Food ScienTech Journal Vol. 2 (1) 2020 ISSN : 2685-4279 DOI:10.33512/fsj.v2i1.7936

# A REVIEW OF STARCH DAMAGE ON PHYSICOCHEMICAL PROPERTIES OF FLOUR

**Nia Ariani Putri[1*], Ila Maratush Shalihah[2], Alina Femi Widyasna[2], Riska Putri Damayanti[2]**

[1]Department of Food Technology, Faculty of Agriculture, Universitas Sultan Ageng Tirtayasa
[2]Student of Department of Food Technology, Faculty of Agriculture, Universitas Sultan Ageng Tirtayasa
Jalan Raya Jakarta Km 4 Pakupatan, Serang-Banten
E-mail: nia.ariani@untirta.ac.id

## ABSTRACT

Starch damage is starch which is damaged by mechanical treatment, such as milling process in flour production. The purpose of this review is to determine the importance of the amount of starch damage affected by the milling process in the physicochemical properties of flour. Starch damage in flour product is influenced by some factors, such as the milling time, methods, and the roller on the milling machine. Beside milling process, the starch modification is also cause damaged to starch, such as fermentation. The presence of starch damage is an important parameter to determine the physicochemical properties of flour. Starch damage in flour will affect the physicochemical properties, such as particle size, amylose content, thermal and pasting properties, retrogradation, microstructure of starch granule, etc. It is very important to pay attention to produce the food product that have a good physicochemical characteristics. The starch damage in flour has an important role in food processing technology, for example: bread, cake, and cookies product. Furthermore, starch damage also affects the shelf life of product that has correlation with retrogradation process.

**Keywords:** Flour, milling, physicochemical properties, starch damage

## INTRODUCTION

Starch is used on several industries, both food and non-food industries. Starch that needed on food industry is closely related to the formation of paste as an adhesive, and is stable to heating and cooling (Nadia *et al*, 2014). Paste as a thickener can form a smooth gel and remain flexible in cold conditions, thereby increasing viscosity, texture, and mouthfeel in food processing product. Functional properties of starch is influenced by it's physicochemical properties. The physicochemical propertieses of starch are influenced by several factors such as starch source, amylose and amylopectin ratio, and starch gelatinization.

Starches of different types show amylose content, gelatinization profile, starch granules morphology, and starch crystallization are different from the others. In addition, the milling process in the flour process production will also affect the physichocemical properties of starch. According to Leon *et al*, (2006), during milling process some starch granules suffered mechanical damage, that the level of damage varied depending on the hardness of the seeds and conditions of milling process.

Hard seeds need more energy for milling than soft seeds milling for reduce endosperm to flour, and during this milling process the number of starch granules that suffer more damage. According Jovanovich *et al* (2003), the damage can be found in the milling process, which the endosperm is broken and crushed, some starch granules are physilcally damaged. Damage to starch granules due to mechanical treatments such as milling process is often called starch damage.

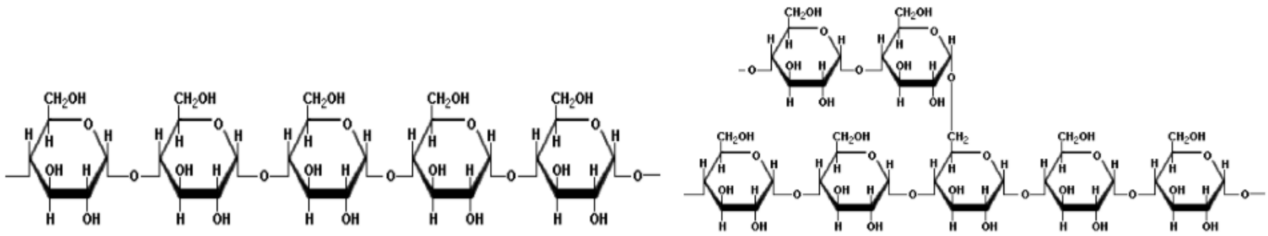
The amount of starch damage is an important parameter in evaluating flour quality (Allister *et al*, 2016). Previous studies shoen that there is correlation between the level of damage to starch with water absorption, entalphy gelatinization, and others (Jovanovich *et al,* 2003). The amount of starch damage on flour production can be changed by certain treatments, such as by increasing pressure on the miller. Another factor that influences the amount of starch damage is the type of wheat (hard or soft wheat), that a harder endosperm will produce the amount of starch damage more (Manley in Jovanovich *et al,* 2003).

