The effect of water volume and mixing time on physical properties of bread made from modified cassava starch-wheat composite flour

S Srirejeki[1*], G J Manuhara[1], B S Amanto[1], W Atmaka[1], P W Laksono[2]
[1] Department of Food Science and Technology, Faculty of Agriculture, Sebelas Maret University, Indonesia
[2] Department of Industrial Engineering, Faculty of Engineering, Sebelas Maret University, Indonesia

*E-mail: sucisrirejeki@yahoo.com

Abstract. Modification of cassava starch with soaking in the whey (by product on cheese production) resulted in changes of the flour characteristics. Adjustments of processing condition are important to be studied in the making of bread from modified cassava starch and wheat composite flour (30:70). This research aims to determine the effect of water volume and mixing time on the physical properties of the bread. The experimental design of this research was Completely Randomized Factorial Design (CRFD) with two factors which were water volume and mixing time. The variation of water volume significantly affected on bread height, dough volume, dough specific volume, and crust thickness. The variation of mixing time had a significant effect on the increase of dough volume and dough specific volume. The combination of water volume and mixing time had a significant effect on dough height, bread volume, bread specific volume, baking expansion, and weight loss.

1. Introduction

Wheat flour is the main ingredients in bread making. With the increasing demand of fresh bread causes the needs of wheat flour increase too. Therefore, efforts should be made to reduce the amount of wheat flour needs in bread making. The superiority of cassava flour compared to other root based flour is cheap, abundant raw materials, neutral color and flavour and has a higher swelling power [1].

However, cassava starch application in bread making produces weak dough strength, so that it produces less expand bread, and hard crumb properties [2]. Therefore, it is necessary to modify cassava starch so it has better characteristics and meet industrial requirement [3]. Based on the preliminary research, white bread produced from composite flour of wheat and cassava flour modified with soaking in whey performed the best properties at substitution level of 30%. However, hard texture, bigger and uneven pore were observed in the bread.

It because the water volume and the mixing time used in all formulations are the same. The addition of sufficient water produce a perfectly hydrated dough and higher expansion after fermentation [4]. Inadequate or excessive water volume affected the interaction between components in the dough [5]. Development of gluten matrix during mixing formed dough gradually. The optimum dough is formed at the maximum point of mixing so that the dough resistance collapsed when the mixing continued [6].

2. Experimental

2.1. Materials
High protein flour, cassava starch, refined sugar, water, salt, shortening, milk powder, yeast used in this study were obtained from local store in Surakarta, Indonesia. The whey used in this study was obtained from local producer in Boyolali, Indonesia.

2.2. Modification of cassava starch
Based on the preliminary research cassava starch was modified by soaking starch in the whey with cassava starch - whey ratio was 1: 3, then heated in waterbath at 50°C for 60 minutes with mixing, and dried in cabinet dryer at 50°C during 10 hours. The dried cassava starch, for further was through the size reduction stage using blender and sieving (80 mesh).

2.3. Bread making
The bread was made by straight dough method which all ingredients were mixed in single mixing step after weighing [7]. Water was added into the 250 g composite flour (wheat flour : modified cassava starch ratio was 70 : 30) bit by bit according to the designed formulas then the ingredients were mixed according to the designed treatments. The formed dough was then rounded and rested for 15 minutes. Then the dough was degassed using rolling pin, rolled, and put in a baking pan. The dough height [8], weight, volume and specific volume [9] was then measured. The next processing was fermentation in proofer for 30 minutes at 45-50°C and relative humidity 75-80%. After that, the dough was baked for 30 minutes at 150°C. The bread was further cooled at room temperature. The bread height [8], bread volume and specific volume [9], baking expansion [10], weight loss [11], and crust thickness [12] was then measured.

2.4. Data analysis
The design of this study used a factorial completely randomized design with two factors: water volume (volume at water absorption capacity/ WAC of the composite flour, WAC+5%, and WAC+10%) and mixing time (time at viscoelastic point/ VEP, VEP+10%, and VEP+20%). The combination of two factors was repetead three times. The data was analyzed using two way ANOVA and continued with Duncan's Multiple Range Test (DMRT) at $\alpha = 0.05$ when significant influence was observed.

