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Modification of Starch Talas Beneng (*Xanthosoma Undipes* K. Koch) with Oktenil Suksinat Anhydrous (Osa) and its application in Mayonaise

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Abstract. Taro beneng is one of the plants that has a high starch content. This resulting natural starch has several drawbacks so modification is needed. This study aims to determine the optimum concentration and pH of OSA in taro starch modification so as to produce the best OSA starch, determine the characteristics of the modified starch, and determine the best formula in the process of making mayonnaise products by using OSA starch as an emulsifier that can produce high-quality mayonnaise. The process of modification of starch with OSA is carried out esterification with a concentration of OSA 1%; 3%; 5% and pH 7.5; 8,5; 9.5. The modifications were tested for DS, amylose content, starch digestibility, development power, emulsion capacity, solubility, SEM, XRD, DSC, and RVA. Then OSA starch is best used in the manufacture of mayonnaise by determining the best formula that can produce mayonnaise with the best pH, fat content, emulsion stability, viscosity, color, and organoleptic. The results showed that OSA starch was best obtained by esterification process using OSA 3% and pH 8.5 with characteristic DS value of 0.0270; amylose content of 20.35%; starch digestibility 187.39%; degree of krisatalinitas 41,7%; peak viscosity 4171 cP; development power of 7.2117 at 90°C and solubility of 76.50% at 90°; granule size 2,077 µm – 3,435 µm with porous and rough polygonal shape; has a crystalline structure of pattern A; ΔH 132 (J/g) at a peak temperature of 96.38°C; and a peak viscosity of 4171 cP at a final temperature of 79.90 °C. Mayonnaise is best obtained at the addition of 1% OSA starch and 4% egg yolk with a pH value of 3.1; fat content of 37.57%; emulsion stability 64.69%; emulsion viscosity 44625 cP; and color brightness of 94,325.

Keywords. Talas Beneng, Oktenil Suksinat Anhydrous (OSA), Mayonaise

Introduction

Indonesia has many plants tubers one of which is taro beneng (Xanthosoma undipes K. Koch). Taro beneng is one of the plants that contains good nutrients, namely carbohydrates 82.56 %, protein 3.4%, fat 0.28% and starch content 84.96% (Rostianti et al., 2018). Taro starch has special characteristics that include a weak texture, cohesive or sticky, the paste is rubbery when cooked, and has certain gel properties. These constraints cause natural starch to be limited in the food industry, so modification is needed in order to produce starch with appropriate characterictics (Koswara, 2009).

Starch is used as a thickener and binder for various products such as puddings, soups, sauces, salads, baby food, mayonnaise, and rerotian. Modified starch is a starch whose hydroxyl group has been altered through a chemical reaction such as esterification, erefikasi, or disrupting its initial structure (Estiasih et al., 2015). Starch modification can be done using 4 ways, namely: physics, chemistry, enzymes and combinations. Based on the consideration of diversity of functional properties, the most widely modified way is chemically. Chemical modification can be done through esterification, etherification, cross-linking, grafting, chemical decomposition, hydrolysis with enzymes, and oxidation (Masina et al., 2017).

OSA modified starch is produced through an esterification process involving the addition of oxtenyl succinate anhydrous. OSA starch can form a strong film layer in the oil and water layer thus preventing the formation of droplet aggregates that trigger coaselan and floccation and the macromolecular arrangement of OSA starch can increase the viscosity of emulsions that can inhibit the movement of oil droplets to approach each other. The dual role of OSA starch as an emulsifier and stabilizer is essential in stabilizing emulsions (Anwar et al., 2018).

Mayonnaise is a food that has a high fat content, with egg yolks as its stabilizer. Excessive fat consumption can increase the risk of non-communicable diseases. Nowadays many people start to reduce the amount of oil and fat consumption in their diet. It is this situation that drives the trend to reduce the amount of fat consumption in various other foods. However reducing fat in food can lead to less good rheological and sensory properties. The solution of this is to use fat substitutes that have oil-like properties so that the low-fat foods produced can still have good quality. The results of previous research reported that modification of OSA pati garut can be used as a substitute for egg yolks so as to produce low-fat mayonnaise (Park et al., 2020). The purpose of this study was to determine the optimum concentration and pH of OSA in the process of modification of taro starch that can produce the best OSA starch, determine the characteristics of modified starch, and determine the best formula in the process of making mayonnaise products by using OSA starch as an emulsifier that can produce high-quality mayonnaise.

