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To cite this article: I K Prameswari et al 2018 J. Phys.: Conf. Ser. 1022 012029

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Effect of water volume based on water absorption and mixing time on physical properties of tapioca starch – wheat composite bread

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Abstract. Tapioca starch application in bread processing change water absorption level by the dough, while sufficient mixing time makes the optimal water absorption. This research aims to determine the effect of variations in water volume and mixing time on physical properties of tapioca starch – wheat composite bread and the best method for the composite bread processing. This research used Complete Randomized Factorial Design (CRFD) with two factors: variations of water volume (111.8 ml, 117.4 ml, 123 ml) and mixing time (16 minutes, 17 minutes 36 seconds, 19 minutes 12 seconds). The result showed that water volume significantly affected on dough volume, bread volume and specific volume, baking expansion, and crust thickness. Mixing time significantly affected on dough volume and specific volume, bread volume and specific volume, baking expansion, bread height, and crust thickness. While the combination of water volume and mixing time significantly affected for all physical properties parameters except crust thickness.

Key words: Substituted bread, water, mixing time, physical properties, texture

1. Introduction
White bread is one of bakery product with high carbohydrate content and nowadays white bread becomes alternative source of carbohydrate aside from rice in south east asia countries. Normally, white bread is made from wheat flour, however the needs of wheat flour in South East Asia countries only can be filled through import. In order to reduce the dependency on wheat flour, the use of wheat flour should be diverted with the local commodities such as tapioca. The utilization of tapioca is because the price is cheaper than wheat flour and with a neutral flavor. Eriksson et al., (2014), states that the higher application of cassava flour in bread making to substitute wheat flour, the harder bread will be produced, while the elasticity and the bread volume are lower [1].

However, the disadvantage of using tapioca is because it has no gluten content [2] which needed to expand the dough in bread making process. Using flour without gluten content increases the hardness level of the bread because of imperfect expansion and it also reduces the bread’s volume which causes bread’s textures becomes hard and dense [3]. This aspect can reduce the level of consumer’s acceptance. Thus, to improve the characteristic of the bread, modification in bread processing are needed, such as the control of water amount, and sufficient mixing time in dough making, especially when the dough consists of different kinds of flour.
According to Jacob (1951), the amount of water that added in bread making process depends on the flour’s capability to absorb water and the expected characteristic of the bread [4]. The normal amount of water added in white bread making is 64-66% of the flour’s portion. Absorption level of the flour shows the percentage of water that can be absorbed by the flour after the dough becomes dull. Wheat flour and tapioca have different level of water absorption [5]. The change of flour’s water absorption caused by flour substitution results to difference volume of water which added differently in different composition of flours of composite flour in order to make dough with optimal characteristic [6] (Adekele and Odedeji, 2010 ; Rauf, 2015).

The ingredients mixing is finished when the dough is formed well (Nur’ain, 2011). In process of mixing, gluten function is to maintain the air inside the dough and gas produced by the yeast while fermenting, which makes the dough expanding [7]. However to Utami (2010) the excessive time in mixing cause the structure of gluten broken and the capability of the dough to hold the gas loses and so the bread does not expand perfectly [8]. On contrary, if the mixing time is too short, the dough will not expand and its texture become stiff. Thus, time management in mixing process must be investigated to produce optimal dough expanding and also the desired texture of the bread. This research is conducted to identify the effects of water amount and mixing time on tapioca starch – wheat composite bread physical characteristic.

2. Research Methods

2.1. Instruments
The instruments are divided into two, first are the tools that used to make white bread such as agitator, oven, basin, analytic scale, pan, spoon, spatula, cloth, plastic, rolling pin, electrical stove and the second one are tools that used to do the analysis such as scale, container with measurement 23 cm x 15 cm x 12 cm, scanner Canon Printer MP287.

2.2. Ingredients
Ingredients that used to make white bread are hard wheat flour, tapioca starch from local producer, bread improver, margarine, yeast, skimmed milk, refined sugar, salt and shortening. Meanwhile, there is white millet to analyze the physical characteristic of the bread.

