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Improvement Particle Size Fineness of Corn Flour by Addition of Papain Enzyme and Its Effects to Their Hardness, Morphology and Pasting Properties

Aton-Yulianto[1,2]*, E. Gumbira-Sa'id[1], Titi Candra Sunarti[1], Bambang Hariyanto[2]

1. Department of Agroindustrial Technology, Faculty of Agriculture Industrial Technology, Bogor Agricultural University, Bogor, Indonesia
2. Agency for the Assessment and Application of Technology (BPPT), Jakarta, Indonesia

* E-mail of the corresponding author: aytiaraipb@gmail.com

Abstract
This study aims to improve on fineness of corn flour particle size by addition of papain enzyme and study the phenomenon of papain enzyme addition for the difference effects to their hardness, morphology and pasting properties. Hardness measurement and protein content analysis results of the two varieties of corn grits resulted from degermination show that incubation with papain on corn grits reduced grit hardness and protein content. Grit hardness reduction is due to protein matrix degradation that covers starch granular of horny endosperm. It is identified that local corn grit reduction difference is bigger than that of hybrid corn grits. Observation on morphology grits shows that there are difference in incubation effect with papain on both variety corn grits. First, local corn horny endosperm starch granular size is smaller and more homogeneous (3-7μm) than that of hybrid corn (3-12μm). Second, local corn horny endosperm granular shape is spherical while hybrid corn's is dominantly polygonal. The association shows that hardness difference on local corn and hybrid corn does not affect directly to corn flour amylograph characteristics produced.
Keywords: Corn-flour, hardness, morphology, papain, particle-size

1. Introduction

Indonesian corn production has increased from year to year. BPS-Statistics Indonesia data showed that corn production in 2002 amounted to 13 million tons and increased to 19 million tons in 2012, an 46.2% increase in a decade. The rise was due to both increase of productivity and acreage of cultivation. Productivity increase of corn occurs in line with the percentage increase of hybrid maize seed use that has reached 50-60% of 4 million hectares of corn plantations in Indonesia (Kementan 2012). However, the use of corn as the raw material of food industry still encounters several obstacles, including the particle size of corn flour industry that does not meet the standards. It may be associated with the hardness of seeds. The corn seed hardness may relate to the corn seed variety. Incubation with papain on the corn grits was done to reduce grit hardness to meet industrial corn flour standard.

The difference in hardness on seed corn was reported by Hoseney (1994) which in the corn seeds exist floury endosperm that is easily milled into flour and horny endosperm that is hard and tough due to starch granules that are arranged in a well-regulated matrix protein hence it is harder to milled using regular dry milling. Chandrashekar and Mazhar (1999) reported the correlation between endosperm and vitrous/opaque (transparant/opacity) seed appearance consistent with the way starch granular packed in protein matrix. Horny endosperm has the appearance of vitreous and floury endosperm has an opaque appearance.

The quality of the resulting corn flour does not meet the requirements of industrial users, mainly due to low standard corn flour particle size, which is only 34-36% commercial corn flour products that pass 60-mesh sieve (BPPT 2009). Its particle size is rougher than that of wheat or rice flour, thus corn flour can not substitute the use of wheat and rice flour in industry. This is noticeable by the unexploited opportunity to widely substitute wheat or rice flour with corn flour.

Rough corn flour produced by corn processing factories was estimated to have connection with corn seed hardness and the limitation of process technology. The use of papain as proteolytic enzyme that works specifically to dissect protein matrix in corn flour process becomes alternative solution proposed in this research to improve the fineness of corn flour. The use of papain in the corn flour production process led to the addition of the stages of production process.

The use of papain in this study is based on research conducted by Jonhston and Singh (2001) who have examined the effect of the use of specific enzymes to improve the yield of starch without the use of SO2 in the starch production who found that enzyme can not penetrate into the corn kernel and decompose matrix proteins that covering the starch granules. It is necessary for size reduction to eliminate diffusion barriers enzyme in the kernels. In 2004, Jonhston and Singh also had developed methods of using enzymes in the wet milling process by first soaking corn kernels in water hydration prior to size reduction. After being soaked with water, kernels are splitted into smaller size to make enzyme easier to be diffused into kernels. Using this method, protease (bromelain) enzyme is reported to have highest result compared to any other enzymes (xylanase, cellobiase, β-glucanase, and combinations thereof). In addition, it is known that the use of the protease enzyme on splitted kernel that has been hydrated proven to reduce the time of immersion.