In addition to milling process and the hardness of seeds, the milling method (dry and wet milling) will also affect the amount of starch damage. The amount of starch damage using wet milling method is lower than dry milling method.

## STARCH

### Starch Granule

Starch is composed of particle that have different characteristics, such as size, shape, morphology, composition, and supramolecular structure which depend on botanical source. Starch granule diameters generally range from less than 1 µm to more than 100 µm, and they are generally round, ovale, angular, or can be quite regular. According to Bertolini (2010), starch is composed by two polysaccharides with α-D-glucose structures, namely amylose and amylopectin (Figure 1). Starch granules are composed by different amylose and amylopectin depend on botanical source. Amylose has a straight D-glucose chain, an avarage glucose unit between 500 and 6000 distributed between 1-20 chains.



(a) (b)

Figure 1. Starch structure chain (a) amylose structure chain, (b) amylopectin structure chain (Zulaidah, 2011)

### Starch Damage

Starch damage mainly is caused by mechanical forces obtained during the milling process. During milling process, 5-12% of the starch is damaged. The difference between natice starch and starch damage can be seen on Figure 2.

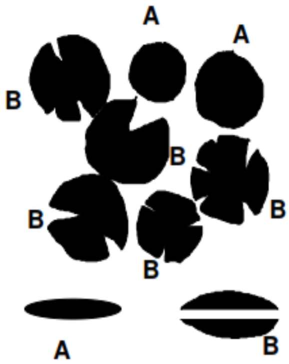



Figure 2. The difference of native starch and starch damage (Loubersac, 2007)

The larger starch granules usually suffer more damage. In Figure 2, it can be seen that native starch has a shape that is still round and flat on its surface, while the starch damage has irregular shape on its surface or is no longer circular. According to Dubois in Dubat (2004), there are two types of starch damage namely cracks and breaks (Figure 3).

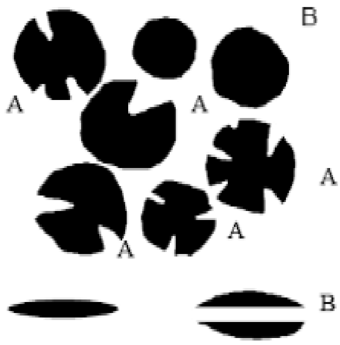



Figure 3. Types of starch damage, A is breaks, B is cracks (Dubois in Dubat, 2004)

According to Dubat (2004), starch damage can affect both the positive and negative effects. One of the positive effect is the presence starch damage causes the water absorbency of starch to be higher, which is 2-4 times its original weight. Pati is said to be 100% damage if it can absorb a number of water that is same with the number of starch at a temperature 30ºC, while the native starch is only able to absorb water 0.4 times its original weight. This is economically important, because water is one of the inexpensive ingredients to increase the yields as bread and noodle.

On the other hand, too much water absorption can cause the dough to become sticky, it makes difficult to form. Starch damage also allows some specific enymes to grow such as β-amylase, and increase the digestibility of starch more. Starch damage shows several similar physical properties that can be seen in Table 1 such as digestibility by α-amylase and β-amylase, birefriengence properties, X-ray type, crytallinity, paste viscosity, absorption capacity, solubility, and component that leach.