3. Results and Discusion

3.1. Dough Height
Statistically, combination of water volume and mixing time time had a significant effect on dough height with p value 0.043 ($p < 0.05$). The dough height rised and then decreased, it was due to the effect of gluten formed. At the highest height, the dough is expected to obtain a strong gluten network. The dough height is influenced by the dough fermentation rate through gas formation and formed gluten network [13]. The stronger gluten network, the dough ability to hold the gas produced during fermentation was optimized so that the higher dough obtained. The highest of dough height was found in the combination of VEP+10% - WAC+5%. It was lower when compared to other studies that used the mixture of wheat flour and tapioca and resulted dough height of 8.35 cm [4]. The difference arised because the difference in composition of flour, water volume and yeast resulted in different gas production.

3.2. Bread Height
Water volume variation had a significant effect on bread height with p value of 0.024 ($p < 0.05$). Water is an important factor in bread making. The addition of water in optimum amounts, form optimum viscoelasticity properties of dough so that gluten-formed network is strong [14]. The stronger the

gluten hold the carbon dioxide gas formed, the greater the bread volume, the higher the bread produced [15]. The combination of VEP - WAC+5% resulted in highest bread height as well as bread volume and specific volume.

Table 1. Physical Characteristic of Dough and Bread from Modified Cassava Starch-Wheat Composite Flour

	Parameter								
	DH (cm)	BH (cm)	DV (cm^3)	DSV (cm^3/g)	BV (cm^3)	SVB (cm^3/g)	BE (%)	WL (%)	CT (mm)
A	5.03	6.30	320.11	0.79	835.87	2.23	283.63	6.36	2.75
B	5.23	6.80	344.58	0.86	820.23	2.18	238.94	5.72	3.12
C	4.96	6.76	316.70	0.80	970.59	2.66	306.42	8.15	3.38
D	5.03	7.15	371.37	0.91	1084.3	2.85	274.20	5.73	3.03
E	5.45	6.95	468.81	1.15	836.92	2.19	178.52	5.89	3.14
F	5.16	6.93	391.12	0.96	1003.76	2.66	257.10	6.67	3.04
G	5.10	6.25	360.10	0.80	689.57	1.82	192.78	7.91	2.43
H	5.00	6.86	345.19	0.84	970.36	2.53	282.78	6.21	2.82
I	5.16	6.86	313.32	0.76	928.42	2.41	296.72	5.72	2.08

[A] VEP - WAC
[B] VEP+10% - WAC
[C] VEP+20% - WAC
[D] VEP - WAC+5%
[E] VEP+10% - WAC+5%
[F] VEP+20% - WAC+5%
[G] VEP - WAC+10%
[H] VEP+10% - WAC+10%
[I] VEP+20% - WAC+10%
[DH] Dough Height
[BH] Bread Height
[DV] Dough Volume
[DSV] Dough Spesific Volume
[BSV] Bread Specific Volume
[BE] Baking Expansion
[WL] Weight Loss
[CT] Crust Thickness

3.3. Dough Volume and Specific Volume

Statistically, water volume and mixing time had a significant effect on dough volume (with p value 0.0001 and 0.021) and specific volume (with p value 0.0001 and 0.024), but there was no interaction between two factors. The resulting trend of dough specific volume was the same as the trend of dough volume. It was because the specific volume of dough is obtained from the ratio of the dough volume and the dough weight, while the dough weight did not change significantly [9]. Optimum mixing form the gluten structure and improve the extensibility and elasticity of gluten. The addition of water in the right amount can form a dough with optimum viscoelasticity properties so that the resulting gluten is also optimal [4]. This gluten ultimately hold the fermentation gas so that the dough is developed so that the optimum volume is generated [14]. The combination of VEP+10% - WAC+5% resulted in the highest dough volume and specific volume as well as dough weight. The result of the dough volume was greater when compared with other studies. The research of the effect of addition of various variations of hydrocolloids on non-gluten bread making with cassava flour formulations obtained the dough volume of 35.50 - 40.91 cm^3 with the total weight of the material 220.798 - 222.5 g [16]. While the research of making non-gluten bread based on cassava flour using hydrocoloid and enzyme obtained the dough volume of 52,06-55,28 cm^3 with the total weight of the material 108,375 g [17].