Efforts to use enzyme in corn processing has been started since 1988 by Caransa *et al*., Steinke and Johnson (1991), Caransa *et al*. (1991), Moheno-Perez *et al*. (1999). The uses of those enzymes are for increasing rendemen and reducing soaking period in SO_2 solution in the production process of corn starch The objective of enzyme use is to increase the yield and shorten soaking period in a SO_2 solution in the production process of corn starch. The use of enzyme to substitute SO_2 usage was just started in 2001 by Johnston and Singh, later followed by Core (2004), Serna-Saldivar and Mezo-Villanueva (2003), Johnston and Singh (2004;2005), and Ramirez *et al*. (2009).

The purpose of the research is to improve on fineness of corn flour particle size by addition of papain enzyme and study the phenomenon of papain enzyme addition for the difference effects to their hardness, morphology and pasting properties.

2. MATERIALS AND METHODS

2.1 Equipment and Materials

The tools used in this study are glassware for soaking, stopwatch, scales, mixer, bucket for washing, container drainer, Retsch disk mill, Siever, analytical balance, cabinet dryer, oven, desiccator, and equipment analyzer.

The main materials used in the research are a local corn grits (Kodok variety with no reg. 3316), hybrid corn grits (Pioneer 21), crude papain powder from papaya latex production of Sigma (CAS No. 9001-73-4) with papain activity at pH 6 after the addition of 0.04M cysteine as a activator was 709 u/g, corn starch product of Redwood Indonesia and chemicals for enzyme activity and proximate component analysis.

2.2 Raw Materials Characterization

Flaking grits both varieties generated from degermination were measured for water content and level of hardness. Subsequently grits were refined using disk mill and measured for particle size distribution and proximate analysis (levels of fat, protein, ash, fiber, starch, and amylose). Then rheological characteristics were analyzed using RVA and starch granules were observed using polarized light microscope while grit surface morphology was analyzed using SEM. Whereas crude papain powder was analyzed at room temperature conditions (30°C).

2.3 Incubation Process

Incubation was performed at room temperature considering when performed at optimum temperature (65°C) is too close to the pasting temperature of corn starch and eliminating the use of heat energy that may increase the production cost. Incubation was performed at concentrations of papain 0.1, 0.5 and 1.0% (70.9; 354.5, and 709 u / g) with incubation time of 3, 6, 12 and 24 hours with a solid to liquid ratio of 1.6:1. Experiment was conducted using completely randomized factorial design with 2 (two) replications. Grits results of incubation were washed twice to 3 (three) times of washing until the filtrate was clear and did not smell the distinctive papain odor. Grits were, dried and weighed. Data were collected for pH changes during incubation. Furthermore the grit water content, color, hardness and morphology were evaluated. Some of grits were refined for measuring particle size distribution, content of protein, observation of starch granules and rheological characteristics. In the final stage data analysis was carried out using the Minitab 16 statistical software.

2.4 Hardness Measurements

Grits hardness measurements conducted was to determine the effect of incubation time and the concentration of the papain enzyme on corn grits hardness before and after incubation. Measurements were carried out using Tinius Olsen type XT-2i Texture Analyzer. Measurements were performed at the load range : 1-100 N, distance range : 0,1-speed 1000 mm and setting of probe speed: 50 mm/min, with a load of 50 N and deformation distance of 0.5 mm.

2.5 Analysis of Protein Content

Analysis of the protein content is done using the Kjeldahl method (AOAC 960.52) the object of protein analysis is to determine changes in the protein content of corn grits before and after incubation with papain.

2.6 Measurement of Corn Flour Particle Size Distribution

Grit is refined using disk mill and measured for particle size distribution using sieve analysis mesh with size of 60, 80 and 100 mesh (German 1994).

2.7 Morphological Observation of Corn Grits

Morphological observation corn grits performed using Scanning Electrone Microscope (SEM) JEOL JSM-6510LA. The focus of the observations were made on the horny endosperm grits and observed without any coating with a magnification of 1000 times. Observations were made on corn grits after incubated under various concentrations of papain and incubation time.

