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Formulation of Food Ingredients (Peanut Flour, Egg Yolks, Egg Whites, and Guar Gum) to the Characteristics of Gluten-Free Noodles

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Abstract. Noodle-processing technology commonly uses primary raw material in the form of wheat flour. One opportunity to increase the value of local flour is processing it into gluten-free noodle products, which can be consumed by people with celiac diseases. Some natural ingredients and food additives can be used to improve the characteristics of gluten-free noodles, including peanut flour, egg yolks, egg whites, and guar gum. This study aimed to analyze the effect of several types of additives on the physical and chemical characteristics of gluten-free noodle products derived from cassava flour. It was designed using a complete randomized design and proximate analysis results were analyzed statistically with SPSS 2.1 to determine the difference between treatments. ANOVA analysis results were analyzed, with completely randomized design method and the results were analyzed using Duncan's test. Based on the results of proximate and energy analysis, differences in treatment affected the quality of moisture, ash, protein, fat, carbohydrate content, and energy, which were significantly different. Cassava noodles added with peanut flour had a higher protein content compared to the controls, with the addition of egg yolks, egg whites, or hydrocolloids. The fat content of cassava noodles added by 5% egg yolk was higher than that of other cassava noodles. The addition of egg whites with a composition of 2% or 5% produced an RVA (Rapid Visco Analyzer) profile that did not form peak viscosity at the optimum temperature and hot-paste viscosity. Based on SEM analysis on cassava noodles, the microstructure profile showed the occurrence of starch gelatinization.

Keywords: Cassava; Characteristic; Food ingredient; Gluten-free; Noodle

1. Introduction

Noodle-processing technology, in general, uses primary raw material in the form of wheat flour derived from wheat. Noodles can be processed using raw materials from flour mixed with other local food ingredients, such as corn flour (Shobha et al., 2015), potato flour (Pu et al., 2017), banana flour (Charoenkul et al., 2011), and sweet potatoes (Ibitoye et al., 2013). One component of flour that affects its quality is the starch contained therein. As a raw material, starch should be able to tolerate a broad range of processing techniques to fulfill the demands of modern and highly dynamic food industries to create diverse products (Maulani and Hidayat, 2016). One opportunity is to process gluten-free noodles without using wheat flour but with raw materials, such as cassava flour. Cassava grows in all habitats without the need for a special cultivation system and contains starch, which has strong elasticity. This crop represents one of the primary sources of food for

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Indonesian people, along with other staples such as rice, sago, and corn (Hawashi et al., 2019).

Characteristics of noodles that use raw materials from cassava flour, in general, have quite good elasticity because of the gluten content contained therein. Some gluten-free noodle-processing technology using local food ingredients is carried out by Purwandari et al. (2014a; 2014b), Sabbatini et al. (2014), Garcia et al. (2016), Herawati and Sunarmani (2016), Mojiono et al. (2016), Rajendran (2019), and Herawati et al. (2019a; 2019b). One opportunity to increase the added value of cassava flour is to process it into gluten-free noodle products. Noodles without gluten is easily broken and has a less elastic texture than noodles from wheat flour. One way to increase the added value of the product is by adding other ingredients that can improve the quality of the noodles produced. One technology for producing gluten-free noodles uses extrusion technology. Several studies using extrusion technology have been carried out (Muhandri et al., 2011; Muhandri, 2012; Herawati et al., 2019a; 2019b).

Additional ingredients can be added to improve the quality of gluten-free noodles. Padalino et al. (2011) added monoglyceride by 1% to improve the quality of gluten-free spaghetti. Meanwhile, Garcia et al. (2016) added egg flour to the process of making gluten-free noodles. In making a gluten-free paste, using eggs improves texture characteristics (Schoenlechner et al., 2010). Egg protein has a positive effect on cooking quality, increases elasticity, and reduces the cooking loss of spaghetti (Matsuo et al., 1972). Most gluten-free products are produced with recipes based on flours and starches with the addition of different types of hydrocolloids. For this reason, gluten-free foods have poor quality and low nutritional value and lack variety with lower palatability (Lerner, 2010; Levent, 2017). Some potential additional ingredients that can be used to improve the characteristics of noodles from cassava flour ingredients include peanut flour, egg yolks, egg whites, and hydrocolloids, namely guar gum. These additives are known to have high protein and fat content. Protein can increase the elasticity of the added product.