Research methods

The research covers several stages, namely the manufacture of starch, modification of OSA starch, and application of OSA starch in mayonnaise products. The process of modification of starch is carried out esterification with oxtenyl succinate anhydrous (OSA) with a concentration of OSA 1%, 3%, 5% and pH 7,5; 8,5; 9.5. The modification results tested its chemical properties, functional properties and characteristics. Chemical properties include substitution (DS), and amylose levels (KA); Functional properties were tested through starch digestibility (DCP), development power (DP), emulsion capacity (KE) and solubility (Kel) and their characteristics using Scanning Electron Microscope (SEM) for morphological tests of starch granules, X-Ray Diffraction (XRD) for starch crystallineity patterns, Differentensial Calorimetry Scanning (DSC) for thermal properties, and Random Viscosity Analyzer (RVA) for gelatinization profiles. Each treatment is repeated 3 times.

Description of OSA starch modification treatment

M1 = Modification of OSA starch concentration of 1% with a pH of 7.5
M2 = Modification of OSA starch concentration of 3% with a pH of 7.5
M3 = Modification of OSA starch concentration of 5% with a pH of 7.5
M4 = Modification of OSA starch concentration of 1% with a pH of 8.5
M5 = Modification of OSA starch concentration of 3% with a pH of 8.5
M6 = Modification of OSA starch concentration of 5% with a pH of 8.5
M7 = Modified OSA starch concentration of 1% with a pH of 9.5

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M8 = Modification of OSA starch concentration of 3% with a pH of 9.5
M9 = Modification of OSA starch concentration of 5% with a pH of 9.5

Results and discussion

Table 1. Physical Characteristics of Starch Talas Beneng

No.	Parameters	information
1	color	Yellowish white
2	texture	soft
3	aroma	Typical starch talas beneng
4	Rendemen	3,38%

The results showed that the yield of starch was 3.38 %. Observation of colors, textures and aromas is done visually with the five senses. Starch taro beneng has a yellowish white color, the resulting texture is very smooth because the process of grinding starch using a 100 mesh si sipping, has a distinctive aroma of taro beneng.

Chemical Properties of OSA Starch

Table 2. OSA Starch Chemical Properties Test Results

Treatment	Chemical Properties Test	
	Degree of Substitution	Amylose Levels (%)
M1	$0.0167^{a} \pm 0.00$	$17.28^{c} \pm 0.00$
M2	$0.0251^{b,c,d} \pm 0.00$	$17.25^{c} \pm 0.05$
M3	$0.0237^{b.c} \pm 0.00$	$16.80^{b} \pm 0.00$
M4	$0.0226^{b} \pm 0.00$	$16.40^{a} \pm 0.00$
M5	$0.0270^{s} \pm 0.00$	20.35s ± 0.32
M6	$0.0237^{b.c} \pm 0.00$	$16.80^{b} \pm 0.00$
M7	$0.0244^{b,c,d} \pm 0.00$	$20.00^{s} \pm 0.00$
M8	$0.0262^{c.d} \pm 0.00$	$16.64^{b} \pm 0.00$
M9	$0.0247^{b,c,d} \pm 0.00$	17.36c ± 0.00

Ket: The numbers followed by the same letter indicate a value that is no different real (P>0.05) M1 = Modified OSA starch concentration of 1% with a pH of 7.5; M2 = Modification of OSA starch concentration of 3% with a pH of 7.5; M3 = Modification of OSA starch concentration of 5% with a pH of 7.5; M4 = Modification of OSA starch concentration of 1% with a pH of 8.5; M5 = Modification of OSA starch concentration of 3% with a pH of 8.5; M6 = Modification of OSA starch concentration of 5% with a pH of 8.5; M7 = Modification of OSA starch concentration of 1% with a pH of 9.5; M8 = Modification of OSA starch concentration of 3% with a pH of 9.5; M9 = Modification of OSA starch concentration of 5% with a pH of 9.5

Based on (Table 2) the highest DS value is found in M5 (combination of pH treatment 8.5 with a concentration of 3%) with a value of 0.0270. While the lowest DS value is found in M1 (combination of pH treatment 7.5 with a concentration of 1%) with a value of 0.0167. According to the FDA the standard for DS value of OSA starch is 0.03. This indicates that the resulting DS value obtained can be applied to the food. At pH 7.5 with the same concentration the hydroxyl group (OH-) present in starch is not sufficiently activated for nucleophilic attacks of anhydride groups. While at pH 9.5 with the same OSA concentration, the concentration of anhydride begins to run out and anhydride hydrolysis occurs causing DS to drop. Similarly, OSA concentrations are 1%, 3% and 5% with the same pH. At a concentration of 5% with the same pH DS dropped.

