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PHYSICOCHEMICAL CHARACTERISTICS OF CROSS-LINK MODIFIED SORGHUM FLOUR IN BANDUNG LOCAL CULTIVARS

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Abstract

Cross-link flour modification accomplished by using a phosphor which is consisted in a phosphate salt, that will form a cross-linking bridges in a granule starch structure. The used of a STPP (Sodium Trypolyphosphate) as a cross-linking reagent is a solution to resolve the issue of a native sorghum starch. The goal of the research is to determine the concentration of STPP which produces the sorghum flour with a proper physicochemical properties. The method that used in this research is an experimental method which is continued by descriptive analysis with five treatments and two replications. Research was accomplished by creating a native sorghum flour and modified sorghum starch (cross-link) with four concentrations of STPP, which are: 0.05%, 0.10%,0.15%, and 0.20%. The result of the research showed the following physicochemical characteristics: whiteness 53.95%, water content 9.62%, water absorption capacity 21.61%, water absorption capacity 21.61%, swelling power 6.53%, solubility 4.67%, oil absorption capacity 11.94%, protein content 6.26%, fat content 1.69%, ash content 1.14%, 81.30% carbohydrate; the starch content 53.16%, amylose content 13.23%, and amylopectin content of 39.94%.

Key words: *cross link, flour modification, sorghum*

INTRODUCTION

Sorghum flour could be used as an alternative food to substitute the needs of flour. In producing sorghum flour with good characteristics, modifications on its starch content should be made, therefore the natural weakness on both physical and chemical characteristics on the starch could be improved. In food industry, the use of cross-link modified starch is widely used to provide stability on starch granule structure and to prevent swelling [5]. Cross-link reaction is a chemical modification by strengthening the hydrogen bond within starch granule using chemical compound acting as a bridge or new bond between the starch molecules, done to thickening, stabilizing, and texturizing the starch [4].
The compound often used in food industry is POCI3, sodium trymetaphosphate (STMP), and sodium trypolyphosphate (STPP) [1]. This research is using STPP reagent which could improve paste clarity, viscosity, and water binding capability. STPP compound could form intermolecular eter or ester by forming cross bond bridges between hydroxyl groups within starch compound [3] will result in biomolecular reaction between phosphate groups and starch, causing starch diester. Stated that the use of STPP reagent with pH balance bigger than 10 could produce diphosphate starch which is able to improve retrogradation endurance, high temperature, and low pH compared to native starch, through cross-linking reactions. World Health Organization (WHO) conducted a review of several countries and the results of the percentage of occurrence gastritis in England 22%, China 31%, Japan 14.5%, Canada 35% and French 29.5%. In the world, gastritis affects 1.8–2.1 million of the population each year. The occurrences of gastritis in Southeast Asia is approximately 583,635 of the population each year. The prevalence of endoscopic confirmed gastritis in population at Shanghai is approximately 17.2% which is substantially higher than the population in the west which approximately 4.1% and is asymptomatic. Gastritis is usually considered as a little thing, but gastritis is the beginning of a disease that could cause a trouble.

MATERIALS AND METHODS

The main materials used in this research are white local Bandung cultivar sorghum flour and STPP. Research method used in this research is experimental method followed by descriptive analysis with 2 repetitions.
Treatments are:
A = native sorghum flour (control)
B = cross-link modified sorghum flour with 0.05% STPP concentrate
C = cross-link modified sorghum flour with 0.1% STPP concentrate
D = cross-link modified sorghum flour with 0.15% STPP concentrate
E = cross-link modified sorghum flour with 0.2% STPP concentrate
A data matriculation table is made to show the difference between modified sorghum flour and native sorghum flour.
Research Implementation:
(i)Production on flour suspension. Flour is dissolved with water with water and starch ratio of 2 : 3 and then added with 10% NA_2SO_4 from flour amount to prevent granule swelling.
(ii)Flour suspension pH conditioning. Flour suspension is conditioned in pH 11 using NaOH 1N which is given drops by drops until the desired pH is achieved.
(iii)Addition of STPP reagent according to treatments
(iv)Heating and stirring for 60 minutes with a temperature of 40^0 C.
(v)Neutralizing flour suspension pH (pH 11) by giving drops of HCl 1 N until the pH reaches 6.5.
(vi)Flour washing, done to remove side substances from cross-link reactions.
(vii)Centrifugations, with speed of 3,000 rpm for 10 minutes, to separate flour and liquid.
(viii)Flour drying using cabinet dryer oven with a temperature of 40^0C for 16 hours.
(ix)Flour drilling using grinder and flour sieving using 80 meshtyler sieve.

RESULTS AND DISCUSSIONS

Whiteness Degree

Whiteness degree is an important parameter in determining quality of a flour product. Research result on whiteness degree of native sorghum flour and cross-link modified sorghum flour is shown on Table 1.