Food ingredients can be derived from raw materials immediately, such as eggs or peanut flour. Food ingredients can also come from food additives derived from the hydrocolloid class. This study aimed to analyze the effect of several types of additives on the physical and chemical characteristics of gluten-free noodle products derived from cassava flour.

2. Methods

2.1. Materials

The main raw material used was cassava flour from the manggu variety purchased from the Setia-Darmaga Farmer Group. Additional ingredients in the form of fine salt, peanuts, and eggs were purchased in commercial markets in Bogor, Indonesia, while hydrocolloids in the form of guar gum powder DHV 74 was purchased from PT BMC-Jakarta. Proximate analysis materials using chemical proximate analysis from MERCK were purchased from CV Jati Mandiri Perkasa, Indonesia. The equipment used includes proximate analysis equipment, Tecmaster Perten RVA (Rapid Visco Analyzer), XRD (X-Ray Diffraction) Type 08 Advance Bruker, and Scanning Electron Microscope (SEM) ZEISS EVO MA 10.

2.2. Gluten-Free Noodle Production

The raw main material used in the gluten-free noodles was cassava flour. In the control production, 99.5 g cassava flour and 0.5 g salt were used without the addition of other food additives, while the food-additive treatments were added on a cassava flour concentration basis. Stages of the processing included mixing flour with the addition of (0.5 g) salt, other additives, and water by 25 ml of dry mixture basis from raw based materials (100 g sample). The concentration variations used were 2 g and 5 g for cassava flour, egg yolks, egg whites, and peanut flour. Meanwhile, the hydrocolloid concentrations were 1 g and 0.5 g . The identification for each example included Control (C), MK (Peanut Noodles), MPT (Egg-White Noodles), MKT (Egg-Yolk Noodles), and MH (Hydrocolloid Noodles). The mixture was mixed until smooth. The dough was then steamed at 100°C for 30 minutes. The ReNoodle tool molded the resulting product in the form of noodles. The results obtained were then dried at 60°C for three hours. The stages of the gluten-free noodle-production process are shown in Figure 1.

Figure 1 The stages of the gluten-free noodle-production process

The analysis included proximate analysis (moisture, ash, protein, and fat content) followed by AOAC (2005), while carbohydrate content was calculated by different RVA profiles, amorphous and crystalline phase profiles, and their microstructure using SEM. The study used a complete randomized design. Proximate analysis results were analyzed statistically using SPSS 2.1 to determine the difference between treatments. ANOVA results were analyzed, and the results obtained were analyzed using Duncan's test.

2.3. RVA Analysis

RVA analysis was performed using the Tecmaster Perten RVA tool. RVA analysis included weighing samples (noodles) that had been crushed with the size of 100 meshes and 3.5 grams into the canister. The sample was then added to the canister with 25 ml of distilled water into the canister. The paddle was inserted into the canister and mounted on an RVA device. The paddle rotation was set from 0 to the 10th seconds, with a speed of 960 rpm. The temperature from 0 seconds to the 1st minute was set at 50° C. The paddle rotation in the 10th seconds was set at 160 rpm. The temperature started to increase in the 1st minute until 4 minutes 42 seconds, from 50°C to 95°C. The temperature was held for 2 minutes 30 seconds at 93°C. The temperature was then lowered from 93°C to 50°C until the 11th minute. The profile ended at the 13th minute. The software-calculation process used the formulas listed below.

