang (*Amorphophallus oncophyllus* Prain) as one of the local commodities has the potential to improve the characteristics of bubble pearls. Glucomannan flour from porang tubers has high glucomannan content, quite high fiber content, and can form a gel. This study aims to determine the characteristics of bubble pearl products with the addition of glucomannan flour and to determine the optimum percentage of glucomannan flour and tapioca. The formulation of bubble pearls was carried out using the Simplex Lattice Design method and their physical, chemical, and hedonic characteristics were analyzed. The optimization parameters included water absorption capacity, gumminess level, and dietary fiber content. The optimum formula produced by the Simplex Lattice Design method is in formula 2, bubble pearls with the addition of 25% glucomannan flour which has the highest desirability value of 0.862. Formula 2 consists of a water absorption capacity of 37.08%, a gumminess level of 45.72 gf, and a dietary fiber content of 5.65%. The hedonic values are 5.73 for color (slightly like), 5.7 for aroma (slightly like), 4.8 for hardness (neutral), 4.73 for chewiness (neutral), 5.23 for taste (slightly like), and 5.4 overall (slightly like). Additionally, the water content is 59.97% and the ash content is 1.41%.**

Keywords* — *Boba, Bubble Pearls, Glucomannan Flour, Porang, Simplex Lattice Design, Tapioca

I. Introduction

The beverage industry in Indonesia has experienced rapid development in recent years. This can be characterized by innovation in presentation and exploration of product flavors. One of the notable developments of the beverage industry in Indonesia is boba drinks. Boba drink also known as bubble tea or boba milk tea, is one of the most popular drinks among the public and has many outlets with a variety of flavors. According to a study, boba milk tea originating from Taiwan is a tea-based drink mixed with fruit or milk flavors, along with the addition of chewy texture balls derived from a blackish tapioca mixture which is often referred to as "bubble pearls", "bubble", or "pearl" [35]. Bubble pearls are generally made from tapioca as the main raw material because tapioca provides a chewy and sticky texture. The general basic ingredients for making bubble pearls consist of water, tapioca, food coloring, and white sugar [19]. Tapioca is derived from the extraction of cassava or cassava in the form of starch and is produced by the main process of crushing and depositing cassava meat, continuing with the drying and grinding process [17]. Tapioca-based bubble pearls with a moisture content of 8.79% contain 0.55% protein, 0.345% fat, 0.32% ash (minerals), 0.10% crude fiber, and 89.62% carbohydrates [22]. The composition indicates that bubble pearls in boba drinks are low in nutrition and fiber content, so it is necessary to improve the functional characteristics of bubble pearl products by utilizing local commodities.

Porang (*Amorphophallus oncophyllus* Prain) is a commodity plant belonging to the *Araceae* family and herbaceous plant in the form of a shrub with a single tuber in the soil [14]. Glucomannan flour is one of the derivative products of porang tubers, extracted and purified either dry or wet by chemical processes to increase glucomannan content and reduce calcium oxalate from crude porang flour [1]. This flour contains 84.44% glucomannan and 13.61% water as its largest component [36]. Glucomannan contained in porang is a polysaccharide from food fiber containing glucose and mannose with a ratio of 5:8 connected by β 1-4 bonds and has characteristics properties that can make the gel stronger, thicken, and improve texture [37, 20]. Porang flour with high glucomannan levels is beneficial for the body because it can reduce the absorption of glucose and cholesterol, making the consumption of foods high in dietary fiber effective in reducing the risk of diabetes and hypercholesterolemia [7]. Based on this, the use of porang tubers processed into flour can be utilized for its characteristics as an additional raw material and has the potential to be a substitute for tapioca in making bubble pearls, adding value in terms of dietary fiber content.

Bubble pearls with the addition of glucomannan flour can be optimized by applying the simplex lattice design method to produce good and preferred characteristics. Simplex Lattice Design (SLD) is an optimization technique in mixture design used to find the optimum formula from at least 2 different mixtures of ingredients with proportions and the total proportion of ingredients equal to 1 (100%) [13]. The application of this method helps determine the formula of ingredients used, optimize formulation variables, know the number of runs, maintain the total concentration to be constant, and produce ANOVA (Analysis of variance) values that can help assess the significance of response analysis between variables and identify the recommended model. The function value in this method called desirability, indicates how well the program can meet the user's needs according to the standard of the final result. The program's capacity to achieve the desired results is considered perfect when the desirability value approaches 1 [23]. This study aims to determine the physical, chemical, and hedonic quality characteristics of bubble pearl products with the addition of glucomannan flour at various percentages and to determine the optimum percentage of glucomannan flour addition so that bubble pearls with good and preferred characteristics are produced.

II. MATERIAL AND METHODS

A. Time and Place

The research was carried out from July to December 2023. The research was conducted in several supporting laboratories including the Laboratory of Engineering Technology and Industrial Environment, Laboratory of Agricultural Product Innovation and Entrepreneurship, and Laboratory of Food Quality Control and Agricultural Products, Faculty of Agricultural Technology, University of Jember.

B. Materials

This research used the following instruments: digital balance, spoon, plastic scraper, pot, stove, sieve, basin, plastic bowl, oven, desiccator, ruler, analytical balance; beaker glass; test tube; volumetric flask; cup; electric furnace; water bath; Universal Testing Machine (Shimadzu); filter paper (Whatman no. 42); measuring pipette; and aluminum foil. The primary materials employed in this study are tapioca and porang tuber *A. oncophyllus* glucomannan flour. Water, palm sugar syrup, ethanol, protease, amyloglucosidase, phosphate buffer, HCl, NaOH, and acetone were also utilized as components.