Table 1. Characteristics of native starch and starch damage

| Charcteristics | Native Starch | Starch Damage |
|---|---|---|
| Digestibility | | |
| a. α-amylase | Slow | Fast |
| b. β-amylase | - | Fast |
| Birefriengence Properties | Positive | - |
| X-ray type | A type | - |
| Crytallinity | Have | - |
| Paste Viscosity | | |
| a. Cold | Low | Medium |
| b. Hot | High | Medium |
| Absorption Capacity | 0,5 | 3-4 |
| Solubility | Low | High |
| Component that Leach | - | Amylopectin |

Source: Arora (2003)

The amount of starch damage can increase with increasing the grain hardness, roll speed of the milling machine, the level of milling, and milling time; also decreasing the rate of material intake (Arora, 2003). According to Morrison and Tester (1994), the differences milling time using a ball mill can changes physical and functional properties of wheat flour that is produced such as colour, swelling volume, and gelatinization profile. Flour industry can set the amount of starch damage, both by increasing or decreasing it. The way to set the amount of starch damage can be seen on Table 2.

Table 2. The way to set the amount of starch damage

| Incresing Starch Damage | Decresing Starch Damage |
|---|---|
| Squeeze a firm roll of milling machine | Prevent exessive roll density |
| Increase a layer compactness | Decrease a layer compactness |
| Decrease flake disrupter | Choose an efficient flake disrupter |
| Cover the flour sieves in front of the milling machine | If possible, increase the ash content using grooved rolls |

Source: Willm in Dubat (2004)

## THE EFFECT STARCH ON FLOUR QUALITY

Different milling methods in producing flour are thought to cause damage to starch and different chemical compositions. During soaking process, the hydrolisis of the constituent polymer become to component that has more solubility in the soaking media, so it can cause the chemical compositions of flour is changed (Usansa *et al*, 2009). In addition, mechanical process such as milling can also cause starch damage 5-14% (Dubat, 2004).

### Particle Size

Milling methos will also affect the particle size of the flour. Using dry milling methid, corn flour which is produced has the larger particle size is about 20-40 µm than on corn flour that using wet milling method, its particle size is about 10-25 µm. It is because particle of flour form the starch granule aggregate and protein matrix, so it has a larger particel size. The smaller particle size will give a smoother and softer texture of product (Suarni and Firmansyah, 2008). The relationship between starch damage and starch particle size can be seen in Figure 4.

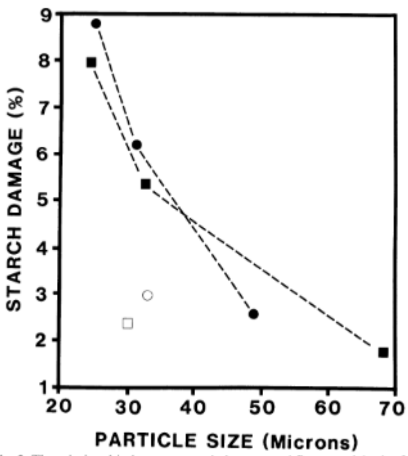


Figure 4. The relationship of starch damage and starch particle size (Gaines *et*, 1988)

In Figure 4, it can be seen that the amount of starch damage has negative correlation with starch particle size, the larger precentage or the amount of starch damage has the smaller particle size. Flour that is produced using dry milling method has the larger the amount of starch damage and the smaller particle size.

**The Amount of Starch Damage**

The milling method also affects the amount of starch damage. Corn flour produced by wet milling method has lower an average of starch damage than corn flour produced by dry milling method. According to Suksomboom *et al* (2005), the absorbed water also functions as a lubrican thereby decrease mechanical power generated and give a cold effect during milling.Because of the decreasing mechanical force and milling temperature cause the amount of starch damage also decreases. Conversely, if the dry milling method the material is still intact and hard, thereby it can increase teh resistency during milling that cause increasing the amount of starch damage (Bolade, 2009).