Table 1. Whiteness Degree of Native and Cross-link Modified Sorghum Flour

STPP Concentration	Whiteness Degree (%)
A Native	60.93
B STPP 0.05%	54.18
C STPP 0.10%	50.88
D STPP 0.15%	55.55
E STPP 0.20%	53.95

Source: Processed Data.

According to Table 1, the value of the degree of white sorghum flour modified cross-linked ranged from 50.88 to 55.55% and for sorghum flour whiteness naturally has a value of 60.93%. Whiteness degree of sorghum flour modified cross-links have a lower value than natural sorghum flour, whereas through visual observation of the colour of white flour is dull. Whiteness degree is measured using whiteness meter method compared to standard whiteness value of 87.5% $BaSO_4$. Change the colour becomes brown after a process of modification resulting from the use of NaOH which causes alkaline conditions at the time of the modification.

Water Content

Table 2. Water Content of Native and Cross-link Modified SorghumFlour

STPP Concentration	Water Content (%)
A Native	7.67
B STPP 0.05%	8.64
C STPP 0.10%	9.03
D STPP 0.15%	9.37
E STPP 0.20%	9.62

Source: Processed Data.

Based on Table 2, cross-link modification on sorghum flour showed an increasing trend towards water content along with the increasing concentration of STPP. The water content of modified flour ranges from 8.64 to 9.62% while the water content of native sorghum flour is 7.67%. Increased water levels are in line with the increased concentration of STPP, caused by the growing substitution of phosphate groups in substituting the –OH group. OH molecules apart would bind and form water, so the water content in sorghum modification increased

[6]. The water content on cross-link modified sorghum flour with 0.05% and 0.20% STPP concentrate is appropriate according to Codex Standard 173-1989 Rev. I-1995, where maximum water content on sorghum is 15%, therefore it is qualify to be stored at room temperature.

Water Absorption Capacity

Table 3. Water Absorption Capacity of Native and Cross-link Modified Sorghum Flour

STPP Concentration	Water Absorption Capacity (%)
A Native	14.31
B STPP 0.05%	17.43
C STPP 0.10%	18.69
D STPP 0.15%	19.56
E STPP 0.20%	21.61

Source: Processed Data.

Based on Table 3, cross-link modification shows an increase in the water absorption capacity along with the increasing concentration of STPP. Values of water absorption capacity of modified sorghum flour ranged between 17.43 to 21.61%, while the value of water absorption capacity of native sorghum flour is 14.31%. Increasing concentrations of STPP is added to the modification of cross-link could be expected as the increasing value of water absorption capacity. Crosslink modification with increased crosslink reagent concentration, increasing the water absorption capacity. The addition of reagents containing phosphorus which acts as a bridge crosslink may affect the ability of water absorption. Cluster phosphorus is a hydrophilic group that is able to bind water. The higher the concentration of STPP, the phosphorus content in the flour will be increased so that the amount of hydrophilic group will increase as well. This greatly affects the increase in water absorption capacity.

The modification process by cross-linking is done in an alkaline pH, also influence the water absorption capacity of flour. This is due, alkaline pH can cause structural modifications granules which can increase the capacity of hydration. Conditioning of pH in alkaline state, causing the phosphorylation process that occurs in the modification of cross-link becomes stronger so as to produce more stable starch granules.

Swelling Power

Table 4. Swelling Power of Native and Cross-link Modified Sorghum Flour

STPP Concentration	Swelling Power (%)
A Native	5.66
B STPP 0.05%	5.78
C STPP 0.10%	6.49
D STPP 0.15%	6.09
E STPP 0.20%	6.53

Source: Processed Data.

Cross-link modification shows an increase in the value of swelling power along with the increasing concentration of STPP than native sorghum flour. Based on the results, the value of a modification sorghum flour swelling power are ranging from 5.78 to 6.53%.

The high value of sorghum flour swelling power on modifications to cross-link due to the presence of a compound suspected to crosslink the starch granules. Negatively charged phosphate groups will give the repulsive force between starch molecules, so is thought to decrease the relationship between the molecular chains of starch and provide hydration levels are higher in starch molecule that causes increased swelling power [2].

Swelling power level of cross-link modified sorghum flour is increased compared to native sorghum flour, but swelling power of native sorghum flour and cross-link modified sorghum flour are lower compared to wheat flour, which is 10.17 g gel/g. The results show that cross-link modified sorghum flour could improve dough expandability, however it is not as good as wheat flour.

Solubility

The results of the analysis of the solubility of cross-link modification sorghum flour showed a decline in the value of solubility along with the increasing concentration of STPP. Native sorghum flour have a higher value than its solubility in sorghum modification crosslink, which amounted to 18.36%.

