Effect of modified starch on quality of 'Korat' noodle

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Ms. NapadaChewcharn

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A special project submitted to school of Biotechnology, Assumption University

In part of fulfillment of the requirements of the Degree of Bachelor of Science,

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Level of study: Bachelor of Science

Department : Food Technology

Faculty : Biotechnology

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Committee

____________________________**Advisor**

(Dr. Tatsawan Tipvarakarnkoon)

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Napada Chewcharn

Abstract

This research was aimed to study the effect of modified starch on Korat noodle. three different types of modified tapioca starch at the concentrations of 5%,10% and 15% w/w modified tapioca starch added to dried milling Chainat rice flour. There were acetylated starch (AC), succinate anhydride starch and octenyl succinic anhydride starch (OSA). Physicochemical properties of rice flour and modified starch have been studied. Pasting properties (RVA), moisture content, ash content, Amylose content, swelling power, and starch granule morphology were determined. The preliminary tests on Korat noodle were conducted. Effect of different ratio of flour : water on quality of noodle, sensory evaluation and appropriate amount of slurry for noodle production were evaluated. The addition of modified starch to the rice flour mill increased peak viscosity, final viscosity, setback and breakdown of the mixture. OSA gave highest peak viscosity of the mixed flour, followed by SA and AC, accordingly. Increased more concentration of modified starch also increased more all pasting properties except pasting temperatures which were slightly decreasing at higher concentrations. Amylose content of Chainat rice flour used in this study was 26.20%. The swelling power was 6.51 which was higher than AC and SA starch, but lower than OSA starch.

The effect of modified starch on quality of Korat noodle was studied. Cooked loss, rehydration ratio, color, %yield, thickness, sensory analysis, and texture analyzer were determined. From cooked loss properties of mixed rice flour with modified starch, they showed lower amount of loss of particle during cooking. While adding 15%OSA showed lowest cooked loss value. The addition of modified starch decreased thickness of cooked and dried noodle. This would cause by smaller size of particle (>100 mesh) of modified starch than used rice flour (80 mesh). Texture analysis showed the results that the addition of modified starch significantly increased elasticity of the noodle. OSA addition increased highest elasticity among all samples by showing longest strengthening distance while tensile. Sensory evaluation showed that higher concentrations of modified starch added to the noodle, higher liking score in preference. 15% OSA gave highest preference score of texture attributes and overall liking ($p \geq 0.05$). In summary, modified starch has effect on quality of noodle especially improve texture of the developed Korat noodle.

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Introduction

Korat noodle is made by rice flour. It's different from the other types of noodle by providing more chewiness than regular noodles. It originally made from broken Chainat 1 by Korat former. Korat noodle is the identity of Korat or Nakhon Ratchasima province as it's originally produces in this region. Moreover, the dish, fried Korat noodle, tastes different from the regular noodle dishes. Fried korat noodle is daily lunch meal of Korat people because it's easy to make and the ingredients, seasoning are easy to find. Fried Korat noodle is popular currently throughput Thailand and some Asian country.

Korat noodle is not available only in Nakhon Ratchasima province but it also available in other province's convenience store. However, there is a few of research about Korat noodle. Moreover, it has been sole as an instant noodles form predominantly. As lifestyles continue to change, convenient and ready-to-eat food products will become more popular.

In order to be ready to eat fried Korat noodle, it must be freeze and serve as frozen ready to eat meal. Freezing process contributes brittle, more opaque noodle which are undesirable characteristics of Korat noodle. Freezing of starch enhances retrogradation that can cause stiff noodle by leading to ice crystals formation (CHATAKANONDA, 2001) Moreover, freezing process causes carbohydrate chain rearrangement to amylopectin which form brittle gel forming (Organic potato starch, 2014).

The addition of optimum modified starch would stabilize starch from synerasis and maintain elasticity of frozen rice noodle product. As shown in some research on rice noodle, hydroxypropyl group in modified starch prevent retrogradation of starch chain in noodle which can prevent stiffness of rice noodle. (Kamonwan A, 2005)

This research was to investigate the effect of modified starch with 3 different concentrations on quality Korat noodles.