2.8 *Analysis of Rheological Properties*

Rheological properties of corn flour was analyzed using the Rapid Visco Analyzer (RVA) Tec Master Newport Scientific Pty. Ltd, Warriewood-Australia. Some parameters observed are pasting temperature, peak viscosity, peak time, through viscosity, breakdown viscosity, final viscosity, and setback viscosity.

3. RESULTS AND DISCUSSION

3.1 *Dimension and Hardness of Corn Kernels*

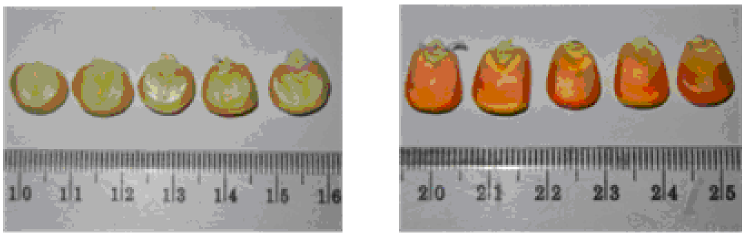
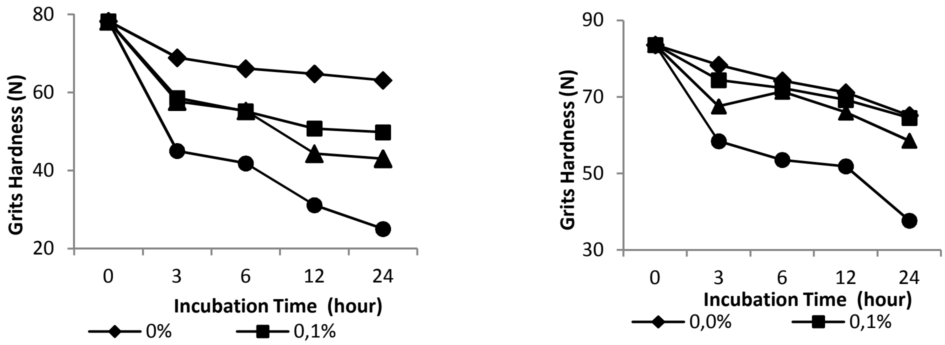


Figure 1. Photo of local corn and hybrid corn kernels

The color appearance of hybrid cord is reddish yellow while the local corn is white. Hybrid corn kernel has length 9.0 mm, width 8.0, thickness 4.0 mm. On the other hand, local corn kernel has length 8.0 mm, width 9.0, thickness 5.0 mm. Results of dimensional measurements of local corn and hybrid corn kernels indicated that local corn (Kodok varieties) is thicker and shorter than hybrid maize (varieties P21). However, The bulk density of hybrid and local corn kernels are 73.5 g/100 ml and 73.0 g/100 ml respectively (Fig.1). The hardness of local corn kernel is 84.80 Newton, while the hybrid corn kernel is 87.85 Newton at deformation 0,5 mm. After degermination, the process resulted corn grits with 78.30 N hardness for local corn grits and 83,61 N for hybrid corn grits.

3.2 *Effect of Incubation with Papain to Hardness of Corn Grits*

Johnston and Singh (2001) reported that incubation using protease enzyme on whole kernels makes enzyme unable to penetrate kernels well so the enzyme can not degrade protein bonding to starches. Corn grit incubation with the papain enzyme is intended to disentangle protein matrix that cover starch granules inside the horny endosperm. The decomposition of the matrix protein is believed to reduce corn grit hardness, and ultimately may facilitate corn grits grinding into flour with a finer particle size. Effect of papain concentration and incubation time to the hardness are done by measuring the hardness grits before and after incubation. Grits hardness measurement results after incubation is shown in Figure 2.