Based on the analysis of fingerprints it is known that there is an interaction between pH and OSA concentrations against amylose levels. The treatment of pH and concentration of OSA has a very noticeable effect on amylose levels ($\alpha = 0.05$). Based on research (Table 2) shows that the highest amylose levels are found in the combination of pH treatment 8.5 with a concentration of 3% with a level of 20.35%. The amylose content contained in the sample affects the DS value obtained. The greater the content of amylose, the greater the value of DS obtained. This is related to the attack of anhydride group during the modification process. Anhydride group will attack the amorphous area of starch, where the amorphous area of starch is dominated in the amylose part. The more starch hydroxy groups attacked, the greater the DS obtained.

Functional Properties of Starch

Table 3. OSA Starch Functional Test Results

Treatment	Functional Test	
	Starch Digestibility (g/100g)	Emulsion Capacity (%)
M1	115.57a ± 0.65	32.75a ± 0.90
M2	129.38d ± 0.65	33.00a ± 0.87
M3	126.62c ± 0.65	31.67a ± 5.80
M4	122.93b ± 0.65	33.38a ± 0.62
M5	187.39i ± 0.65	34.58a ± 4.73
M6	181.87h ± 0.65	33.58a ± 1.23
M7	162.99g ± 0.00	32.92a ± 1.91
M8	150.10f ± 0.00	34.42a ± 3.71
M9	145.96e ± 0.65	33.50a ± 2.38

Starch digestibility is an ability of starch-breaking enxim in hydrolyzing starch into smaller units. The higher the digestibility of a starch, the more starch can be hydrolyzed in a given time. Based on the results of the study (Table 3) shows that the digestibility value of natural starch is lower when compared to OSA starch. The high value obtained proves that OSA starch has a higher level of ease to be digested by digestion. The digestibility of starch is influenced by amylose content and the DS value obtained. The higher the amylose content and DS value, the higher the digestibility of starch.

Emulisi capacity is a solution's ability to emulsify oil and declare the amount of fat that can still be fastened that does not cause the emulsion to rupture. Based on the research (Table 3) the highest emulsion capacity was found in the M5 sample at 34.58% and the lowest emulsion capacity was in the M3 sample at 31.67%. The greater the value of the emulsion capacity, the more fat it can be bound so that the chances of the emulsion breaking will be reduced. The strength in the formation of this emulsion depends on the number of hydrophilic-lopophilic groups in forming emulsions.

Power development (*swelling power*)is an analysis used to see the ability of starch in absorbing water by measuring the amount of water absorbed by each gram of dry samples. Based on research shows that natural starch when heated at temperatures of 25°C, 60°C, 70°C, 80°C and 90°C produces lower development power compared to OSA starch development power. This is due to the presence of anhydrous group that replaces the hydroxyl group so that hydrogen bonds become weak and eventually causes water to become easier to enter the granules of starch. Granules of starch will expand with a high temperature in sufficient water conditions. Then it will be dispersed out and dissolved into a solution. The ability to dissolve it shows starch soluble power.