**Amylose Content**

The differences treatment of flour production method such as soaking and milling will affect the flour properties due to chemical composistions changes in flour and damage to starch. On corn flour which is produced using wet and dry milling method have a different average of amylose content. The average amylose content of corn flour which is produced by wet milling method is lower (28% bk) than corn flour which is produced by dry milling method. This is caused by activated amylase enzyme on soaking process using wet milling method. It can hydrolize amylose into soluble dextrin (Usansa *et al,* 2009).

**Physicochemical Properties**

According to Jovanovich *et al* (2003), entalphy of starch gelatinization has positive correlation with the amount of starch damage when the defferences level of starch damage result from defferences in the roll pressure used during the milling process. In wheat, the level of starch damage depends on the hardness of the grain and its milling method. Hard wheat flour is more difficult to change into flour particle size, so the hard wheat flour has a larger the avarage particle size than soft wheat flour (Barrera *et al*, 2007).

Hard wheat flour produce more starch damage during milling process. In addition, Leon *et al* (2006) conducted a study to determine the effect of the amount of starch damage on the thermal properties of flour and bread staling. The results of this study indicate that the amount of starch damage has a large effect on falling number tests on flour but not on triticale flour.

Analysis using DSC showed a higher amount of starch damage significantly decreased the entalphy of gelatinization of starch and flour formations such as amylose-lipid complex, but was not examinded in pasting properties, which is an amylose activity might be able to hydrolyze starch damage. The effect disc mill time on the amount of starch damage, amylose content, falling number, and entalphy gelatinization of starch samples can be seen in Table 3.

In addition, Leon *et al* (2006) also permoed an analysis using Rapid Visco Analyzer (RVA) to determine the pasting properties of samples that are affected by the amount of starch damage. When the starch dispersion in water is heated and shear is applied, the starch granules absorb water and swell, thereby increasing viscosity. During this period, the integrity of the granules is disrupted and amylose molecule comes out. Paste viscosity increases to the point where the intact starch granules swell maximally. Peak viscosity indicates the ability of starch to absorb or bind the water (Thomas and Atwell in Leon *et al*, 2006). The broken of starch during high temperature and shear cause decreasing viscosity into minimum (minimum viscosity).

Table 3. Effect of disc mill damaged starc and amylose contents, falling number, and gelatinization entalphy of starch

| Sample | Milling Time (minute) | *Starch Damage* (%) | Amylose Content (%) | *Falling Number* (s) | Gelatinization Entalphy (J/g) |
|---|---|---|---|---|---|
| B0 | 0 | 9,3 b | 21,5 a | 694 f | 3,92 d |
| B1 | 2 | 14,7 e | 22,2 a | 568 d | 3,70 c |
| B2 | 5 | 17,2 f | 21,6 a | 519 c | 2,76 a |
| DE0 | 0 | 8,4 b | 21,3 a | 630 e | 4,45 e |
| DE1 | 2 | 12,8 d | 20,1 a | 505 c | 3,57 c |
| DE2 | 5 | 17,7 f | 20,1 a | 419 b | 2,85 a |
| T0 | 0 | 6,1 a | 20,5 a | 234 a | 4,32 e |
| T1 | 3,5 | 10,4 c | 20,3 a | 229 a | 3,64 c |
| T2 | 7 | 14,0 e | 19,8 a | 231 a | 3,27 b |

Note: B (Baguette), DE (Klein Don Enrique), T (Tatu); 0, 1, and 2 corresponded to the milling time. Source: Leon *et al* (2006)

When gelatinized starch is cold, amylose rearrangement occurs so that viscosity increases again, it form the gel in end the test (final viscosity). This increasing viscosity is called setback and it shows retrograde amylose chain. The results of the analysisng of the pasting profile can be seen on Table 4.