C. Research Design

The research design to know the characteristics and determine the optimum formula of bubble pearls was carried out using the Simplex Lattice Design method using Design Expert software version 13. The material formulation was carried out with variations in the composition of glucomannan flour (TGP) and tapioca (TP). The fixed variables in this study were palm sugar syrup and water. The proportion formulas for making bubble pearls from Design Expert are presented in Table 1 and the final composition of ingredients for making bubble pearls is presented in Table 2. The optimized ingredient usage limit between glucomannan flour and tapioca has an upper limit concentration of 100% and a lower limit of 0%.

TABLE I. FORMULATION OF INGREDIENT'S VARIATION PROPORTION FROM DESIGN EXPERT

Formula	Glucomannan Flour (TGP)	Tapioca (TP)
F1	0	1
F2	0,25	0,75
F3	0,50	0,50
F4	0,75	0,25
F5	1	0

TABLE II. FINAL COMPOSITION OF BUBBLE PEARLS INGREDIENTS

Formula	Glucomannan Flour (TGP) (g)	Tapioca (TP) (g)	Palm Sugar Syrup (g)	Water (g)
F1	-	55	20	25
F2	13,75	41,25	20	25
F3	27,50	27,50	20	25
F4	41,25	13,75	20	25
F5	55	-	20	25

D. Methods

1. Production of Bubble Pearls

Tapioca, glucomannan flour, and palm sugar syrup were weighed using a digital balance according to each formulation according to the design of the Simplex Lattice Design method. The ingredients were mixed until evenly distributed. The dry ingredients were then mixed with hot water (T = 100 ℃) until smooth. The use of hot water aims to make the dough easier to become smooth. After that, proceed with the molding stage, the dough is formed into rounds with a diameter of approximately 1 cm. The molded dough is then heated by boiling process (T = 100℃) using a stove for 15 minutes and then drained. The bubble pearl dough is drained with a sieve and poured with water to prevent the bubble pearls from sticking to each other.

2. Analysis of Bubble Pearls Characteristics

Bubble pearls with various proportions of ingredients were analyzed related to their characteristics including hedonic quality analysis with organoleptic testing which includes color, aroma, texture (hardness and chewiness), taste, and overall acceptance. Chemical analysis involved determining water content, ash content, and dietary fiber content. Additionally, physical tests were conducted to measure gumminess, hardness, and water absorption capacity.

3. Determination of Optimum Formulation

a. Optimization Parameter Analysis

Bubble pearls, which have been analyzed for their characteristics, undergo optimization to determine the optimal formulation. This optimization involves several parameters such as gumminess level, dietary fiber content, and water absorption capacity tests using the Simplex Lattice Design method in Design Expert software. The desirability value is determined to ascertain the optimum formula, along with ANOVA significance, mathematical equations regarding material variation effects, and predicted values from software simulations.

b. Verification of Optimum Formula

The bubble pearls formula with the highest desirability value was further validated through testing using the one-sample t-test. This test compares the obtained results with the predicted values from the Simplex Lattice Design method to determine the tendency of formulas that are not significantly different from the predicted values.

E. Analysis Procedure

The research was conducted by analyzing its characteristics including hedonic quality analysis in SNI 01-2346 (2006) with organoleptic testing which includes color, aroma, texture (hardness and chewiness), taste, and overall acceptance. The chemical analysis includes analysis of water content (AOAC, 2012), ash content (AOAC, 2012), and dietary fiber content (AOAC, 1990), alongside physical analysis in the form of gumminess and hardness tests and water absorption capacity. Determination of the optimum formula was carried out using the Simplex Lattice Design method based on the results of the bubble pearls optimization parameter characteristic tests that had been carried out.

F. Data Analysis

Data analysis on hedonic quality characteristics was carried out with the Kruskall-Wallis test to determine the influence of the treatment and followed by the Mann-Whitney test to further identify significant differences between formulations. Determination of the optimum formula applied Simplex Lattice Design method using Design Expert software version 13. The test results of the optimization parameters were analyzed using ANOVA. If the generated data followed a normal distribution, then One Sample T-Test was conducted with a confidence level of $p>0.05$. The data from the research of supporting parameters on the chemical and physical characteristics of bubble pearls in this study were tested for normality and an ANOVA test was conducted to determine the effect on the treatment and continued with Duncan's test to further show significant differences between formulations. All data analysis results will be presented descriptively, complemented by graphs and tables to enhance the clarity of the research findings.

III. RESULTS AND DISCUSSION

A. Hedonics of Color

The color hedonic parameter of bubble pearls tested with the Kruskall Wallis test showed that all formulas had significant differences in the treatment of the color of bubble pearls made from tapioca with the addition of glucomannan flour that had been cooked with palm sugar syrup. The hedonic test results on the color parameter of bubble pearls with the addition of glucomannan flour resulted in an average score ranging from 4.33-6.07 which states in the range of neutral to like. The results of the color hedonic test of bubble pearls are presented in Figure 1.