A B

Figure 2. Graphs of incubation time effect on local (A) and hybrid corn grits (B) hardness

In Figure 2 a trend of hardness decrease as concentration increase is obvious for two varieties of corn grits. Figure 2 also shows differences in the effect of incubation with papain on local corn grits and hybrid corn grits, which on incubation with papain 0.5% for 12 and 24 hours, local corn grit hardness was down from 64.8 and 63.2 to 44.4 N and 43.1 N, whereas the hybrid corn grits on the same conditions, grits hardness after incubation decreased from 71.1 and 65.2 N to 65.9 N and 58.5 N. So the difference in the reduction of hardness in the local corn grits incubation with papain 0.5% for 12 and 24 hours, were respectively 20.4 and 20.1 N, whereas the difference in the reduction of hybrid corn grit hardness were only 5.2 and 6.7 N.

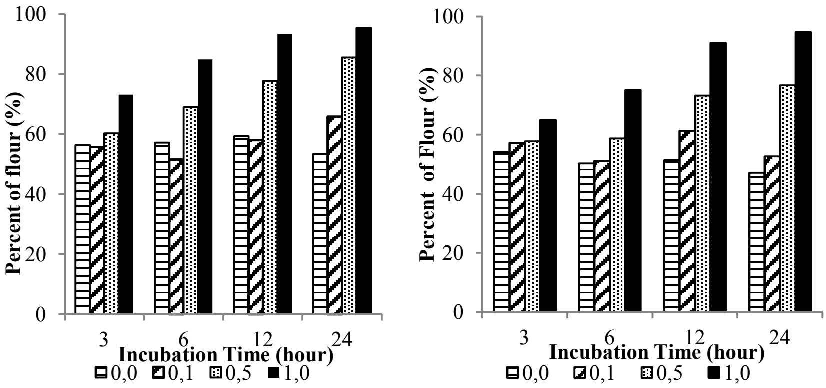
Results of correlation analysis showed that the pearson correlation among the concentration of papain and incubation time toward both variety grit hardness is negative. It indicates that as the concentration of papain and the incubation time of incubation increase, corn grits hardness will decrease. Correlation between incubation time and local corn grit hardness confirms that at concentration of 0.5%, pearson correlation is 88.5% and increases to 96% at concentration of 1% with p-value 0.04. On the other hand, significant correlation between incubation time and hybrid corn grit hardness occurs only at papain concentration of 1% with pearson correlation of 98.2% and p-value 0.02. The correlation between the concentration of papain with local corn grits hardness is significant at the 12-hour incubation time up to 24 hours with Pearson correlation, respectively 94.5% and 96.5% with a p-value of 0.05 and 0.04. The difference shows the strength of the matrix protein in the horny endosperm corn hybrids are more powerful than local corn.

This result indicated that hybrid corn horny endosperm is classified into hard corn group, while local corn horny endosperm is soft corn group. Hardness difference beetwen hard and soft corn was previously observed by Martinez et al (2006). According to Martinez, observation result using SEM shows that hard corn kernels have a distinctive pattern of starch granules from soft corn. Soft corn starch granule shapes are spherical and loosely arranged in the matrix protein, whereas the hard starch granules are generally polygonal shaped and arranged in closely packed in the protein matrix thus hard corn seeds have a very high density and rigidity.

3.3 Effect of Papain Incubation toward the Particle Size Distribution of Corn Flour

Grits that have been incubated with papain furthermore are milled using disk-mill and measured particle size distribution using multilevel siever in the sizes of 60, 80 and 100 mesh. The measurement results are classified into 4 (four) groups The groups consist of flour particle that does not pass 60 mesh size sieve (+ 60 mesh), the flour particle size between 60 mesh and 80 mesh size sieve (60/80 mesh) , flour particle size between 80 mesh sieve and 100 mesh sieve (80/100 mesh), and flour particle that passes 100 mesh sieve (100/0 mesh). Corn flour that does not pass 60 mesh size sieve is separated due to roughness, or re-processed into milling process again. This is the reason why the yield of milling process influenced by the amount of flour that passes 60 mesh siever. On the other hand, the quality of flour from the perspective of flour particle size is determined by the amount of flour sieve size of 80 mesh. So the yield of flour milling process is determined by defined as the amount of flour sieve size of 60 mesh. Likewise, the more flour passes 80 mesh siever, the flour has better quality.