2.3. Research Stages
2.3.1. Determining Water Volume and Mixing Time. Determining the water volume depends on water absorption of the flour. Mixed wheat flour and tapioca starch, both are tested along side with the formula to analyze the water absorption level. The result of the analysis used to determine the water volume in the dough. Then, there was consideration to determine the exact time of mixing using mixer until the dough is formed perfectly.

2.3.2. Determining Initial Formula of Products. The ratio between wheat flour and tapioca starch were taken from the preliminary research resulted in 70 : 30 ratio (wheat : tapioca starch). The ingredients to make white bread were 175 gram wheat flour, 75 gram tapioca starch, 3.75 gram salt, 10 gram shortening, margarine, 1 gram bread improver, 5.5 gram yeast and water (111.8 ml; 117.4 ml; or 123 ml).

2.3.3. Making White Bread with Tapioca Starch Substitution. The stages in made white bread as follows; first weigh all ingredients based on formula. Before the other ingredients are added, mixed the wheat flour and tapioca in the mixer until evenly distributed. Then, added 15 gram of refined sugar, 3.75 gram of salt, 5 gram of skimmed milk, 10 gram of shortening, 1 gram of bread improver and 5.5 gram of yeast into the mixer alongside with the mixed wheat flour and tapioca. Added water gradually according to the treatment (111.8 ml; 117.4 ml; 123 ml) and mixed the dough until it formed perfectly according to the proper mixing time (16 minutes, 17 minutes and 36 seconds, 19 minutes and 12 seconds). After the dough formed perfectly, formed it into round shape and wraped it in the plastic
for 15 minutes in room temperature. After that, formed the dough into flat shape by using rolling pin then roll it and put it into pan which already been coated with margarine. Steamed the dough for 45 minutes with temperature between 45-50 °C and RH 75-80%. The last stage baked it inside the oven for 40 minutes at temperature 150ºC.

2.4. Analysis
The analysis of physical characteristic consists of dough volume and specifc volume, bread volume and specific volume, baking expansion, height of dough and bread, weight loss and thickness of crust.

2.5. Analysis of Data
The data is analyzed by using Two Way Analysis of Variances (ANOVA). If the effect of treatments are found, then the analysis continued with Duncan Multiple Range Test (DMRT) in significant degree 5% (p ≤ 0.05).

3. Result and Discussion

Table 1. Physical Characteristics of Dough and Bread with 30%-Tapioca-Substitution.

| Parameters | VD (cm³) | SVD (cm³/g) | VB (cm³) | SVB (cm³/g) | BA (%) | DH (cm) | BH (cm) | WL (%) | CT (mm) |
|------------|----------|-------------|----------|-------------|--------|---------|---------|--------|---------|
| A          | 395,71   | 1,00        | 952,37   | 2,67        | 240,70 | 5,03    | 6,43    | 9,15   | 6,20    |
| B          | 366,41   | 0,91        | 958,87   | 2,55        | 261,69 | 5,33    | 6,60    | 5,82   | 6,27    |
| C          | 379,37   | 0,94        | 948,40   | 2,50        | 249,94 | 5,27    | 6,65    | 6,22   | 5,67    |
| D          | 384,79   | 0,94        | 1077,37  | 2,80        | 279,78 | 5,27    | 7,20    | 5,99   | 5,73    |
| E          | 407,54   | 1,00        | 997,50   | 2,65        | 244,80 | 5,10    | 6,77    | 7,62   | 5,67    |
| F          | 368,55   | 0,91        | 1014,14  | 2,66        | 270,31 | 5,23    | 6,67    | 7,79   | 6,13    |
| G          | 411,98   | 1,00        | 997,62   | 2,60        | 242,15 | 5,20    | 6,43    | 6,63   | 5,93    |
| H          | 390,89   | 0,94        | 977,81   | 2,56        | 250,50 | 5,30    | 6,23    | 7,11   | 5,33    |
| I          | 398,15   | 0,97        | 1266,06  | 3,32        | 318,00 | 5,07    | 8,43    | 6,73   | 5,53    |

3.1. Volume and Specific Volume of Dough
The result of two way ANOVA analysis showed that the varied water volume and mixing time affected the volume of white bread dough with p value 0.0002 (p<0.05) and 0.003 (p<0.05). Table 1. showed that the increased of dough volume was in line with water volume and in contrary with mixing time. Hera et al. (2013), said that the larger amount of water that added in the dough, made more flour particles hydrated, and it affected the characteristic range of dough in process of mixing [9]. Water hydrates the ingredients to make dough and expand the starch granule. Thus, the water hydrates starch granule sufficiently and it made the granule starch bigger and expands [10].