Peak = peak (tool-read.ing) – corrective baseline

Breakdown = breakdown according to the reading of the results of software calculations in the tool

2.4. Microstructure Analysis

The analysis was carried out on the microscopic structure of gluten-free noodle products produced using a Scanning Electron Microscope (SEM) ZEISS EVO MA 10. The stages of analysis covered the preparation of samples in the form of transverse slicer noodles, followed by preparing the specimen holder that had been coated with carbon tape. The noodle sample was fastened to the surface of the carbon tape. The coating process was carried out using the Quorum Type Q150R-ES Sputter Coater and the material of gold, sputter 20 (mA), with a 60-second sputter time. The samples that had been coated in the specimen holder were then placed in a stage for SEM analysis. The stage that contained the sample was inserted into the chamber for further image retrieval using the ZEISS-brand SEM tool with type EVO MA 10. The picture was taken using an SE detector (secondary electron) with a working distance (WD) of nine, with Zero mm and an EHT of 16.00 kV setting tool.

2.5. Crystallinity Analysis

An analysis using XRD Type 08 Advance Bruker was conducted to determine the crystallinity profile of noodles. The noodles were first crushed to a size of 100 mesh. The device for heating was then turned on while the sample preparation was conducted. The sample (1–2 grams) was taken and entered into the holder or a particular sample place in XRD tool. The sample was analyzed with the desired angle of 2θ in the range of 5° to 80°. The peak profile can be seen from the analysis results, and the calculation results of the amorphous and crystalline phase compositions can be seen based on the analysis results of the software attached to the tool. The degree of crystallinity is the ratio of the crystalline area to the area under the refined X-ray diffraction curve (the sum between the crystalline and amorphous regions).

3. Results and Discussion

3.1. Proximate Analysis

Optimization was done by adding ingredients to improve the quality of the cassava noodles produced, including egg whites, egg yolks, peanuts, and hydrocolloids, which were compared in quality with controls without adding other ingredients. The resulting noodles were then analyzed by their proximate composition. Based on the analysis of water, ash, fat, protein, and carbohydrate content in the noodles added with some food additives, the results of the proximate analysis are listed in Table 1 below.

Table 1 Proximate-analysis results of cassava gluten-free noodles.

Sample	Content (%)					
	Moisture	Ash	Fat	Protein	Carbohydrate	Energy
C	11.02^{c}	1.63^{c}	0.30^{b}	2.05^{c}	84.94^{b}	351.30^{c}
MK 2%	10.11^{e}	1.40^{c}	0.38^{c}	2.74^{b}	85.25^{b}	356.60^{a}
MK 5%	10.20^{de}	1.81^{bc}	0.52^{b}	3.43^{a}	84.21^{c}	353.81^{b}
MKT 2%	10.32^{d}	2.14^{ab}	0.37^{c}	1.21^{f}	85.29^{b}	355.39^{ab}
MKT 5%	9.68^{f}	2.16^{ab}	1.05^{a}	1.74^{d}	86.14^{a}	354.16^{b}
MPT 2%	11.47^{b}	1.74^{bc}	0.30^{d}	1.21^{f}	85.41^{b}	348.10^{d}
MPT 5%	9.67^{f}	2.18^{ab}	0.18^{e}	1.43^{e}	86.62^{a}	354.12^{b}
MH 0.5%	11.75^{a}	2.11^{ab}	0.22^{e}	1.00^{g}	85.00^{b}	345.43^{e}
MH 1%	11.54^{b}	2.30^{a}	0.17^{e}	0.94^{g}	85.23^{b}	344.66^{e}

Remark: Numbers followed by a different letter showed a statistically significant difference with a confidence interval level of 95%

Based on the proximate analysis, different types and concentrations of raw materials and additives caused a significant difference in moisture, ash, protein, fat, carbohydrate, and energy at a confidence interval of 95%. Thus, the types and concentrations of the ingredients affected the proximate quality of the gluten-free noodles produced. The types of yolk and egg white and their concentrations also affected the proximate-analysis results of gluten-free noodles produced.

Cassava noodles added with peanut flour had a higher protein content compared to the controls, with the addition of egg yolks, egg whites, or hydrocolloids added. The fat content of cassava noodles added to 5% egg yolk was higher than that of other cassava noodles.