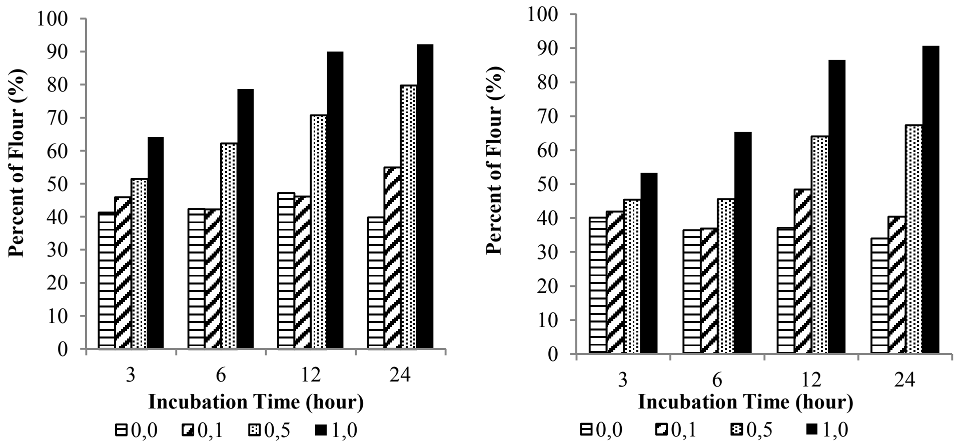
Corn flour milling yield results after incubation with papain at various concentrations are presented in Figure 3(A) and 3(B). Figure 3(A) shows the amount of local corn flour particles which have passed 60 mesh size sieve, and Figure 3(B) the number of particles of the hybrid corn flour sieve size of 60 mesh. In the second image can be seen the trend of an increasing number of flour sieve size of 60 mesh with the increasing concentration of papain at various times of incubation. In addition, it can also be seen that in both types of local and hybrid corn produce flour yield more than 90% at 12 hours soaking time starting with a concentration of 1% papain. However, the trend of the number of local corn flour sieve size of 60 mesh papain at concentrations ranging from 0.5 to 1% at various incubation time is always greater than hybrid corn flour. This was due to a local corn grits hardness after incubation with papain is lower than the hardness of hybrid corn grits (Figure 2).



A B

Figure 3. Percentage of flour particle that passes 60 mesh siever for local (A) and hybrid corn flour (B)

Statistical analysis showed that in all the incubation time, the influence of the papain concentration on the amount of flour sieve mesh size of 60 is significant for both types of corn were used. Where the p-value for both varieties at the time of incubation 3, 6, 12 and 12 are less than 0.05 with Pearson correlation 95.5 to 99.0% for local corn and 95.1 to 99.2% for hybrid corn. Meanwhile, the effect of incubation time on the amount of local corn flour sieve size of 60 mesh is only significant at a concentration of 0.5% papain on the p-value of 96.1%, whereas for hybrid corn flour incubation time effect on yield flour produced in various concentrations was not significant because the p-value> 0.05. This indicates that the effect of the increasing concentration of papain is more significant than the effect of duration of incubation.



A B

Figure 4. Percentage of particle that passes size 80 mesh siever for local (A) and hybrid corn flour (B)

Determination of the number of particles of flour sieve 80 mesh as a reference in determining the quality of corn flour is intended to meet the Indonesian National Standard (SNI) No.01-3727-1995 on the quality of corn flour and SNI No.3549-2009 on the quality of rice flour, which each requires a minimum of 70% and 90% powder size 80 mesh sieve, and SNI No.3751-2009 on the quality of wheat flour, which requires a minimum of 95% powder sieve size of 70 mesh/212 microns (BSN 1995;2009a;2009b). In this study, 90% corn flour produced is expected to pass 80 mesh size sieve so that the resulting flour has a particle size similar to wheat and rice flour. Accordingly, as shown in Figure 4A and 4B that for local corn flour requirements can already be met after incubation for 12 hours at a concentration of 1% papain. Meanwhile, the new requirements for the hybrid corn flour can be met after incubation for 24 hours at a concentration of 1% papain. This proves the existence of differences in the effect of concentration and time of incubation of the hardness on both varieties of corn grits, local and hybrid. The presence of these differences are real differences directly affect the quality of the resulting corn flour.