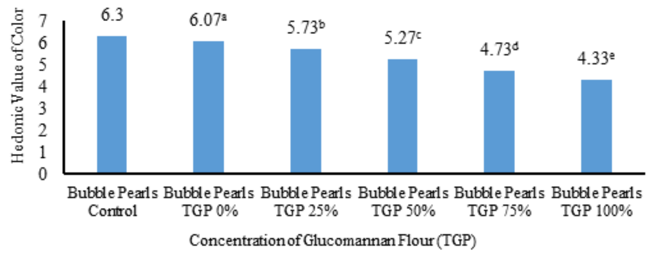

Fig. 1. Graph of hedonic value of color

Bubble pearls with the addition of glucomannan flour tend to have a lower liking value for the color parameter than the control bubble pearls, which is 6.30 (like). This can be caused because the control bubble pearls have a formulation of tapioca composition and natural caramel coloring that gives a blackish color which is similar to conventional bubble pearls on the market so that it is more familiar to the public, while the bubble pearls formulation used in this study uses tapioca, palm sugar syrup and glucomannan flour.

The color hedonic test showed that panelists tended to like the brighter color of bubble pearls with palm sugar based on the color hedonic test value which decreased as the concentration of glucomannan flour addition increased. Based on Tapioca Quality Requirements, tapioca has a degree of whiteness (brightness) of at least 91% so the color is brighter than glucomannan flour [6]. According to [36], the best treatment of glucomannan flour has a degree of whiteness (brightness) of 50.87%, so the more the addition of glucomannan flour, the darker the bubble pearls produced.

The nature of glucomannan in glucomannan flour that easily absorbs water can also make the color of bubble pearls darker. In the process of re-cooking bubble pearls with palm sugar syrup, glucomannan will absorb more palm sugar syrup which causes bubble pearls to become darker as the flour concentration increases. The nature of glucomannan allows the formation of gels that can increase the number of water molecules in the gel structure so that the gelling interaction with water becomes tighter. A greater proportion of gelling material leads to an increase in the amount of liquid trapped in the gel [28].

B. Hedonics of Aroma

Kruskall Wallis test analysis of the hedonic parameters of bubble pearls aroma resulted in the overall formula there is a significant difference in the treatment of the aroma of bubble pearls made from tapioca with the addition of glucomannan flour that has been cooked with palm sugar syrup. Hedonic test on the aroma parameter of bubble pearls with the addition of glucomannan flour resulted in an average score ranging from 4.10-6.23 which states in the range of neutral to like. The results of the bubble pearl aroma hedonic test are presented in Figure 2.

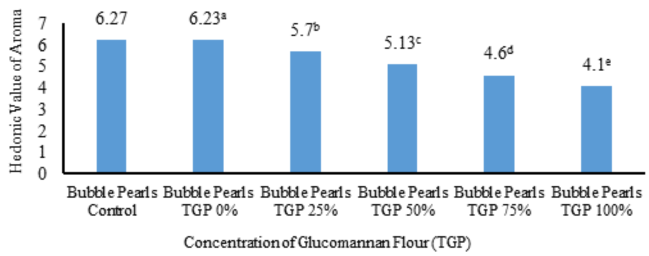

Fig. 2. Graph of hedonic value of aroma

The liking value of bubble pearls aroma with the addition of glucomannan flour tends to be lower than the control bubble pearls, which is 6.27 (like), and there is a decrease in liking value. The lower favorability value than the control bubble pearls and the decrease in favorability can be caused by the increasing concentration of glucomannan flour added. Glucomannan flour with increased concentration can cause the resulting product to have a distinctive aroma of porang tubers whereas porang flour has a rather unpleasant aroma [21].

C. *Hedonics of Hardness*

Kruskall Wallis test analysis of the hedonic parameter of bubble pearls hardness showed that all formulas had significant differences in the treatment of the hardness of bubble pearls made from tapioca with the addition of glucomannan flour that had been cooked with palm sugar syrup. The hedonic test results on the hardness parameter of bubble pearls with the addition of glucomannan flour resulted in an average score ranging from 2.33-5.9 which states in the range of dislike to slightly like. The results of the hedonic test on the hardness of bubble pearls are presented in Figure 3.

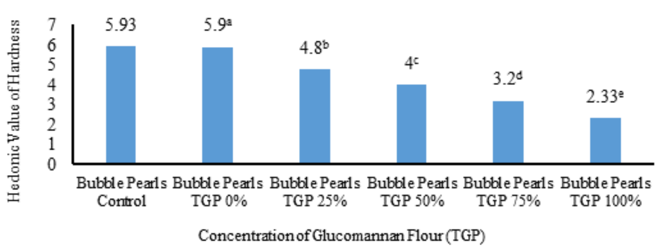

Fig. 3. Graph of hedonic value of hardness

These results show the liking value of the hardness of bubble pearls with the addition of glucomannan flour tends to be lower than the control bubble pearls, which is 5.93 (slightly like) and there is a decrease in the liking value due to the reduction in the level of hardness of bubble pearls due to an increase in the concentration of glucomannan flour and a decrease in the concentration of tapioca. According to [21], glucomannan content in porang flour can bind water and is a water-soluble fiber. Glucomannan will absorb more and more water when the bubble pearl's boiling process is carried out, resulting in a reduction in the level of hardness of bubble pearls. The reduced concentration of tapioca and the moisture content of the ingredients used can affect the texture of the resulting bubble pearls [32]. Tapioca can also affect the tensile strength value of food products where wet noodles with increased tapioca substitution have increased tensile strength values because tapioca has sticky properties of starch, namely amylopectin [9].