Garcia et al. (2016) produced gluten-free noodles with a mixture of several types of flour and obtained raw noodles, which had a moisture content of 26.972%, a protein content of 8.64%, a fat content of 2.047%, and a carbohydrate content of 61.699%. The use of jabuticaba peel flour by 15% and 30% resulted in changes in protein and fat levels in the resulting gluten-free noodles.

Afifah and Ratnawati (2017) conducted research on gluten-free noodle processing technology using a combination of raw materials in the form of modified casava flour (mocaf), rice flour, and corn flour. The moisture content produced was quite varied (10.98% to 14.18%). The protein content also varied from 4.09% to 5.58%. The composition of the raw materials used affected the proximate levels of the gluten-free noodles produced. An increase in moisture content was quite high, indicating a decrease in quality and the possibility of a reduction of shelf life (Omeire et al., 2015). High moisture content leads to the degradation of components and the possibility of higher microbial contamination, thus shortening the shelf life of gluten-free noodle products.

3.2. RVA Analysis

To determine the characteristics of gluten-free noodles by using several types of food additives, an analysis of the viscosity-profile characteristics was carried out using RVA analysis. Based on the results of the viscosity analysis with the addition of water and the temperature treatment of its characteristics, the results obtained are shown in Figure 2.

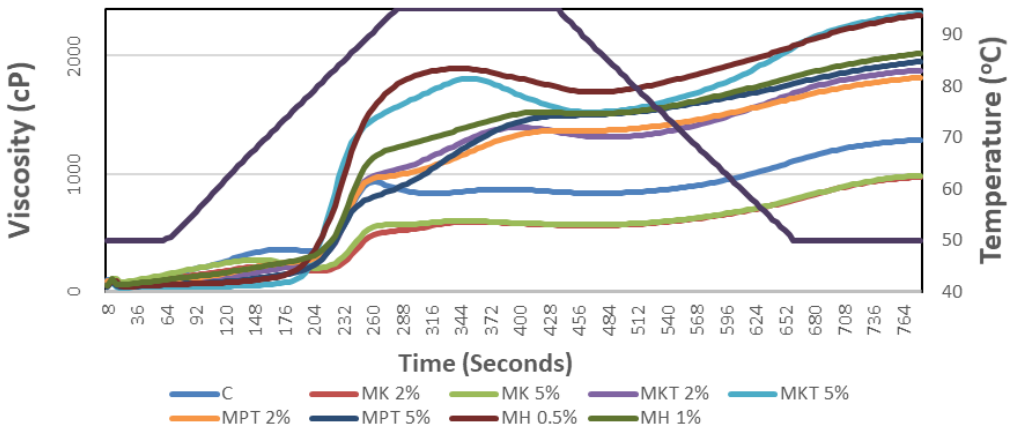

Figure 2 The RVA profile of gluten-free noodles with additional ingredients

RVA analysis was carried out to determine the peak viscosity and formation of pasta from the resulting noodles. The analysis results showed that different types and concentrations of additional ingredients affected the peak point of viscosity, setback, and breakdown from the results of the RVA analysis profile. Some RVA-analysis parameters produced from cassava noodles generated results listed in Table 2.

The difference in the addition of additional ingredients affected peak viscosity, hot-paste peak viscosity, cold-paste viscosity, viscosity-beginning plateau, viscosity-end plateau, breakdown, setback, and consistency. The highest peak viscosity was obtained from the treatment of the addition of hydrocolloids at 0.5% (MH 0.5%) 1602.5 cP. The increase in the concentration of hydrocolloids further decreased the peak viscosity of the noodles produced. The analysis results showed that the addition of egg whites with a composition of 2% or 5% produced an RVA profile that did not form peak viscosity at the optimum temperature and hot-paste viscosity. This resulted in not being able to analyze the resulting breakdown formation patterns. The highest point of viscosity was in gluten-free noodles with the addition of hydrocolloids by 0.5% and egg yolks by 5%. The addition of these ingredients resulted in increased viscosity in gluten-free noodles with the treatment of adding water and temperature during the RVA analysis process. This indicated that the addition of the two types of additives would affect the increase in the viscosity of the resulting gluten-free noodles, because its ingredient made interaction with cassava starch as main based material.