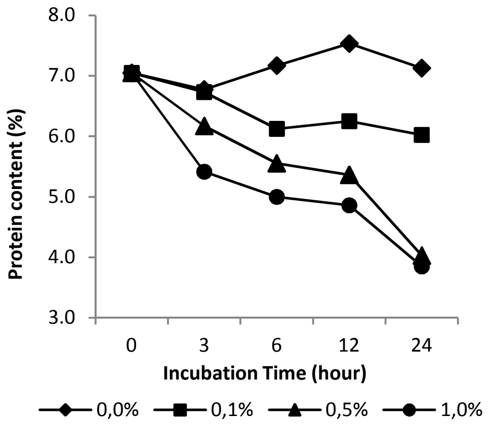
Figure 4 above also shows that in general there is a tendency that an increase in the amount of corn flour passing 80 mesh size sieve along with increasing of incubation time and the concentration of papain for both varieties. Statistical analysis showed that the relationship between the concentration of papain with amount of corn flour passing 80 mesh size sieve at various incubation time for both varieties was significant (p-value <0.05) with Pearson correlation ranged from 95.6% to 99.3 % for local corn and 98.2 to 99.6% for hybrid corn. On the other hand, the effect of incubation time with the amount of corn flour passing 80 mesh size sieve is only significant at a concentration of 0.5% papain for local corn (Pearson correlation = 94.8%), while for hybrid corn p-value for all concentrations is greater 0.05. This again suggests that the effect of the increasing concentration of papain is more significant than the effect of duration of incubation.

3.4 Effect of Papain Incubation on the Grit Protein Content

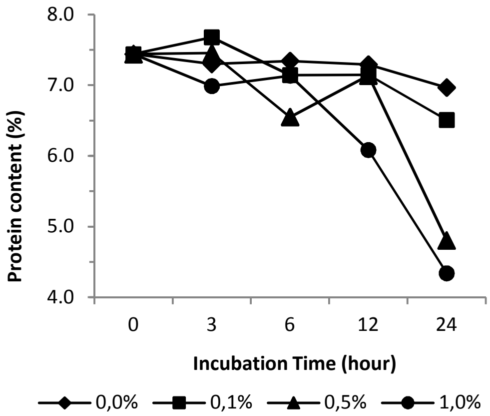
A decrease in corn grit hardness, followed by an increase in the number of particles of corn flour that passes mesh size sieve of 60 to 100 indicate the decomposition of the protein matrix covering the starch granules in the horny endosperm. One indicator of the decomposition of the matrix protein is a decrease in the protein content of corn grits after incubated with papain. Protein content of corn grits after incubation is shown in Figure 5.

Figure 5 shows that protein content of corn grits of both varieties tends to decrease along with the increase of papain concentration. Decrease of protein content occurred very sharply starting from 6 hour of incubation time for local corn and 24 hours for hybrid corn. It is estimated that hybrid corn grits have stronger protein matrix on horny endosperm than local corn. The decrease of corn grit protein content after incubation with papain verifies that disentanglement of protein due to papain enzyme works.

Nevertheless, effectivity of papain use on hybrid corn is observable at papain concentration of ±1,0% and soaking time of ±24 hours. This indicates how strong protein matrix covering starch granular of horny endosperm. The strength of protein matrix of corn endosperm is observable by the soaking period in SO2 solution (0,1-0,4%) in corn starch production that takes up to 36 hours at temperature of 48-52ºC (Watson and Eckhoff, 2004).



A



B

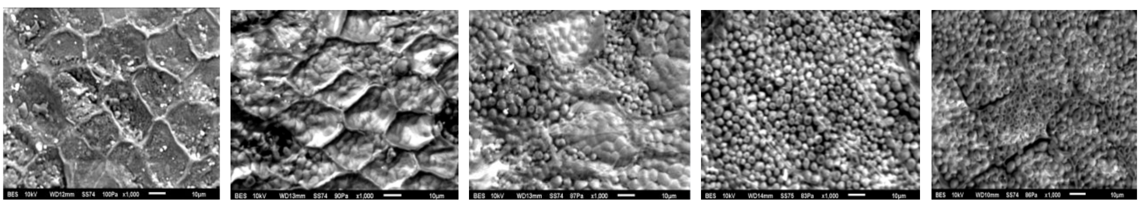
Figure 5. Effect of incubation time on protein content of local corn grits (A) and hybrid (B)