3.4. Bread Volume and Specific Volume

The variation of mixing time significantly affected the volume of the bread with p value of 0.009 ($p < 0.05$). The longer of the mixing time causes the greater volume. Longer mixing time allows the development of sufficiently formed gluten [18]. Water volume variation significantly affected the volume of the bread with p value of 0.012 ($p < 0.05$). The optimum addition of water, form a strong gluten network [4]. Reduced gluten network causes lower dough volume so that the volume of bread obtained decreases [14]. While the combination of water volume and mixing time used significantly affected the bread volume with p value 0.0003 ($p < 0.05$). The stronger the gluten holds the carbon dioxide gas formed, the greater the bread obtained [15]. The resulting trend of bread specific volume was the same as the trend of bread volume. In this research the highest of bread volume and specific volume was found in the combination of VEP - WAC+5%. The range of bread volume and specific volume in this research was comparable with other study (study of breadmaking from wheat flour substituted with cassava flour and soybean as an improver) resulting the bread volume and specific volume 803 - 1400 cm^3 and 2,35 – 3,93 cm^3/g at 0-50% substitution of cassava flour with total weight 406 g [9].

3.5. Baking Expansion
Based on statistical results of two way ANOVA, the mixing time and combination of water volume and mixing time significantly affected baking expansion with p value of 0.007 and 0.003 ($p < 0,05$). The dough resistance to mixing or mixing tolerance is usually 10-20% of the optimum mixing peak [19]. In this research, mixing until VEP+20% increased baking expansion. The maximum bread volume is obtained sometime after the point of maximum resistance [19]. In this research, the highest baking expansion was found in the combination of VEP+20% - WAC. The baking expansion was lower when compared with the research of the production of white bread from wheat flour substituted by 10-30% tapioca and added with glycerol monostearate which performed 290 - 345% baking expansion [20].

3.6. Weight Loss
Based on statistical results of two way ANOVA, combination of water volume and mixing time had a significant effect on weight loss of the bread with p value 0.015 ($p < 0.05$). The weight loss of bread was the same trend as the baking expansion. This is related to the formation of gluten, so the dough is ready to hold CO_2 gas from fermentation activity [14]. In this research the highest of weight loss of bread is produced equal to the highest baking expansion of bread. It was found in the combination of VEP+20% - WAC. The resulting weight loss is considerably lower when compared with other studies of baking with tapioca substitution derived from sweet and sour cassava flour [21].

3.7. Crust Thickness
Based on statistical result of two way ANOVA, water volume variation significantly influence to crust thickness of the bread with p value 0.001 ($p < 0.05$). The results showed that the more water volume, the crust was thinner. The crust thickness occured due to the baking process [22]. During baking, heat causes the water vapor pressure from the inner layer (crumb) while the outer layer of bread get dry. Gelatinization during baking caused the formation of layers on the surface of materials that inhibited the transfer of moisture mass [23]. The water vapor pressure from inside the crumb caused the outer structure of the bread to become deflated and solid structure. This structure is called the crust [22].
The resulting crust thickness was lower when compared with other studies, ie, the production of bread with temperature differences (185, 195 and 205 °C) and baking time (25, 30 and 35 minutes) obtained a much larger crust thickness 6.08 - 9.0 mm [12].

The best method of breadmaking was the combination of VEP - WAC+5%. WAC+5% obtained the largest bread volume so that WAC+5% was selected in terms of water volume variations. Meanwhile, in terms of variation in the amount of mixing time, VEP and VEP+10% was not significantly different, but both were significantly different with VEP+20%. So that VEP is chosen due to its cheaper operational costs than VEP+10%. Furthermore this research still needs to be studied further to know the quality of bread made with best method when compared with bread of wheat flour (commercial bread).

4. Conclusion
The variation of water volume significantly affected on bread height, dough volume, dough specific volume, and crust thickness. The variation of mixing time had a significant effect on the increase of

dough volume and dough specific volume. The combination of water volume and mixing time had a significant effect on dough height, bread volume, bread specific volume, baking expansion, and weight loss

Acknowledgments
This work was the part of research project financially supported by research grant of PNBP UNS 2017 from Universitas Sebelas Maret, Indonesia.

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