Table 2 The RVA analysis results of gluten-free noodles with several food ingredients compared to the control

Sample	Centipoise (cP)							
	Peak viscosity (PV)	Hot-paste peak viscosity (HPV)	Cold-paste viscosity (CPV)	Viscosity-beginning plateau (VBP)	Viscosity-end plateau (VEP)	Break down (BD)	Set back (SB)	Consistency (CS)
C	617^{g}	519.5^{f}	973f	558.5^{f}	534.5^{f}	97.5^{c}	356^{f}	453.5^{e}
MK 2%	409^{h}	375.5^{g}	787^{g}	333^{g}	381.5^{g}	33.5^{d}	378^{e}	411.5^{f}
MK 5%	363^{i}	329^{h}	745.5^{h}	329.5^{g}	334^{h}	34.0^{d}	382.5^{e}	416.5^{f}
MKT 2%	1250.5^{e}	1166^{d}	1735.5^{d}	897^{d}	1221.5^{e}	84.5^{c}	485^{b}	569.5^{c}
MKT 5%	1812^{a}	1471.5^{b}	2308.5^{a}	1522^{b}	1516.5^{b}	285^{a}	552^{a}	837^{a}
MPT 2%	1189^{f}	1188.5^{e}	1640.5^{e}	814.5^{e}	1189^{e}	0.5^{d}	451.5^{cd}	452^{e}
MPT 5%	1391^{c}	1391^{c}	1849.5^{c}	783.5^{e}	1391^{c}	0^{d}	458.5^{c}	458.5^{e}
MH 0.5%	1812^{a}	1602.5^{a}	2251.5^{b}	1670.5^{a}	1652.5^{a}	209.5^{b}	439.5^{d}	649^{b}
MH 1%	1347.5^{d}	1327.5^{d}	1836.5^{c}	1046.5^{c}	1340^{d}	22^{d}	489^{b}	511^{d}

Remark: Numbers followed by a different letter showed statistically significant differences with a confidence interval level of 95%

Based on the above analysis of the gluten-free noodles, the peak viscosity ranged from 363–1812 cP. Meanwhile, according to the literature, the peak viscosity of cassava flour ranged from 1200–1440 cP, and cassava starch ranged from 2400–3000 cP (Charoenkul et al., 2011). Meanwhile, according to Purwandari et al. (2014a), who processed gluten-free noodles using gathotan flour (cassava flour fermentation), the gelatinization profile of gathotan flour was shown by the peak viscosity of 5663 cP, trough viscosity of 2171 cP, breakdown viscosity of 3492 cP, final viscosity of 3432 cP, peak time of 8.72 minutes, and pasting temperature of 72.8°C.

The use of raw materials and additives influences the quality of the viscosity of the gluten-free noodles produced. The high value of peak viscosity (PV) indicated that starch or ingredient materials could expand freely before a breakdown occurred (Fari et al., 2011). Hot-paste peak viscosity (HPV) indicated the ability of starch to withstand heating and shear stress. The ability of mature starch granules to disintegrate can be seen from the results of the breakdown-viscosity value. Final viscosity (FV) shows the ability of the material to form a viscous paste or gel after cooking and cooling. The tendency of starch retrogradation can be predicted using setback viscosity values (Afifah and Ratnawati, 2017).

3.3. *XRD Analysis*

The XRD profile of cassava noodles was obtained from the addition of several types of additives, including peanut flour, egg yolks, egg whites, and hydrocolloids, and in comparison, with the controls. The results are shown in Figure 3.

The XRD results on gluten-free noodles produced a peak point at an angle of 2θ with an almost similar profile but different intensity. Generally, at an angle of 2θ, the noodles formed a peak at 15°, 17°, 18°, 20°, and 23°.