Objectives

1. To determine the physicochemical properties of rice flour and modified starch
2. To preliminary test on 'Korat' noodle production
3. To study the effect of modified starch on quality of Korat noodle

Literature reviews

Rice is a staple food for Thai people for long time until now. Rice (*Oryza sativa L.*) is a member of the family Poaceae (Gramineae or grass). Rice grain consists of hull (21%), rice bran (8%), embryo (1%) and endosperm (70%).

In most common types of cereal endosperm starches, the relative weight percentages of amylose and amylopectin range between 72 -82% amylopectin, and 18- 33% amylose(Chongsrimsirisakhol, 2012) However, the Korat noodle is commonly made from Chinat rice. The chemical composition of Chainat rice is showed in Table 1

Table1: Chemical composition and amylose content of starch from Chainat rice grown in Thailand

Rice varieties	Moisture (%)	Protein(%)	Fat(%)	Ash(%)	Amylose(%)
Chainat rice	12.6 ±0.7	0.43±0.03	0.09±0.02	0.26±0.01[a]	26.9±1.0[a]

[a]means (±standard deviation of five replicates) followed by the same letter in the same column are not significantly different at $P \leq 0.05$. (Hauisan K. et al., 2009)

Amylose is linear molecule of D-glucopyranosyl units link with (1→4), but it also known that some molecules were slightly branch by (1→6)-α-linkages. Branches are usually placed near the reducing. The conformation is helix which there is six residues per turn of helix.

Amylopectin is branch chain component of starch. It is α-D-glucopyranosyl residues linked together mainly by (1→4) linkages and linked with (1→6) bonds at the branch points. The amylopectin conformation was explained by A, B and C chains. Thus, the outer chains (A) were glycosidically linked at their reducing group at C6 of a glucose residue to an inner chain (B) as branches. The single C chain was major chains that contained reducing end. The ratio of A-chains to B-chains referred to degree of multiple branching which is an important parameter. The A-chains than B-chains with ratios ranging from 1.0:0 to 1.5:1 referred to largest molecular weights (107–109), usually 108. Amylopectin involve in the crystalline regions in the starch granule. The lamellae were represent the crystalline (side-chain clusters) and the amorphous regions (branching regions) of the amylopectin molecule. Amylopectin was built with three types of chains: first, short chains(S); consisting of both outer chain A or inner chain B with a mean polymerization degree (DP) around 14-18, secondly inner chain B long chains (L) of DP 45–55, and thirdly a few B-chains of DP above 60. The length is measured by high-performance anion-exchange chromatography with pulsed amperometric detection. The differences related to the botanical species which concerned with the L: S ratio expressed on a molar basis. The normal genotype of cereal usually has 8-10 ratios from A-crystalline type granules. The chains were differentiated into four kinds by DP ranging in the intervals 6–12, 13–24, 25–36 and more than 37. Amylopectin with high and low amounts of the DP 6–12 fraction respectively, show A- and B-type X-ray diffractions of starch granules respectively. These S-chains with DP between 6 and 12 determined the starch crystalline allomorph. The DP 6–12 fraction should play an important role in the determination of starch crystallite polymorphs.