This is caused due to an increase in cross-link density compounds in the structure of starch that can reduce the level of damage to the starch granules during gelatinization. While the value of solubility of modification sorghum flour ranged between 4.67 to 5.73%. Value indicates a low solubility in sorghum increasingly difficult to dissolve in water. Crosslinking bonds can increase the strength of the starch granules that can reduce damage granules during gelatinization which causes a decrease in solubility.

Table 5. Solubility of Native and Cross-link Modified Sorghum Flour

STPP Cncentration	Solubility (%)
A Native	18.36
B STPP 0.05%	5.73
C STPP 0.10%	5.50
D STPP 0.15%	4.91
E STPP 0.20%	4.67

Source: Processed Data.

Oil Absorption Capacity

Table 6. Oil Absorption Capacity of Native and Cross-link Modified Sorghum Flour

STPP Concentration	Oil Absorption Capacity (%)
A Native	8.30
B STPP 0.05%	9.56
C STPP 0.10%	10.70
D STPP 0.15%	11.20
E STPP 0.20%	11.94

Source: Processed Data.

Cross-link modification shows an increase in the oil absorption capacity along with the increasing concentration of STPP. Sorghum flour naturally has a lower value than the oil capacity of the modified sorghum flour. Based on the results, the value of a modification of the sorghum flour ranged from 9.56 to 11.94%, while the value of natural sorghum flour was 8.30%.

Oil absorption capacity increased in the sorghum flour modification, suspected due to an increase in fat content occurs. Oil absorption capacity is related to levels of fat contained in flour. The greater the fat content of the flour, the greater the oil absorption capacity. It is associated with the presence of amylose-lipid complexes formed during the modification process. Increased levels of amylose and fat levels in the sorghum flour modification cause more amylose-lipid complexes are formed, which result in increased oil absorption capacity.

Protein Content

Based on Table 7, it can be seen that the protein content of sorghum flour modified by cross-link using STPP ranges from 6.26 to 6.67% while the protein content of native sorghum flour has a value of 8.39%. The modification process cross-link on sorghum showed a decrease in the protein content with increasing concentrations of STPP used.

Table 7. Protein Content of Native and Cross-link Modified Sorghum Flour

STPP Concentration	Protein Content (%)
A Native	8.39
B STPP 0.05%	6.67
C STPP 0.10%	6.57
D STPP 0.15%	6.46
E STPP 0.20%	6.26

Source: Processed Data.

Decreased levels of a protein thought to be caused by the process of dissolving the protein in a saline solution. The presence of salt can cause increased protein solubility. This is because the inorganic ions contained in salt compounds will bind to the surface of the protein and prevent the incorporation of protein molecules. Increasing concentrations of STPP made in the modification process causes the solubility of proteins to salt increased. This causes the protein contained in the modification of the sorghum flour decreased.

Protein content of native sorghum flour and cross-link modified sorghum flour with 0.05%, 0.10%, 0.15%, and 0.20% STPP concentrate is not appropriate according to sorghum flour on Codex Standard 173-1989 Rev. I-1995, where the minimum protein content of sorghum is 8.5%.

Fat Content

Table 8. Fat Content of Native and Cross-link Modified Sorghum Flour

STPP Concentration	Fat Content (%)
A Native	1.20
B STPP 0.05%	1.93
C STPP 0.10%	1.75
D STPP 0.15%	1.81
E STPP 0.20%	1.69

Source: Processed Data.

According to Table 8, the fat content of sorghum flour crosslink modification has a higher value than native sorghum flour, which ranged from 1.69 to 1.93%, where the value of the fat content of native sorghum flour is 1.20%.Increasing concentrations of STPP could be expected to cause more ionic bonds contained in starch.

Ionic bonds have a strong electron potential, the higher the electronegativity of an atom, then the ability of an atom to attract bonding electrons when the atom is present as a molecule becomes stronger. The addition of STPP made on the basis crosslink modification causes some proteins that are in the globulin fraction undergo dissolution. Potential electrons more strongly held STPP lead compounds bind to the protein easier phosphate salt compounds that cause covalent protein and fat is dismissed. The more the concentration of salt STPP is added, the more proteins are dissolved, resulting in the termination of covalent bonds so that the fat count as fat content increased.

Fat content of native sorghum flour and cross-link modified sorghum flour with 0.05%, 0.10%, 0.15%, and 0.20% STPP concentrate is not appropriate according to sorghum flour in Codex Standard 173-1989 Rev. I-1995, where the minimum fat content of sorghum flour is 2.2%.

Ash Content

Table 9. Ash Content of Native and Cross-link Modified Sorghum Flour

STPP Concentration	Ash Content (%)
A Native	0.81
B STPP 0.05%	1.52
C STPP 0.10%	1.28
D STPP 0.15%	1.14
E STPP 0.20%	1.14

Source: Processed Data.