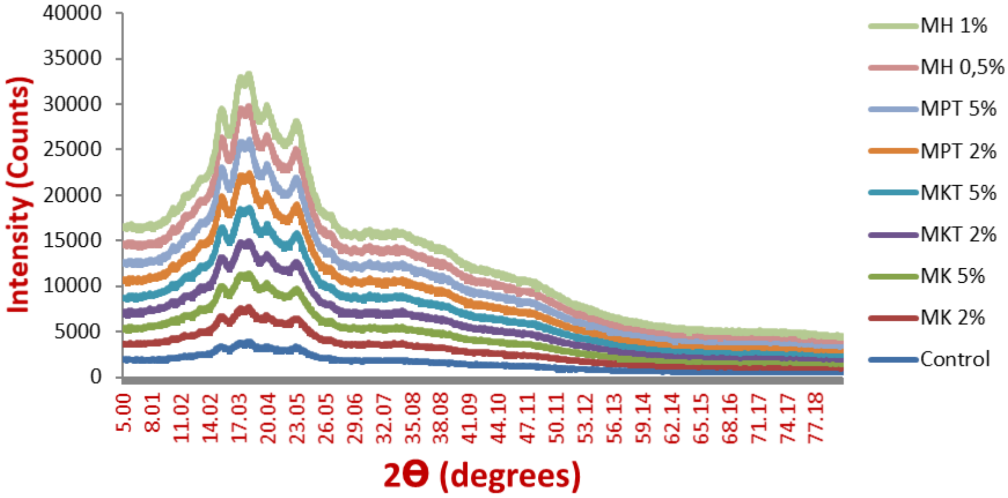

Figure 3 The XRD graph of cassava gluten-free noodles with food-ingredient additions

The XRD pattern of the native cassava starch displayed peaks at around 2θ = 5.5°, 10.1°, 11.4°, 15.1°, 17.1°, 18.0°, 20.0°, 23.2°, and 26.6° (Akuzawa et al., 2012). Furthermore, Sivamani et al. (2018), who conducted a study of cassava starch, showed the XRD pattern crystallinity with major diffraction peaks at 15° and 23° and a double peak at 17° and 18°. V-type diffraction patterns of XRD result analysis with additional reflections at (20) 12.7 and 19.8 are shown in Mestres et al. (1988). Based on the results analysis, no type-V starch interactions were formed. This is possible because the gelatinization process has not been formed completely, so starch and fat complexes have not been formed completely in this research. Usually, after the gelatinization process occurs, secondary bonding between starch and water is restored (Judawisastra et al., 2018).

Variety differences also determined the types and characteristics of starch from raw materials for gluten-free noodle makers. The addition of food additives affected the XRD profile of the gluten-free noodles produced. The addition of the type and concentration of these additives also influenced the composition of the amorphous and crystalline phases of cassava gluten-free noodles. The XRD profile showed differences in the amorphous and crystalline phase patterns with the addition of other ingredients to cassava noodles. Based on the analysis results, the amorphous and crystalline-phase compositions were quite different between the treatments and controls produced. The addition of the types and concentrations of additional ingredients affected the amorphous and crystalline phase composition of the gluten-free noodles produced. The addition of hydrocolloids caused differences in the rheological properties of the starch network (gellan gum, carboxymethylcellulose, pectin, agar, egg protein powder, tapioca starch, guar seed flour, and chitosan), mainly due to changes in granule gelatinization, gum solubilization, or starch–gum interactions (Padalino et al., 2011).

The amorphous phase of gluten-free noodles increases in concentration of ingredient materials such as hydrocolloids and egg yolks increase concentration addition in this formula. The opposite occurred with an increase in egg-white concentration. The addition of types and concentrations of egg whites and yolks affected the different levels of the amorphous phase of the XRD analysis results.

3.4. SEM Analysis

Microstructure profile analysis was carried out using SEM tools. The analysis results of the microstructure profile of the noodles with the addition of several types of additional ingredients are shown in Figure 4.