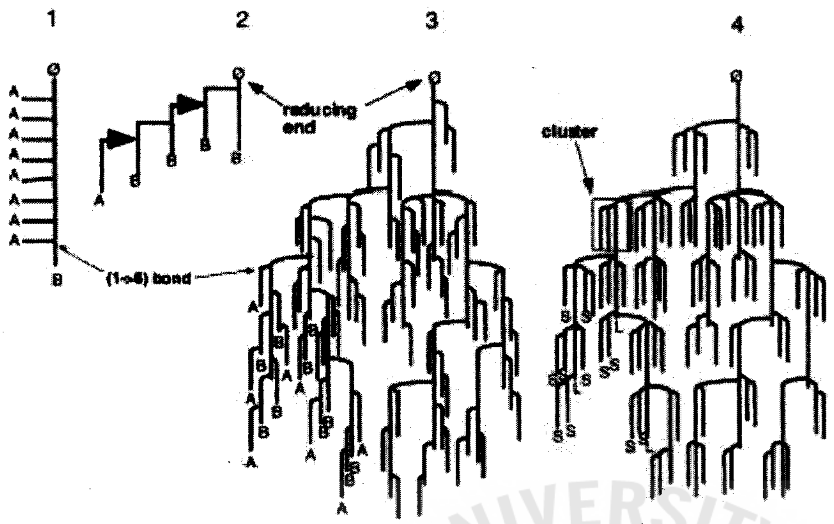

Figure 1: The structure of amylopectin.

Physicochemical properties of starch

- **Swelling power and solubility**

Native starch granules are insoluble in cold water but swell in warm water. The hydrogen bonds are broken and link with water. The swollen granules disperse in suspension which is reversible until the heating temperature reach gelatinization temperature which is irreversible. The cooked product is called a starch paste. Starch paste can be classified in two phases; dispersed phase of swollen granules (swelling power) and a continuous phase when amylase leach out from starch granule(solubility). Swelling power and solubility showed interaction between starch chains within the amorphous and crystalline regions. The interaction is influenced by amylose content, amylose and amylopectin structure, and other factors.

- **Gelatinization**

Gelatinization occurs when starch granules are heated in the presence of water. The starch granules can absorb water (starch swelling). Amylose and low molecular weight amylopectin leach out from the granules at temperature below the gelatinization temperature is at amorphous regions and it is small molecule. The order of the molecular in the starch granule is change due to the situation such as granular swelling, crystallite melting, loss of birefringence, viscosity development, and solubility property. Gelatinization, an energy absorbing process can be measured by differential scanning calorimetry (DSC), which measured both the temperature and the enthalpy of gelatinization. It showed in term of thermal curves generated by the calorimeter. It explain rice starch gelatinization by three temperature; onset (T_o), peak (T_p), and conclusion (T_c) and by the gelatinization enthalpy (ΔH) as J/g, calculated by area under the curve

- **Retrogradation**

The retrogradation is process that occurs when starch molecules recombine and form more order structure which increase viscosity after cooling starch paste. There are 2 stages of starch retrogeradation. First, stage which is fastest stage, the formation of crystalline regions of amylose. The second stage is formation shorter double helices structure of amylopectin from restriction of branch, lengths of the branches. That results in viscosity increase, gel firming, and textural staling. Most of the crystallites formed during starch retrogradation are related to the recombination of amylopectin chains because the amount of amylopectin is more than amylase in most starch. Thus, amylopectin retrogradation occurs at several weeks of storage and contributes to the long term rheological and structural changes of starch systems. The retrogradation properties can be measured by DSC and starch gel hardness.

Chainat 1 Rice

Characters

- Rice tall 113 cm
- Light insensitive
- Harvest duration 121-130 days
- Paddy size: 10.4 x 2.3 x 1.7 mm
- Rice grain size:7.7 x 2.1 x 1.7 mm
- Amylose 26-27%
- Cooked rice is hard and loosely

Production: 221 kg/Acres

Dominant feature

- high production
- good with Nitrogen fertilization
- Ragged Stunt Disease resistance
- Blast Disease resistance
- Plant hopper resistance

Weak feature

- No yellow orange leaf disease resistance
- No Bacterial Leaf Blight Disease resistance

Rice noodle

Rice noodle is a popular rice product in Thailand. Rice noodle was prepared from milled rice or milled rice flour cook to thin rice sheet by steamer and cut to a strip.