D. *Hedonics of Chewiness*

Kruskall Wallis test on the hedonic parameter of bubble pearls chewiness showed that all formulas had significant differences in the treatment of the chewiness of bubble pearls made from tapioca with the addition of glucomannan flour that had been cooked with palm sugar syrup. Hedonic test results on the chewiness parameter of bubble pearls with the addition of glucomannan flour resulted in an average score ranging from 2.23-5.87 which states in the range of dislike to slightly like. The results of the hedonic test on the chewiness of bubble pearls are presented in Figure 4.

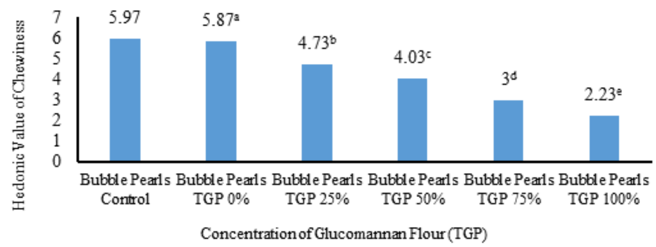

Fig. 4. Graph of hedonic value of chewiness

The hedonic test shows that the liking value of bubble pearls with the addition of glucomannan flour tends to be lower than the control bubble pearls, which is 5.97 (slightly like) and there is a decrease in the level of liking which can be caused by a decrease in the level of chewiness of bubble pearls due to an increase in the concentration of glucomannan flour and a reduction in tapioca concentration. This cause is similar to the research of [21] which shows that the presence of substituted porang flour will increase fiber content due to glucomannan content and increase water absorption, thereby reducing elasticity in wet noodle products.

E. *Hedonics of Taste*

The hedonic parameter of the taste of bubble pearls tested with the Kruskal Wallis test showed a significant difference in the treatment of the taste of bubble pearls made from tapioca with the addition of glucomannan flour that has been cooked with palm sugar syrup. Hedonic test results on the flavor parameter of bubble pearls with the addition of glucomannan flour resulted in an average score ranging from 3.00-6.00 which states in the range of slightly dislike to like. The results of the bubble pearl flavor hedonic test are presented in Figure 5.

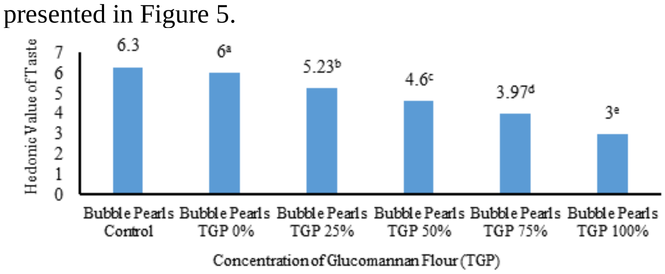

Fig. 5. Graph of hedonic value of taste

The hedonic test shows that the liking value of bubble pearls with the addition of glucomannan flour tends to be lower than the control bubble pearls, which is 6.3 (like) and there is a decrease in the liking value due to the increase in the concentration of glucomannan flour added, where the increased concentration of glucomannan flour can cause bubble pearls to have a distinctive taste of porang tubers, salty, rough and fibrous. Glucomannan flour is the result of purification from porang flour so it has a salty taste because purification through a chemical process with the help of salt increases glucomannan content and reduces calcium oxalate from coarse porang [31, 1]. Wet noodles that experience an increase in the amount of porang flour substituted make the noodles become somewhat coarse and experience an increase in fiber content, thus affecting panelists' assessment of taste [21]. The research showed that increasing the concentration of porang flour can affect the taste of rice paper because it can make the rice paper taste more typical of porang tubers [23].

F. Hedonics of Overall

Kruskall Wallis test analysis of the overall hedonic parameters of bubble pearls with the addition of glucomannan flour showed that all formulas had significant differences in the treatment of the overall hedonic value of tapioca-based bubble pearls with the addition of glucomannan flour that had been cooked with palm sugar syrup. The hedonic test results on the overall parameters of bubble pearls with the addition of glucomannan flour resulted in an average score ranging from 2.87-6.27 which states in the range of dislike to like. The overall hedonic test results of bubble pearls are presented in Figure 6.

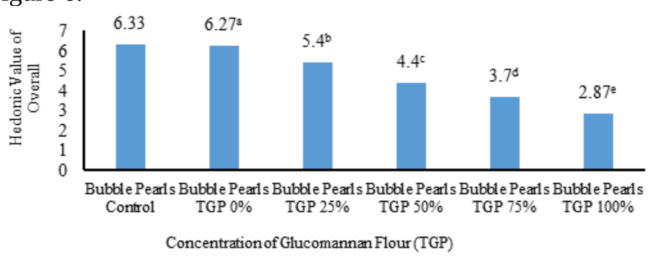

Fig. 6. Graph of hedonic value of overall

Overall, bubble pearls with the addition of glucomannan flour have a color, aroma, hardness, chewiness, and taste that is quite different from the control or conventional bubble pearls on the market, so that makes overall liking value of bubble pearls with the addition of glucomannan flour are lower than the control bubble pearls and experience a decrease in the level of liking or increasingly less favored by panelists due to an increase in the concentration of glucomannan flour. Increased concentration of glucomannan flour can affect the color, aroma, hardness, chewiness, and taste of the bubble pearls produced. The best treatment of glucomannan flour has a degree of whiteness (brightness) of only 50.87% [36], so increasing the concentration of glucomannan flour makes the bubble pearls produced darker. Porang flour has a less pleasant aroma and increasing the concentration of porang flour can cause the texture of food products to be somewhat rough, which will affect the assessment of aroma and taste. Porang flour also has fiber content which can cause increased water absorption, thus reducing texture [21].