Excessive time in mixing process can reduced the volume of the bread which the consistency of the dough also getting lower and sticky. According to Gomez et al. (2011), excessive time of mixing makes the dough softer but it has low consistency and becomes sticky [11]. It was marked by spatial power and the deceased of dough endurance level. The result showed that the mixing of the bread
dough in more than 24 minutes lead to broken structure of the gluten. The both combinations affected on dough volume with p value 0.00006 (p<0.05).

The result of two way ANOVA analysis showed that the varied water volume did not have significant effect with p value 0.065 (p>0.05) and the mixing time had the real impact on p value 0.005 (p<0.05) towards specific volume of white bread dough. Table 1. showed that adding larger amount of water increased the specific volume of dough. The specific volume of the dough was a comparison between volume of the dough and dough’s weight [12]. Therefore, specific volume of the dough was in line with dough’s volume. The combinations of water volume and mixing time affected on dough specific volume with p value amount 0.00004 (p<0.05).

Figure 1. Bread with 30%-Tapioca-Substitution

3.2. Volume and Specific Volume of Bread
The two way ANOVA analysis showed that the varied water volume in process of mixing affected on white bread’s volume with p value 0.00002 (p<0.05) and 0.0004 (p<0.05). Table 1. told that the more water in mixing increased bread volume. The application of tapioca starch reduced the number of gluten. The existed capacities of flour have to absorb large amount of water in order to bind the starch
with water. Therefore, the considerable amount of starch can raise its viscosity followed by the swollen starch granule [13].

The increasing of swelling power increased the volume of bread. The water and gas holding are achieved which results to higher bread volume. Moreover, the more numbers of mixing quantity in longer period of mixing caused gluten matrix were formed because the flour absorbs enough water and it allows more expansion [14]. Meanwhile, the combination of mixing time and water volume affected on bread volume with p value 0.000007 (p<0.05).

The statistic result of two way ANOVA showed that the varied water volume and mixing time affected the specific volume of white bread with p value 0.0001 (p<0.05) and 0.002 (p<0.05). Table 1. told that the more water volume increased the specific volume of bread. Bread specific volume was in line with the bread volume in contrary with the weight of bread [12]. Generally, there was an assumption that the higher amount of water makes higher specific volume of the bread. However the crumb will be larger if the amount of water is overly added in longer time of proofing. Besides, overly hydrated bread produces weak final structure and difficulties in slicing [15]. However, the combinations of mixing time and water volume affected on bread specific volume with p value 0.000007 (p<0.05).

3.3. Baking Expansion
The analysis result of two way ANOVA showed that the varied water volume and time mixing affected on the level of white bread expanding with p value 0.001 (p<0.05) dan 0.00001 (p<0.05) and mixing time affected on the level of white bread expansion with p value 0.001 (p<0.05) and 0.00001 (p<0.05). On the Table 1., the result of bread expansion level was increasing along with the increasing of water volume.

The capability to hold gas inside tapioca starch – wheat coamposite bread was lower compared to wheat flour because of less gluten to develop bread volume. By bonding more amount of water, the additional water that was needed to expand the bread because tapioca starch has large amount of amylopectin which make the structure of starch easier to open then water is easy to be absorbed. The expansion of starch granule can be seen through the large number of apex value in flour viscosity. The apex value of flour viscosity is 5387.94 mPas higher compared to the apex value of wheat flour 2375.25 mPas (Imanningsih, 2012).