Morphology of granule starch

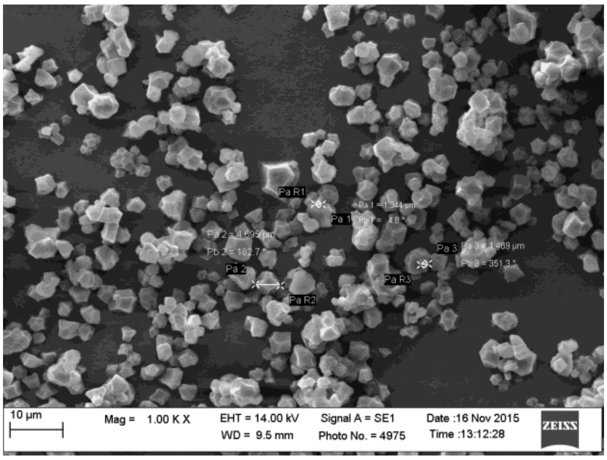

Figure 1. SEM analyst results on natural starch magnification 1000x

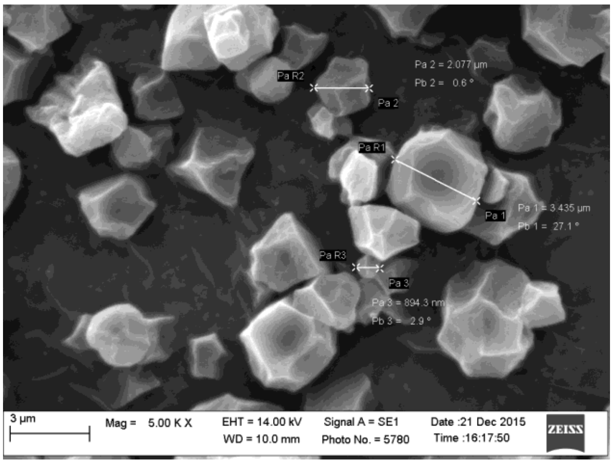

Figure 2. Results of SEM Analysis on OSA Starch Magnification 5000x

Sem analysis shows that natural starch granules (Figure 1) have a polygonal and irregular shape. The size of natural starch granules in micro sizes ranges from 1,344 µm – 4,695 µm (Table 4). This is also in accordance with nita research that states that natural taro starch has a polygonal and irregular form (Aryanti et al., 2017).

Table 4. Diameter Size Of Natural Granules and OSA Starch

Sample	Granule Size Diameter
Natural starch	1,344 µm – 4,695 µm
OSA starch	2,077 µm – 3,435 µm

Eximia Journal
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A SEM investigation (Figure 2) showed that modifications with OSA led to some changes in the structure of starch granules. OSA starch granules have a rough, porous surface and there are many cavities. This happens because OSA first attacks the surface and then forms surface pores. The size of OSA starch granules in micro sizes ranges from 2,077 µm – 3,435 µm (Table 4).

Crystalline Starch Pattern

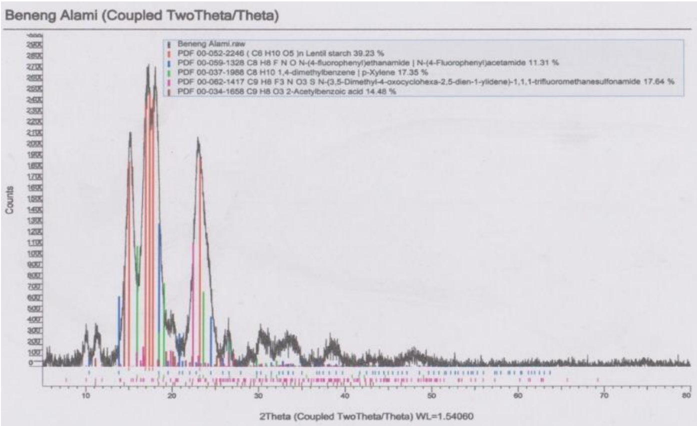

Figure 3. Natural Starch CrystallineIty Pattern

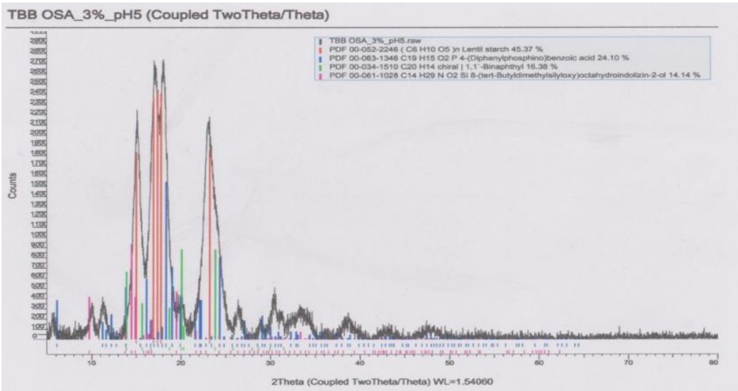

Figure 4. OSA Starch CrystallineIty Pattern

The results (Figures 3 and 4) showed that natural starch and OSA starch have crystallineity of 44.1% and 41.7% respectively, which are characterized by peaks of 2θ of 15°C, 17°, 18°C, and 23°C, respectively. This suggests that natural starch and OSA starch have type A crystalline.