G. Water Content

The amount of water in a food product can be indicated by its moisture content. The flavor, texture, shelf life, and appearance of the product can be influenced by the percentage of moisture content of the food product [10]. The results of moisture content analysis using the gravimetric oven method showed the percentage of bubble pearls with the addition of glucomannan flour in the range of 53.81%-75.05% and control bubble pearls of 55.67%. ANOVA test on the parameter of moisture content of bubble pearls with the addition of glucomannan flour showed significant differences in the treatment of moisture content of tapioca-based bubble pearls with the addition of glucomannan flour. The results of the bubble pearls moisture content test are presented in Figure 7.

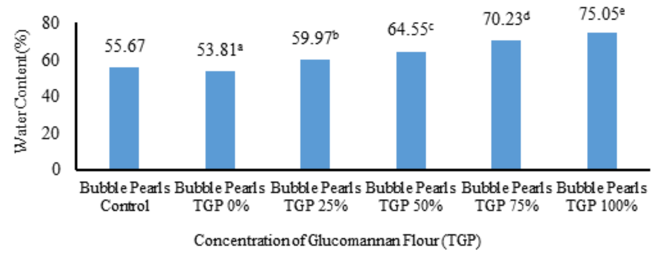

Fig. 7. Graph of water content

These results show that bubble pearls with the addition of glucomannan flour have a water content that tends to be higher than the control bubble pearls, which is 55.67% and there is an increase in the water content value of bubble pearls which can be caused by an increase in the concentration of glucomannan flour added which has a higher water content than tapioca and glucomannan flour content. According to research, control bubble pearls with 100% tapioca formulation have a moisture content of 53.92% due to the low moisture content of tapioca because it only contains 9% water [18]. The research also showed that the moisture content of glucomannan flour was 13.61% where the moisture content was higher than the moisture content of tapioca [36]. Food products with the addition of glucomannan flour can produce higher water content following the research of [21] where porang flour can increase the water content of wet noodles due to the ability of its glucomannan content to absorb water. Glucomannan content according to [1] able to absorb large amounts of water.

H. Ash Content

Analysis of ash content can help determine the presence of mineral content in food ingredients. The results of ash content testing showed the percentage of bubble pearls with the addition of glucomannan flour in the range of 0.01%-4.48% and control bubble pearls of 0.05%. Based on the ANOVA test on the ash content parameter, there was a significant difference in the ash content of bubble pearls made from tapioca with the addition of glucomannan flour. The ash content test results of bubble pearls are presented in Figure 8.

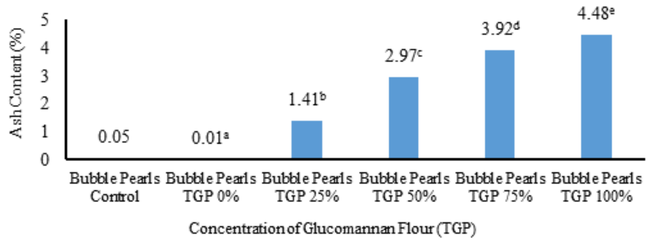

Fig. 8. Graph of ash content

These results state that the ash content of bubble pearls with the addition of glucomannan flour tends to be higher than the control bubble pearls, which is 0.05% and there is an increase in the ash content of bubble pearls. The ash content test shows that as the concentration of glucomannan flour increases, it will affect the concentration of ash content in food ingredients because the ash content of glucomannan porang flour is higher than tapioca. Based on research tapioca has a chemical composition of ash of only 0.02-0.33% [12]. The ash content is lower than the ash content of glucomannan flour which is 0.37% and another research is 4.612% [36, 1], so when bubble pearls are added with glucomannan flour, bubble pearls tend to have higher ash content as the concentration increases.

I. Dietary Fiber Content

Food fiber comes from components in edible food plants and is a carbohydrate that is resistant to digestion and absorption in the human digestive tract and is fully or partially fermented in the human colon [31]. The results of testing dietary fiber content showed the percentage of bubble pearls with the addition of glucomannan flour in the range of 1.56%-12.77% and control bubble pearls of 1.18%. The ANOVA results of the linear model of the Simplex Lattice Design method on the parameters of dietary fiber content have a p-value <0.05, it is 0.0007, which means that the entire formulation has a significant effect on the results of testing dietary fiber content, so that it can be used as a reference for determining the optimum formula. The counterplot graph of bubble pearls' dietary fiber content is presented in Figure 9.

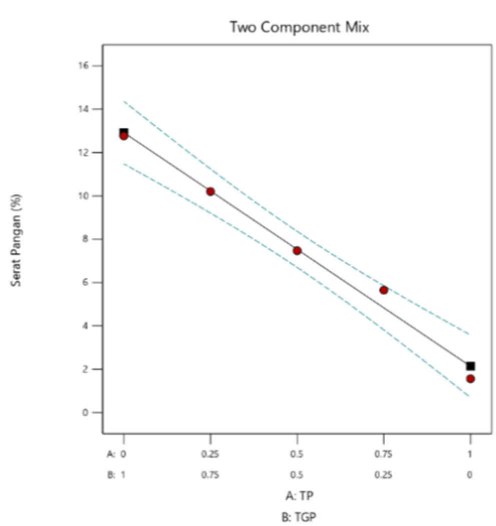

Fig. 9. Counterplot graph of the dietary fiber content

The results of testing the value of dietary fiber content in each formulation showed an increase in the graph along with the increasing concentration of glucomannan flour addition, where the highest value was in formula 5 at 12.77% with 100% glucomannan flour and the lowest value in formula 1 at 1.56% with 0% glucomannan flour. The mathematical equation obtained from the test results of dietary fiber content is Y=2.14A+12.92B with the coefficient values of A (tapioca) and B (glucomannan flour) having a considerable difference. These results indicate that the effect of glucomannan flour is greater than tapioca on dietary fiber content and bubble pearls with the addition of glucomannan flour have dietary fiber content that tends to be higher than the control bubble pearls which is 1.18% and the increase in dietary fiber content of bubble pearls as the concentration of glucomannan flour increases.