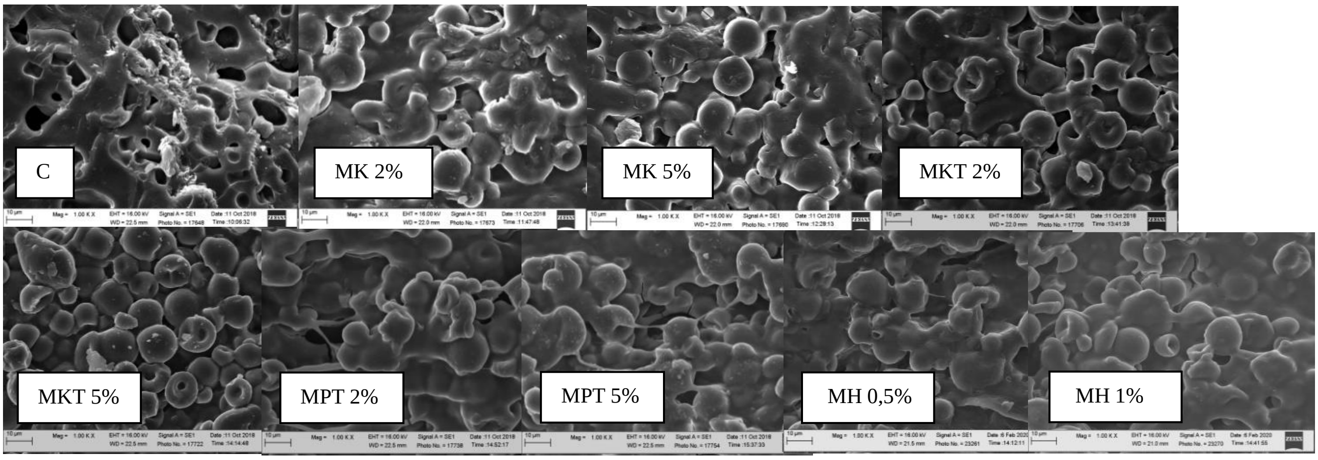

Figure 4 Microstructure profile of cassava gluten-free noodles (1000x magnification)

The microstructure profile of cassava noodles, in general, became well-gelated. This can be seen by the presence of starch granules that started to break up and join one another. The microstructure profiles of cassava starch granules, based on the SEM images, were either spherical or dome-shaped (Akuzawa et al., 2012). With the addition of egg yolks, relatively more starch granules remained intact compared with the other controls and treatments. With the addition of hydrocolloids, many starch granules began to break and merge. Manno et al. (2009) added inulin to the paste, and after the addition of inulin by 10% and above, that concentration resulted in a different SEM structure with 5% addition and control. The use of additional concentrations of ingredients affected the process of breaking down starch granules in making gluten-free noodles.

Sun et al. (2019) studied on the effect of adding a yam concentration to wheat flour on the characteristics of the yam-wheat noodles produced. SEM results showed that the addition of yam flour increased the bond between starch and protein in the resulting noodle mixture. The colloidal properties of yam flour allow starch particles to be more firmly filled in the gluten network than wheat noodle (Mirmoghtadaie et al., 2009). This study did not use gluten, which is usually found in wheat flour. Bonding was caused more by starch components and other types of protein found in the additional ingredients or cassava flour used.

4. Conclusions

Adding the types and concentrations of additional ingredients could increase the levels of protein and fat from the noodles produced. Noodles with the addition of peanut flour had a higher protein content compared to those with other treatments. Meanwhile, egg-yolk noodles produced a higher fat content. Adding eggs and hydrocolloids increased the amorphous phase of the resulting XRD results. Various noodles with several types of food additives formed a peak at an angle of 2θ at 15°, 17°, 18°, 20°, and 23°. The microstructure profile of gluten-free noodles showed that the starch granules began to break down and gelatinization occurred when SEM results indicated that the starch granules had started to break apart and join one another. For further research, a technoeconomic feasibility analysis can be done by adding several more ingredients to produce optimal quality gluten-free noodles.

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