Results of correlation analysis shows the effect of incubation with papain on protein content of local corn grits are significant occuring at concentrations ranging from 0.5 to 1.0% (both p-value less than 0.02 and pearson correlation 98.2%). On the other hand, the effect of incubation time on hybrid corn grits to the protein content of corn grits is only significant at a concentration of 1.0% papain (p-value <0.05 and pearson correlation of 98.4%). Pearson correlation value for both varieties is negative which indicates that as the length of the incubation time increases, the protein content of corn grits will decrease. The difference in the effect of incubation with papain to corn grits of local and hybrid varieties confirms hypothesis that protein matrix of hybrid corn is stronger than that of local corn.

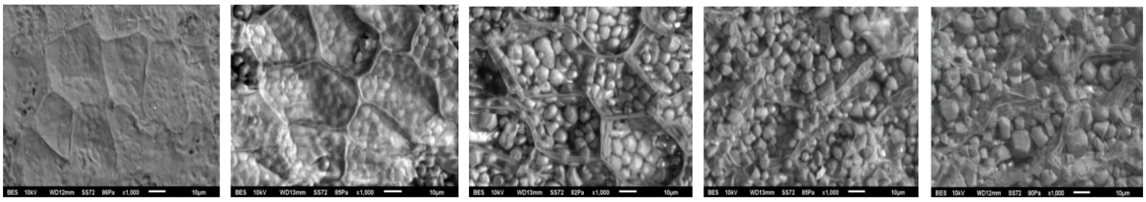
3.5 Effect of Incubation with Papain to the Morphology of Corn Grits

Observations using SEM provides important information to answer the allegations of the decomposition of the matrix protein as a result of the enzyme papain action. Indication of decomposition have been submitted previously, that can be seen from the decrease in the protein content of corn grits after incubation, and the reduction of hardness grits, followed by an increase in fineness of the flour produced. Figure 6 shows the results of the observation of local corn grits horny endosperm part (Figure 6(A1) to (6A5)) and hybrid corn grits (Figure 6(B1) to 6(B5)) using a SEM. Observations were made on local and hybrid corn grit after incubation for 3, 6, 12, and 24 hours at a concentration of 1% papain. Thick layers shown in Figure 6(A1) and 6(B1) are believed to be the protein matrix covering the starch granules contained in the horny endosperm.

Figure 6 shows that as the time of incubation increases, it makes protein matrix layers covering the starch granules thinner, moreover on 12 to 24 hours of incubation, the thick layers keep on diminishing. The occurance of protein matrix decomposition confirms that the work of papain enzyme added during incubation. Decomposition of protein matrix during incubation influence to the decrease of grit hardness and eventually flour partice size fineness. Those result, as reported by Serna-Saldivar dan Mezo-Villanueva (2003) who added cell wall degrading enzyme (CWDE) on coarse grounded yellow corn and sorghum with 4 to 48 hours soaking is proven to increase starch rendemen due to loose protein matrix. Effort to ease corn seed milling was also carried out by Core (2004) who used ammonia gas and then continued by using protease enzyme to loose protein matrix bonds in corn kernels, resulting that it only takes 6 hours for soaking process. It is much more efficient than conventional process that takes about 24 to 36 hours. As a consequence, observation result using SEM on corn grits after papain addition has proved that protein matrix decomposition occurs in the horny endosperm part as indicated by decrease of protein content and grit hardness.



A1 A2 A3 A4 A5



B1 B2 B3 B4 B5

Figure 6. The observation by SEM for local (A) and hybrid (B) corn (1:(3h;0.0%), 2:(3h;1.0%), 3:(6h;1.0%), 4:(12h;1.0%), 5:(24h;1.0%))

Figure 6 also shows obvious difference on incubation influence with papain to grits of both variety corns. First, on 12 to 24 hours of incubation (Figure 6. A4, A5 and B4, B5), protein matrix of local corn grit has disappeared, while there is a little left in hybrid corn. Second, the size of local corn horny endosperm starch granular is smaller and more homogeneous (3-7µm) than that of hybrid corn (3-12µm). Third, granular shape of local corn horny endosperm is spherical while hybrid corn's is dominantly polygonal. This result agrees with research result done by Martinez et al (2006) who stated hard corn granule is polygonal shape and closely arranged, while soft corn granule is spherical shape and loosely arranged inside protein matrix. Consequently, it can be concluded that local corn is soft corn and hybrids corn is hard corn.