The increased dietary fiber content can be caused by the high glucomannan content in glucomannan flour as much as 84.44% [36]. Glucomannan in porang flour is a water-soluble fiber and compared to other dietary fibers able to absorb high water [24]. Another research states that glucomannan is included in water-soluble dietary fiber which has strong hydrocolloid properties. The increase in fiber content along with the concentration of porang flour added is because porang flour has a specialty with a high glucomannan content of 43.98%-70.35%. Kue baruasa with 15% porang flour substitution has the highest fiber content of 7.16%, compared to kue baruasa with 0% porang flour substitution [25]. As the concentration of porang flour increased, there was an increase in the amount of dietary fiber content of meatballs [34]. The increased dietary fiber content is due to the substitution of porang flour which is rich in food fiber due to its glucomannan content of 64%-84%. Fiber content in bubble pearls with the addition of glucomannan flour will affect the texture of the bubble pearls produced due to the nature of glucomannan which can crystallize and form fine fiber structures [27].

J. Gumminess and Hardness

The capacity of a material to return to its initial shape after being subjected to a force as well as when the force is released is referred to as gumminess [15]. The maximum peak strength in the first analysis period that simulates the initial bite when eating food is the texture hardness of the product [8]. The gumminess and hardness test aims to determine the texture quality of the bubble pearls produced. The test results showed the gumminess value of bubble pearls with the addition of glucomannan flour in the range of 53.20gf-14.52gf and the hardness value in the range of 70.65gf-38.18gf, while the control bubble pearls were 55.25gf for gumminess and 71.58gf for hardness.

The ANOVA results of the linear model of the Simplex Lattice Design method for the gumminess level parameter have a p-value <0.05, it is 0.0004, which means that the entire formulation has a significant effect on the results of the gumminess level test, so that it can be used as a reference for determining the optimum formula. The counterplot graph of the gumminess level of bubble pearls is presented in Figure

10. The ANOVA test on the hardness parameter showed a significant difference in the treatment of the hardness of bubble pearls made from tapioca with the addition of glucomannan flour. The test results of the hardness level of bubble pearls are presented in Figure 11.

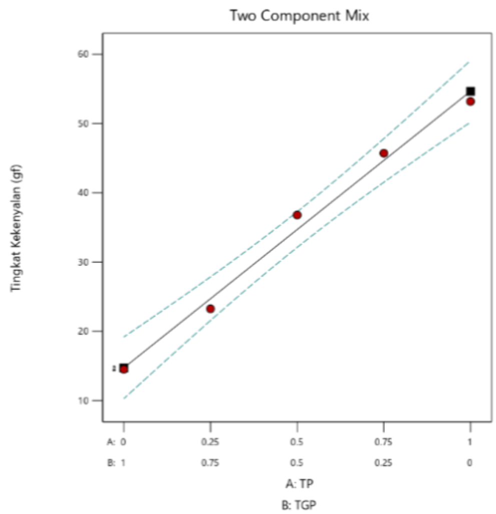

Fig. 10. Counterplot graph of the gumminess level

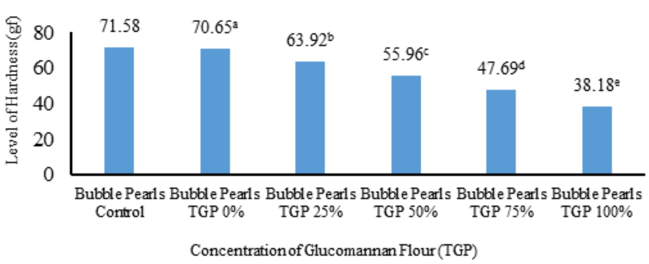

Fig. 11. Graph of hardness level

The test results of the level of gumminess in each formulation showed a decrease in the graph along with the increasing concentration of glucomannan flour addition. The mathematical equation of the results of the chewiness level test is Y=54.66A+14.74B with the coefficient values of A (tapioca) and B (glucomannan flour) having a considerable difference. These results indicate that tapioca has a greater influence on the gumminess of bubble pearls. The gumminess and hardness test showed that bubble pearls with the addition of glucomannan flour had gumminess and hardness values that tended to be lower than the control bubble pearls and the gumminess and hardness values of bubble pearls decreased as the concentration of glucomannan flour increased.

The lower value of chewiness and hardness of bubble pearls with the addition of glucomannan flour and a decrease can be caused by an increase in the concentration of glucomannan flour and a decrease in the concentration of tapioca. The reduced concentration of tapioca has a major effect on the texture of the bubble pearl's hardness [32]. The chemical composition of tapioca contains 73.3-84.9% starch, which consists of 17% amylose and 83% amylopectin [12]. The gelatinization process can change the texture and gelling ability of tapioca starch based on the amount of amylose and amylopectin present. A high amount of amylopectin can produce chewy characteristics due to its strong stickiness [15].