According to Faridah (2015), the high apex value in viscosity shows the capabilties of starch granule to swell in heating process [16]. Thus, it produces bread with larger volume. The sufficient mixing time allowed yeast to adapt with its medium and the gas distribution into the dough [11]. The more amount of mixing time makes gluten can expand and maintain gas better. Meanwhile, the combinations of mixing time and water volume affected on baking expansion with p value 0.0000004 (p<0.05).

3.4. Dough and Bread Height
The result of the analysis using two-way ANOVA showed that experiments involving different volume of water and mixing time did not have big impact in changing height of white bread dough, as it p value was 0.902 (p>0.05) and 0.360 (p>0.05). The volume of water and mixing time unsignificantly affect the increasing height of bread dough. Adding amount of water and increasing mixing time likely influenced the dough height to decrease. It was because high water content in the dough make dough mass increase and the dough tend to widen, filling the space in pan because its consistency was low. According to Gomez et al. (2011), excessive time of mixing can make dough softer but it lowers dough consistency and makes it stickier [11]. Besides, combination of mixing time and water volume significantly affected the dough height with p value of 0.0009 (<0.05).

The analysis result of two-way ANOVA indicated that the varied water volume did not give any significant effect meanwhile mixing time affected height of white bread significantly with p value of 0.057 (p>0.05) and 0.003 (p<0.05). Height of bread increased as the volume of water was added. This was in line with treatment of mixing of which the longer dough is mixed, the dove height also
increased. Moreover, the high bread height is related to the rising of dough. Height of bread is also related to volume of bread. In the process of baking, there was a quick increasing volume which caused by the evaporation of water from the starch molecules so that the volume after baking increases [17]. The increasing of bread volume resulted in the increasing height of bread. However, the combination of mixing time and water volume significantly affected the height of bread with p value of 0.00003 (p<0.05).

3.5. Weight Loss
The analysis result using two-way ANOVA showed that volume of water and mixing time did not contribute significant impact in terms of white bread weight loss with p value of 0.615 (p>0.05) and 0.598 (p>0.05). Bread weight loss decreased as volume of water and mixing time increased although did not represent significant result. According to Sundari et al. (2015), high level of heat affected the decreasing water content of dough in large quantities [18]. Besides, fat and protein would be damage if more heat is given.

Moreover, Roos et al. (2011) states that bread weight loss in baking was associated with water-binding capacity of bread matrix. Tapioca application in the white bread contributed in reducing amount of gluten as starch binder so that water shall be increased to help gluten bind more starches. Tapioca mainly consists of amylopectin. According to Muflihati et al. (2015), amylopectin has a structure that makes it absorb water easily that the water will be bound after absorbing [17]. Water content prevent dehydration of bread so it also prevent the bread from weight loss [19]. High rising bread likely has a chance to get a slight weight loss [20]. However, combination of mixing time and water volume significantly affected with p value of bread weight loss 0.001 (p<0.05).

3.6. Bread Crust Thickness
The analysis result of two-way ANOVA showed that varied volume of water and mixing time did not significantly influence on crust thickness of white bread with p value of 0.066 (p>0.05) and 0.478 (p>0.05). Crust thickness of bread decreased as volume of water was increased. It was in line with treatment of mixing time of which long duration also made crust thickness decreased. According to Gallagher et al. (2003), adding for about 10% or 20% water to dough reduce crumb firmness and thickness of crust which is caused by decreased starch retrogradation [21].

According to Charley (1982), the high quality bread performed when its convex shaped, not too thick with golden color crust [22]. Good crust layer showed the appearance of white bread cohesive. However, combination of mixing time and water volume did not affect the thickness of bread crust with p value of 0.084 (p>0.05).

4. Conclusions
Varied treatments of water volume showed significant effect to dough volume, volume and specific volume of bread, level of rising, and crust thickness. Varied treatments in mixing time indicated significant impact to volume and specific volume of dough, volume and specific volume of bread, baking expansion, bread height, and crust thickness. Moreover, combination of water volume and mixing time affected all parameters of physical characteristics except crust thickness. The more water and the longer mixing time, volume and specific volume of bread, baking expansion, and bread height also significantly increased.

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