Table 4. Effect of the amount of starch damage on flour pasting properties

| Sample | *Peak Viscosity* (cP) | *Minimum Viscosity* (cP) | *Breakdown* (cP) | *Final Viscosity* (cP) | *Setback* (cP) |
|---|---|---|---|---|---|
| B0 | 1880 ± 30 | 1133 ± 47 | 752 ± 52 | 2364 ± 33 | 1231 ± 23 |
| B1 | 1834 ± 56 | 1075 ± 34 | 759 ± 42 | 2359 ± 40 | 1284 ± 46 |
| B2 | 1742 ± 51 | 1007 ± 55 | 735 ± 47 | 2228 ± 24 | 1221 ± 27 |
| DE0 | 1697 ± 36 | 1151 ± 16 | 546 ± 31 | 2405 ± 19 | 1254 ± 39 |
| DE1 | 1628 ± 32 | 1056 ± 36 | 572 ± 48 | 2371 ± 37 | 1315 ± 41 |
| DE2 | 1439 ± 38 | 922 ± 44 | 517 ± 26 | 2132 ± 38 | 1210 ± 32 |
| T0 | 947 ± 18 | 269 ± 31 | 678 ± 39 | 830 ± 48 | 561 ± 29 |
| T1 | 882 ± 31 | 283 ± 22 | 599 ± 28 | 1019 ± 51 | 736 ± 34 |
| T2 | 836 ± 28 | 263 ± 51 | 573 ± 35 | 992 ± 53 | 729 ± 21 |

Note: B (Baguette), DE (Klein Don Enrique), T (Tatu); 0, 1, and 2 corresponded to the milling time. Source: Leon *et al* (2006)

**Microstructure of Damaged Starch**

Different milling methods in producing flour are thought to cause damage to starch and differences in the microstructure of starch granule. Furthermore, microstructure of native starch is different with microstructure of modified starch. Microstructure of starch granule can be analyzed using trinocular microscope and Scanning Electron Microscopy (SEM).

According to Putri *et al* (2018), MOCAF starch granules that produced using dry amd wet milling method with the differences of fermentation time is different. The particle size of MOCAF starch granule after fermentation is smaller than before fermentation process.

Furthermore, the particle size of MOCAF starch granule using wet milling method is also smaller than MOCAF starch granule using dry. It is caused in wet milling method the milling milling process is twice. The differences of MOCAF starch granule mircrostructure are presented in Figure 5.

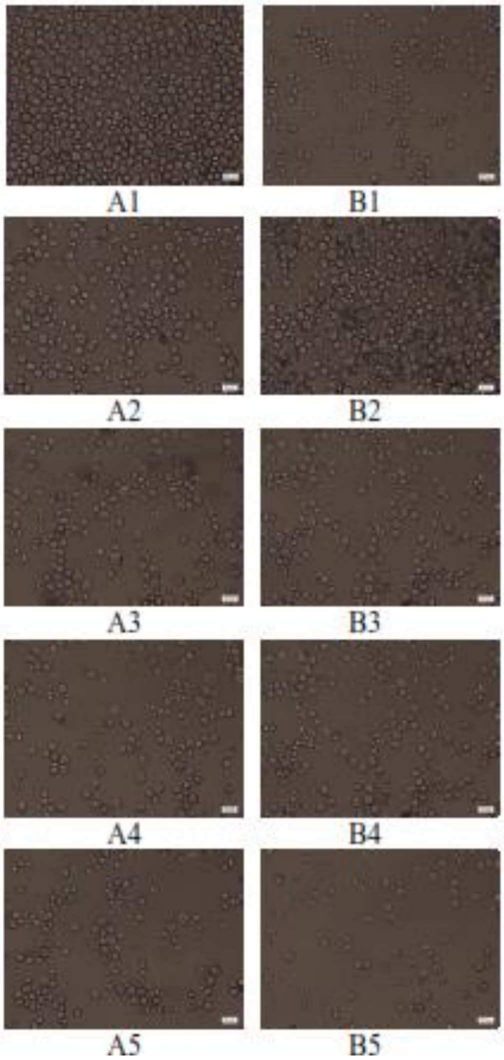



Figure 5. MOCAF starch granule microstructure with different milling method, (A= dry milling method, B= wet milling mehod), and fermentation time (0,6,12,18,24 hour) (Putri *et al,* 2018)

Scanning Electron Microscopy (SEM) of native and oxidized cassava starch granule shown in Figure 6. According to Sangseethong *et al* (2010), native cassava starch granules had round shape with a truncated end on one side. The surface of native starch granules was smooth with no evidence of any fissures.