According to Table 9, it is known that the ash content of sorghum flour modified by cross-link using STPP has a higher value than native sorghum flour. The ash content in sorghum modifications ranging from 1.14% - 1.52% while the ash content of native sorghum flour is 0.81%.Increased levels of ash caused by the use of reagents STPP during the modification process. The more phosphate groups attached, hence increasing ash content because phosphate is a constituent component of ash [7].

Ash content on native sorghum flour and cross-link modified sorghum flour with 0.10%, 0.15%, and 0.20% STPP concentrate is appropriate according to sorghum flour on Codex Standard 173-1989 Rev. I-1995, where the maximum ash content is 1.5%, but ash content of cross-link modified sorghum flour with 0.05% STPP concentrate has not yet appropriate according to Codex Standard 172-1989 Rev. I-1995.

Carbohydrate Content

Table 10. Carbohydrate Content of Native and Cross-link Modified SorghumFlour

STPP Concentration	Carbohydrate Content (%)
A Native	81.94
B STPP 0.05%	81.23
C STPP 0.10%	81.18
D STPP 0.15%	81.24
E STPP 0.20%	81.30

Source: Processed Data.

Carbohydrate levels are calculated by difference, it means that the content is obtained from the reduction of the number 100 as a percentage of other components, such as moisture content, ash content, fat content and protein content. The downward trend of carbohydrate levels occurred along with an increase in the concentration of STPP. Decreased levels of carbohydrates suspected due to leaching processes during the process of cross-link modification. The use of HCl during the modification process can lead to the dissolution of sugar and carbohydrate components contained in the sorghum flour.

Carbohydrate level on native sorghum flour and cross-link modified sorghum flour are higher compared to wheat flour, which has carbohydrate level of 77.30%. Starch level of native sorghum flour and modified sorghum flour are lower compared to starch level of corn flour, which is 60.07%.

Starch, Amylose, and Amylopectin Content

Sorghum starch modification has a lower value than natural sorghum starch content, which ranged from 53.16 to 57.90%, while the starch content of native sorghum flour's value is 59.78%.The hydrogen bridges in the starch molecule is substituted by a phosphate compound that forms the phosphate bridge.

Bound starch phosphate bridges are not counted as starch compounds, so more bridges phosphate is formed, the decreased levels of starch is detected.

Table 11. Starch, Amylose, Amylopectin Content of Native and Cross-link Modified Sorghum Flour

STPP Concentration	Starch Content (%)	Amylose Content (%)	Amylopectin Content (%)
A Native	59.78	11.64	48.14
B STPP 0.05%	57.90	12.24	45.67
C STPP 0.10%	55.55	13.10	42,45
D STPP 0.15%	54.36	13.35	41.01
E STPP 0.20%	53.16	1.23	39.94

Source: Processed Data.

According to Table 11, amylose content of modified sorghum flour has a higher value than native sorghum flour. Amylose content of modification cross-linked sorghum flour ranged from 12.24 to 13.35%, while amylose content of native sorghum flour is 11.64%, while the amylopectin content is decreased when the sorghum flour is modified. The amylopectin content ranged from 39.94-45.67%, while the amylopectin content of native sorghum flour is 48.14%.

Increased level of amylose is in line with the increased concentration of STPP added. This is due to the higher concentration of STPP is used, the more the phosphate groups which replaces the hydroxyl group binds to amylose in higher numbers, which causes the proportion of amylose changes. The amylopectin molecules are more prone to crosslinking than amylose molecules, so that the amylopectin molecules join together to produce a few molecules in size large. This causes the proportion of amylopectin to amylose increased. The increasing levels of amylose in the starch structure, will cause a lower levels of amylopectin in starch content.

Based on Table 11, starch and amylopectin level on modified sorghum flour has a lower value compared to native sorghum flour, but higher amylose level compared to native sorghum flour. Based on the classification from IRRI (International Rice Research Institute), amylose level of starch food is classified into three, which are low amylose (<20%), medium amylose (20-25%), and high amylose (>25%). Therefore based on amylose level test, cross-link modified sorghum flour using STPP with 0.05-0.20% concentrate is classified as starch food with low amylose level.

CONCLUSIONS

The modification of the sorghum flour using a modified cross-link concentrations of 0.20% STPP produced a sorghum flour with physicochemical characteristics better than natural sorghum flour as follows: whiteness 53.95%, water content of 9.62%, water absorption capacity of 21.61%, swelling power of 6.53%, solubility of 4.67%, oil absorption capacity of 11.94%, protein content of 6.26%, fat content 1.69%, ash content of 1.14%, 81.30% carbohydrate, the starch content of 53.16%, amylose content of 13.23%, and amylopectin content of 39.94%.

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