An increased concentration of glucomannan flour can affect the texture of bubble pearls because the glucomannan content will absorb more water when the bubble pearl's boiling process is carried out, resulting in a reduction in the level of hardness and chewiness of bubble pearls. High water absorption will cause an increase in water content which can affect the softness level of the resulting bubble pearls. Based on research [29], glucomannan has properties that can reduce the percentage of syneresis. The added glucomannan flour will make the texture of the resulting bubble pearls fibrous because glucomannan can crystallize and create a fine fiber structure due to its characteristics similar to cellulose and galactomannan due to contact with water on heating [27]. According to [21], the glucomannan content in porang flour can bind water and includes water-soluble fiber. The texture of wet noodles with the addition of porang flour becomes clumpy and soft due to an increase in the stickiness of the noodles and an increase in fiber content which causes higher water absorption, thus reducing the elasticity of the noodles.

K. Water Absorption Capacity

The capacity of the product to absorb water can be shown by the water absorption test. The ability to absorb water can affect the moisture content, shelf life, and texture of food [30]. The results of water absorption testing using the boiling method showed the percentage of bubble pearls with the addition of glucomannan flour in the range of 31.24%-81.36% and control bubble pearls of 33.54%. The ANOVA results of the linear model of the Simplex Lattice Design method on the water absorption parameter showed a p-value <0.05, it is 0.0107, which means that the entire formulation has a significant effect on the results of the water absorption test, so it can be used as a reference for determining the optimum formula. The counterplot graph of the water absorption of bubble pearls is presented in Figure 12.

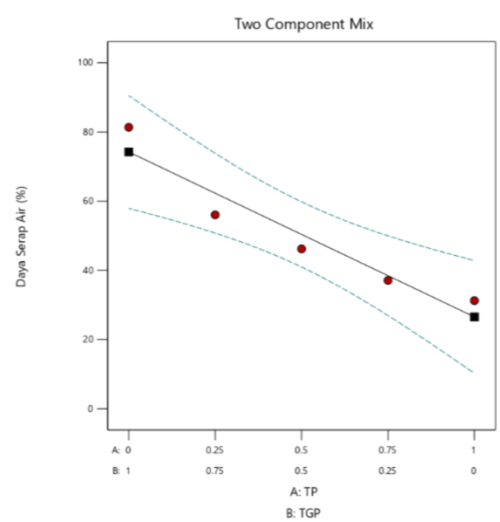

Fig. 12. Counterplot graph of the water absorption capacity

The test results of the water absorption capacity value in each formulation showed an increase in the graph along with the increasing concentration of glucomannan flour addition, where the highest value was in formula 5 of 81.36% with 100% glucomannan flour and the lowest value in formula 1 of 31.24% with 0% glucomannan flour. The mathematical equation obtained from the water absorption capacity test results is Y=26.55A+74.23B with the coefficient values of A (tapioca) and B (glucomannan flour) having a considerable difference. These results show that the effect of porang glucomannan flour is greater than tapioca on water absorption capacity and bubble pearls with the addition of porang glucomannan flour have a higher water absorption capacity than the control bubble pearls, which is 33.54%, and the water absorption capacity of bubble pearls increases as the concentration of glucomannan flour increases.

The increasing water absorption capacity is caused by the glucomannan content in glucomannan flour. This is in line with the research, where the ability of glucomannan to absorb water is included in the polysaccharide group with high water absorption properties, causing beef meatballs with porang flour formulation to contain high water content [33]. The increasing concentration of glucomannan flour based on the research of [2] can reduce the percentage of syneresis which causes more water to be trapped due to the superior nature of glucomannan to absorb water and make gels. The value of water absorption capacity that increases along with the increase in the concentration of glucomannan flour can affect the value of water content and texture of bubble pearls.

L. Determination of the Optimum Formula

The research on bubble pearls made from tapioca with the addition of glucomannan flour involved five formulations using two variations of ingredients: tapioca and glucomannan flour. The optimum formula was analyzed using Design Expert by applying the simplex lattice design method also the parameters used to determine the optimum formula of bubble pearls with the addition of glucomannan flour in simplex lattice design were water absorption capacity, gumminess level, and dietary fiber content. According to [11], the optimization parameter test was conducted a test by applying the analysis of variance (ANOVA) to assess the significance of the response analysis and identify the model recommended by the Design Expert. ANOVA test results showed that the variable component values had a significant effect because they have a p-value <0.05 and could be used to determine the optimum formula by considering the desirability value of each response produced.

The desirability value shows how far the expected criteria have been met. The solution provided is close to the expected optimization process and the expected criteria are increasingly fulfilled, which can be indicated by the higher desirability value and closer to the value of 1 [16]. A value of 0 indicates a mismatch between the factor and the estimate, while a value of 1 indicates a perfect match. In the process of determining the optimum formula, the highest desirability value is selected [38]. According to the results of parameter optimization, all formulas produced desirability values ranging from 0.465 to 0.862 as shown in Figure 13.