In general, similar pattern of changes on external morphology of starch granule was observed for oxidized starches produced by either hypochlorite or peroxide oxidation (Figure 7). After 60 min, a slightly roughened surface was observed, with the oxidation time 120 and 300 min, the granule surface became rougher (Sangseethong *et al,* 2010).

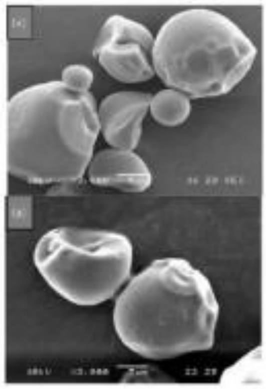


Figure 6. Microstructure of cassava starch, (a) native cassava starch, (b) modified cassava starch (Putri, 2018)

According to Putri (2018), all of starch granule MOCAF samples shown two type a damage of starch are cracks and breaks due to milling process (Figure 8).

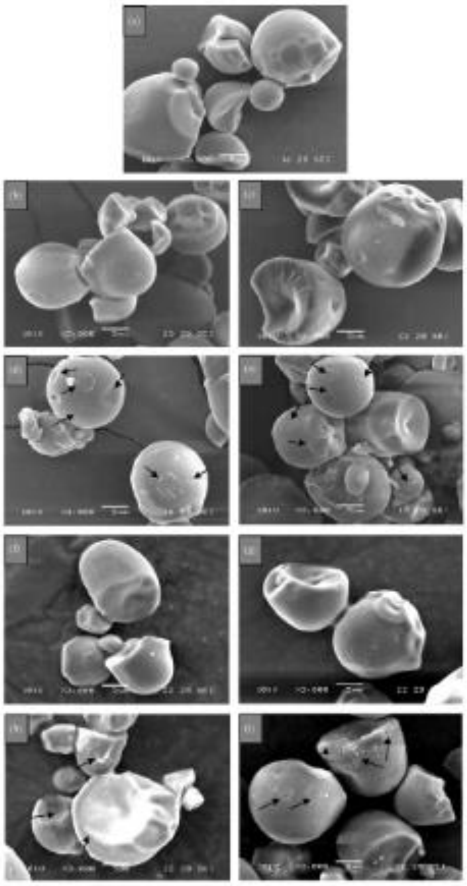
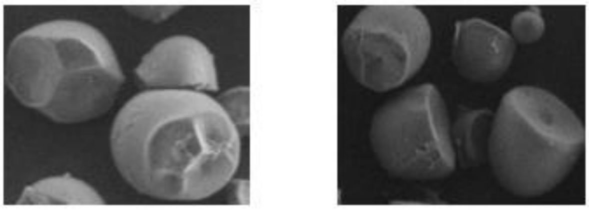


Figure 7. Microstructure of cassava starch, (a) native; (b-e) oxidized cassava starches prepared with hypochloride, and (f-i) peroxide at various reaction times: 30 min (b and f), 60 min (c and g), 120 min (d and h), and 300 min (e and i) (Sangseethong *et al,* 2010)



(a) (b)

Figure 8. Starch damage type in MOCAF (a) breaks, (b) cracks (Putri, 2018)

## CONCLUSION

The main factor causing damage to starch is mechanical treatment, such as milling process. Starch modification can also cause damage to starch. Starch damage can affect physicochemical properties such as as particle size, amylose content, thermal and pasting properties, retrogradation, and microstructure of starch granule. It is important parameter to determine quality of flour.

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