Thermal Properties of Starch

Table 5. Thermal Properties of Natural Starch and OSA Starch

Sample	Parameters	
	ΔH (J/g)	Peak Temperature (°C)
Natural starch	41	92,3
OSA starch	132	96,38

Based on Table 5 shows that the temperature and enthalpy of natural starch are lower than OSA starch. Natural starch and OSA starch temperatures of 93.3°C and 96.38°C and ΔH respectively of 41 J/g and 132 J/g. The higher the gelatinization temperature of OSA starch, the greater the energy required in the gelatinization process. This is due to the presence of OSA clusters that replace starch-free OH so that energy and temperature increase. High gelatinization temperature can be used in products that require heating with high temperatures.

Gelatinization Profile

Table 6. Gelatinization Profile of Natural Starch and OSA Starch

Parameters	Natural Starch	OSA starch
Peak viscosity (cP)	3017	4171
Viscosity *breakdown* (cP)	2352	2193
Final viscosity (cP)	3515	2774
Viscosity *setback* (cP)	1091	796
Peak time (minutes)	5	4,20
Peak viscosity temperature (°C)	93	99
Final temperature viscosity (°C)	78,95	79,90

Based on Table 6 shows that the viscosity of OSA starch peaks is higher than natural starch. The viscosity of starch peaks increased from 3017 cP to 4171 cP. Similarly, the viscosity temperature of the peak OSA starch is higher than the natural starch from 93°C to 99°C. Peak viscosity temperature is the temperature at which gelatinization is formed. In contrast, peak time (the time required for peak viscosity) decreases from 5 minutes to 4.20 minutes. This is due to the merger of a large group such as the increase in the capacity of OSA paste from starch and the destruction of starch structures, so OSA starch tends to form pastes at shorter times (Hui et al., 2009).

Characteristics of Mayonnaise With the Addition of OSA Starch and Egg Yolk As Emulsifier

Mayonaise characterizations include; pH, emulsion stability, fat content, and viscosity. Mayonaise characterization results are presented in Table

Table 7. Average Mayonnaise Characteristics Results

Sample	Fat Content (%)	Ph	SE (%)	Viscosity (Cp)
F1	$44.57^{e} \pm 0.36$	$3.4^{a} \pm 0.00$	$60.65^{a} \pm 0.44$	$38250^{a} \pm 353.55$
F2	$43.66^{d} \pm 0.14$	$3.3^{a} \pm 0.00$	$61.16^{a} \pm 0.45$	$38875^{a} \pm 176.78$
F3	$42.65^{c} \pm 0.17$	$3.2^{a} \pm 0.00$	$62.18^{b} \pm 0.47$	$40250^{b} \pm 353.55$
F4	$41.05^{b} \pm 0.18$	$3.2^{a} \pm 0.00$	$63.01^{c} \pm 0.22$	$43375^{c} \pm 176.78$
F5	$37.57^{a} \pm 0.07$	$3.1^{a} \pm 0.00$	$64.69^{d} \pm 0.19$	$44625^{d} \pm 176.78$

Ket: F1 = Formulation of OSA starch concentration 0% with 5% egg yolk: F2 = Formulation of OSA starch concentration 0.25% with 4.75% egg yolk: F3 = Formulation of OSA starch concentration 0 5% with 4.5% egg yolk: F4 = Formulation of OSA starch concentration of 0.75% with 4.25% egg yolk: F5 = Formulation of OSA starch concentration of 1% with 4% egg yolk

Based on the research (Table 7) showed the highest fat content in the F1 sample was 44.57% and the lowest fat content was in the F5 sample at 37.57%. Fat levels decrease from F1 to F5. This is due to the presence of OSA starch emulsifier combined with egg yolk. The higher the OSA starch used the lower the fat content.

Based on research (Table 7) shows that the pH range of all samples is 3.1 – 3.4. Then by increasing the egg yolk replacement (OSA starch) from 0.25-1%, the pH of the mayonnaise sample is reduced. Egg yolks and OSA have a pH of about 6.9 – 6.11 (Suryono &Lukman, 2020),but as the amount of weight from egg yolks and OSA starch used in various mayonnaise formulations decreases with an increase in the number of yolks replaced with OSA flour, the pH value becomes low.

Based on the research (Table 7) showed that the highest stability was found in the F5 sample of 64.69% and the lowest stability was found in the F1 sample of 60.65%. The results showed that the higher the OSA starch the stability value of the emulsion the higher, the visible from the increasing stability value of the emulsion from F1 to F5.