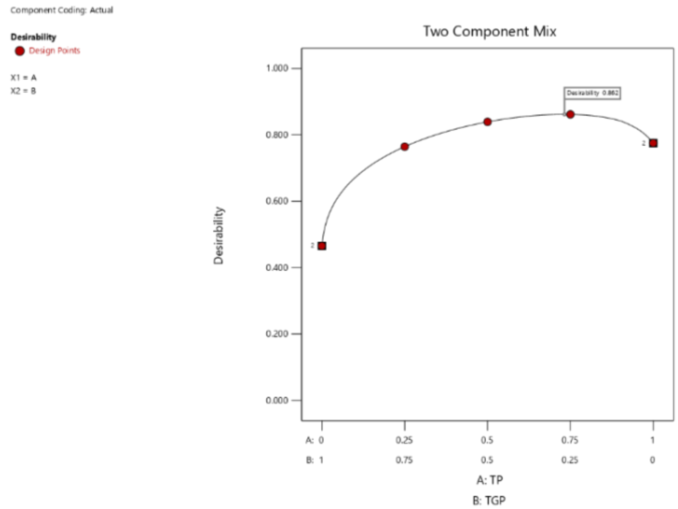

Fig. 13. *Desirability* graph of *bubble pearls*

The highest desirability values are found in formula 2 and formula 3, which have desirability values of 0.862 (25% glucomannan flour) and 0.839 (50% glucomannan flour). Those formulas meet the criteria for the optimum formula as they have a desirability value closest to 1 and the highest value of desirability. Based on [11], the simplex lattice design method using Design Expert software is also able to produce predictive values for the optimization parameters and can provide mathematical equations for each optimization parameter. The predicted values generated by this method are close to the actual test results because they are estimates based on the parameter test results. The predicted values of all optimization parameters are shown in Table 3.

TABLE III. PREDICTIVE VALUES AND MATHEMATICAL EQUATIONS OF OPTIMUM FORMULA

Parameters	Predictive values	Equations	ANOVA	p-value
Dietary Fiber Content	5.026	Y=2.14A+12.92B	0.0007	p<0.05
Gumminess Level	43.967	Y=54.66A+14.74B	0.0004	p<0.05
Water Absorption Capacity	39.322	Y=26.55A+74.23B	0.0107	p<0.05

The predicted values of the simplex lattice design serve as a basis for comparison with the formula test results based on predetermined parameters to obtain the optimum formula [11]. The results show a significant ANOVA value where the significant ANOVA value shows a real difference effect between the variations in the use of tapioca and glucomannan flour in the overall formula. The resulting mathematical equation shows the effect of the optimized ingredient variation, where the letter A refers to tapioca and B refers to glucomannan flour. The mathematical equation generated from the value of dietary fiber content is Y=2.14A+12.92B and water absorption is Y=26.55A+74.23B which shows that the coefficient of B is greater which indicates that glucomannan flour affects dietary fiber content and water absorption capacity of bubble pearls, while the gumminess level is Y=54.66A+14.74B which shows that the coefficient of

A is greater which indicates that tapioca influences in forming the gumminess of bubble pearls. According to [11], the optimum formula from the simplex lattice design results, which has the highest desirability value, was further evaluated using a one-sample t-test to compare the actual test results with the predicted values presented in Table 4 and Table 5.

TABLE IV. ONE SAMPLE T-TEST BUBBLE PEARLS FORMULA 2

Parameters	Predictive Values	Test Results	T-test	Sig. Value (*2-tailed*)
Dietary Fiber Content	5.026	5.65	0.213	>0.05
Gumminess Level	43.967	45.72	0.172	>0.05
Water Absorption Capacity	39.322	37.08	0.085	>0.05

TABLE V. ONE SAMPLE T-TEST BUBBLE PEARLS FORMULA 3

Parameters	Predictive Values	Test Results	T-test	Sig. Value (*2-tailed*)
Dietary Fiber Content	5.026	7.47	0.036	<0.05
Gumminess Level	43.967	36.80	0.033	<0.05
Water Absorption Capacity	39.322	46.22	0.013	<0.05

The one sample t-test in formula 2 with 25% glucomannan flour showed sig (2-tailed) values >0.05 in all optimization parameter test results. The test shows that there is no significant difference between the test results and the predicted values. The test results of Formula 3 with 50% glucomannan flour showed a significant difference with a sig (2-tailed) value <0.05, indicating a difference between the test results and the predicted values. Formula 2 and formula 3 can be declared as the optimum formula because both have desirability values that are almost the same and close to 1 according to the results of the simplex lattice design. The one sample t-test on the parameter test results with the predicted values of the two formulas showed some differences, especially in formula 3. The difference between the two formulations can be known by statistical tests that have been carried out previously according to the ANOVA test and Duncan test for chemical and physical characteristics as well as the Kruskal Wallis test and Mann Whitney test for organoleptic characteristics. These tests show that there is a significant difference in the effect of tapioca formulation and the addition of glucomannan flour on the results of water content, ash content, hardness level, and organoleptic characteristics of bubble pearls produced.

IV. CONCLUSIONS

Based on the results of this research, it can be concluded that glucomannan flour added to tapioca-based bubble pearls has a noticeable effect on their physical, chemical, and hedonic quality characteristics as the concentration increases. The optimum formula for tapioca-based bubble pearls with the addition of glucomannan flour based on the simplex lattice design method is formula 2 (25% glucomannan flour: 75% tapioca) which produces the highest desirability value of 0.862. This formulation is associated with hedonic ratings indicating a slight likeness for color (5.73) and aroma (5.7), neutrality for hardness (4.8) and chewiness (4.73), a rather likeness for taste (5.23), and a slight likeness for overall acceptance (5.4). Additionally, this optimum formula exhibits a water content of 59.97%, ash content of 1.41%, water absorption capacity of 37.08%, gumminess level of 45.72gf, hardness level of 63.92gf, and dietary fiber content of 5.65%.

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