The difference in starch granular shapes leads to the difference in density of both variety horny endosperms and may result in the difference in hardness as well as rigidity of the grits. Those variations is the prove of difference in corn grit hardness of both corn varieties. This condition is predicted may affect directly to different incubation process condition for both local and hybrid corn varieties.

3.6 Effect Of Incubation With Papain On The Pasting Properties of Corn Flours.

Testing with RVA on both corn varieties at different incubation time and concentration showed a change in amylograph profile, as shown in Figure 7. These changes are believed to be caused by the decomposition of the matrix protein in the horny endosperm during the incubation process so starch granular can undergo gelatinization without a hitch.

The increase of incubation time and papain concentration are so obvious to cause peak viscosity and breakdown viscosity increases. On the other hand, increase of incubation time and papain concentration obviously cause the decrease of pasting themperature and peak time. These changes occur due to degradation of protein matrix on horny endosperm and decrease of micro component content other than starch during incubation time, so starch granular can go through gelatinization well. On the other side, as shown in Table 1, the value of testing parameters of two varieties of corn flour after incubated for 24 hours at a concentration of 1% papain resembles value testing parameter of commercial corn starch. This result shows that corn flour particle size fineness and swelling power of corn flour produced is similar to those of corn starch as published by Navickis et al. (1986). This provided an opportunity to use corn flour produced using this process to substitute corn starch in food processing plants, such as corn vermicelli factory, especially if the price of corn flour produced from this process is cheaper than the price of corn starch.

Table 1. Comparison of RVA Test Result of Local, Hybrid Corn Flours and Commercial Corn Starch

Corn Variety	Incubation Treatment	Pasting Time (°C)	Peak viscosity (Cps)	Breakdown viscosity (Cps)	Setback viscosity (Cps)	Final viscosity (Cps)
Local	3 h; 0.0%	91.00	1254	-4	1613	2871
	24 h;0.5%	72.05	3472	1418	1995	4049
	24 h;1.0%	71.20	4297	2060	2116	4353
Hybrid	3 h; 0.0%	88.95	1379	-6	1960	3345
	24 h;0.5%	78.05	2787	787	1623	3623
	24 h;1.0%	73.70	4327	2387	1902	3842
Commercial corn starch*		75.25	4041	1691	4420	2070

*Produced by PT. Redwood Indonesia

Difference in hardness of both corn variety grits does not give a tangible difference toward amylograph characteristics of flour yielded. As shown in Table 1, under 24 hours incubation for with papain concentration of 1%, maximum viscosities of local and hybrid corn flours are 4297 and 4327 cps respectively, and the peak time of local and hybrid corn flours are 8.2 and 8.0 minutes along with pasting temperature 71.2 and 73.7°C respectively. Furthermore, the breakdown viscosity, and set back viscosities of both variety corn flour have value range which does not differ much. This shows the difference both local and hybrid corn hardness had no direct effect on the amylograph properties of corn flour generated by semi-dry process with the addition of papain.

4. Conclusions

Results of hardness measurement and protein content analysis of the two varieties of corn grits resulted from degermination show that incubation with papain on corn grits reduce grit hardness and protein content which grit hardness and protein content decrease as incubation time and papain concentration increase. Grit hardness reduction is due to protein matrix degradation that packs starch granular of horny endosperm. Particle size distribution measurement on corn flour after incubation with papain verifies that grit hardness difference affect absolutely to corn flour particle size, as the grits hardness decrease makes more amount of corn flour particles passes 80-mesh sieve. To fulfill 90% flour passes 80 mesh sieve requirement, local corn takes shorter time (12 hours or more) than that of hybrid corn at 1% papain concentration. Therefore, it can be concluded that local corn is soft corn and hybrids corn is hard corn. The association shows that hardness difference on local corn and hybrid corn does not affect directly to corn flour amylograph characteristics produced by the process.

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