Based on research (table 7) showed that the highest viscosity was found in the F5 sample of 44625 cp while the lowest viscosity was found in the F1 sample of 38250 cp. The increase in the viscosity of mayonaise corresponds to the increasing concentration of OSA starch, since the surface of oil molecules can be coated well, so that it can unite with water. A greater number of internal phases than the external phase can increase the viscosity of an emulsion, as its particles are pressed in the emulsion system. This is in line with Shen *et al.'s research,* reporting increased mayonaise viscosity with increased dextrin oats (Shen et al., 2011).

Mayonaise Colors

Table 8. Mayonaise Color Analysis Average Results

Sample	value				
	L*	a*	b*	h (°)	Free wi
F1	93,97	-3,80	21,62	99,98	77,24
F2	93,44	-3,84	21,88	99,94	76,84
F3	93,34	-3,01	23,12	97,41	75,76
F4	93,60	-2,91	23,54	97,06	75,43
F5	94,33	-3,01	21,11	98,13	77,94

Ket: F1 = Formulation of OSA starch concentration 0% with 5% egg yolk: F2 = Formulation of OSA starch concentration 0.25% with 4.75% egg yolk: F3 = Formulation of OSA starch concentration 0 5% with 4.5% egg yolk: F4 = Formulation of OSA starch concentration of 0.75% with 4.25% egg yolk: F5 = Formulation of OSA starch concentration of 1% with 4% egg yolk

Based on research (Table 8) shows that the L value ranges from 93.34 – 94.33 which indicates that the sample has a high level of brightness. Samples F1 to F5 samples have a *hue* value range (h) of 97° – 100° and WI values of 75.43 – 77.94. Based on the results obtained, mayonaise has a yellow color of brightness. This corresponds to the standard color in the market that indicates a *hue* value (h) approaching 100. Bortnowska and Grzegoorz reported a WI score of about 76 – 80 (Bortnowska &Tokarczyk, 2009).

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Organoleptic Results

Table 9. Data Processing Results Rating Test and Hedonic Mayonnaise Ranking

Sample	Rating Test				Ranking Test
	color	aroma	texture	taste	
F1	5.3[a]	4.9[a]	5.5[a]	4.1[a]	3.3[a]
F2	5.1[a]	4.6[a]	5[a]	3.9[a]	3.3[a]
F3	5.5[a]	5[a]	5.6[a]	4.6[a]	2.4[a]
F4	5.2[a]	4.7[a]	5.2[a]	4.2[a]	3.1[a]
F5	5.1[a]	4.4[a]	4.9[a]	3.9[a]	3[a]

Ket: F1 = Formulation of OSA starch concentration 0% with 5% egg yolk: F2 = Formulation of OSA starch concentration 0.25% with 4.75% egg yolk: F3 = Formulation of OSA starch concentration 0 5% with 4.5% egg yolk: F4 = Formulation of OSA starch concentration of 0.75% with 4.25% egg yolk: F5 = Formulation of OSA starch concentration of 1% with 4% egg yolk

The results of the fingerprint analysis showed that the treatment between OSA starch and egg yolks had no interaction effect on the rating test that had parameters in the form of color, aroma, taste and texture or ranking test. Based on the results obtained, any treatment given to the sample, will give the same result. Based on the ranking results obtained by F3 mayonnaise samples (OSA starch 0.5% and egg yolk 4.5%) most liked by panelists.

Conclusion

The study "Modification of Talas Beneng Starch (Xanthosoma Undipes K. Koch) with Oktenil Suksinat Anhydrous (OSA) and its application in mayonnaise produced the following conclusions:

1. The best OSA starch results from chemical and functional properties test are found at concentrations of 3% and pH 8.5 which have DS 0.0270; amylose content of 20.35%; starch digestibility 187.39%; emulsion capacity 34.58%; development power 7.2117 at 90°C and solubility 76.50% at 90°C.
2. The best characteristics of OSA starch have granule sizes of 1,344 µm – 4,695 µm with porous and rough polygonal shape, have a crystalline structure of pattern A, ΔH 132 (J/g) at a peak temperature of 96.38°C, and a peak viscosity of 4171 cP at a final temperature of 79.90°C.
3. Mayonnaise is best found in the treatment of 1% OSA starch and 4% egg yolk with a pH value of 3.1; fat content of 37.57%; emulsion stability of 64.69%; emulsion viscosity of 44625 cP; and color brightness of 94,325.

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