Rice noodle processing

1. Preparing rice slurry

Concentration of rice slurry showed positive correlation with noodle quality. The rice flour concentration depends on the type of milled rice flour. The concentration of wet milled flour for prepared rice noodle usually between 38-40% (w/w), dry milled flour was prepared with lower flour portion(Chongsrimsirisakhol O, 2012) Since Korat noodle is only made from the Chainat rice, the pasting properties of Chainat rice is in the Table2

Table 2: pasting properties of laboratory isolated starch from Chainat rice grown in Thailand

Rice varieties	Peak viscosity (RVU)	Trough 1 (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Set back (RVU)	Pasting temperature (°C)
Chainat starch	279.9 ± 15.2[a]	143.4 ± 2.1	136.6 ± 16.8	298.8 ± 15.1	18.9 ± 30.1	79.1 ± 0.9

[a]Means (± standard deviations of three replicates) followed by the same letter in the same column are not significantly different at $P \leq 0.05$. RVU = rapid visco units. Pr > F= P value of the F test (Hauisan K. et al., 2009)

2. Steaming

The rice slurry was cooked with steam. Heat from the steam will make the starch granule changes into a rice sheet gel.

3. Aging

The aging process was used to make the moisture spread on the sheet of rice gel. The rice gel sheet will become stronger by retrogradation after cool system.

4. Cutting

The rice sheet is cut strips to size.

Freezing rice noodle

1. Freezing process

The basic principle of freezing process is reducing the temperature then prevents the microorganism and chemical reaction of food product. In general, freezing process use -18°C or lower to change the state of water in food into ice crystal. The freezing process is dividing into three periods. The first phase is pre-freezing. The temperature of food is reduced until the water turns to crystalline ice. The second phase is frozen and the last phase is reduction the temperature to storage, the temperature should not change throughout the system by the heat.

Frozen food structure was changed by first is nucleation phase, second is crystal growth phase. The important factor that affects the size of ice crystal is temperature fluctuate. If the rate is high the crystal will be small. However if the rates of heating out is low the ice crystal will be large and change food quality.

2. Freeze-thaw

The starch gel after freeze-thaw was changed to stiff structure and syneresis by retrogradation process. (Chongsrimsirisakhol O, 2012)

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Freezing of starch products can cause retrogradation as it leads to the formation of ice crystals and thus the starch is concentrated in a non-ice phase. As a result, retrogradation is often enhanced when starch gels are subjected to freezing and thawing treatments.

Freezing and thawing temperatures are important in determining the stability of starch gels. Freezing at –40 °C(retrogradation is slightly slower) and thawing at 90 °C(amylopectin enthalpies is not increase as its thawing temperature exceeded the melting temperature of amylopectin.) can provide high stability of rice starch noodles in terms of reduced retrogradation.

Method of making Korat noodle from the original

1. Clean the rice, use the old rice to get rid of all the resin
2. Grind rice into starch liquid
3. Add minor ingredient the salt and additives
4. Pour mixture into thin plate
5. Run it into steam oven, the noodle sheet achieved
6. heat to dry the excess moisture out
7. paint vegetable oil on the noodle sheet

8. sliced into the desirable size

Municipal N. 2005

Recipe of Pad-mhee Korat (Korat fried noodle)

<u>Ingredient</u>

1. dried Korad noodle	1 cup
2. grinded garlic	1 teaspoon
3. Chopped shallot	1 teaspoon
4. chopped meat	2 table spoons
5. fermented soy bean sauce	1 table spoon
6. fish sauce	2 table spoons
7. sugar	2 table spoons
8. ripe tamarind juice	1 teaspoon
9. sweet soy sauce	1 teaspoon
10. pepper	1 teaspoon
11. water	3 table spoons
12. bean sprout and shallot leaves	1 cup
13. grinded peanut	1 table spoon
14. grinded chili	1 teaspoon

<u>Recipe</u>

1. put oil on the pan
2. add garlic, shallot, and meat. Fried them together
3. add drid Korad noodle, fish sauce, sweet soy sauce, ripe tamarind juice, fermented soy bean sauce, and water. Fried it together until get the soft noodle
4. add bean sprout and shallot leaves. Fried it together
5. serve with pepper, grinded peanut, grinded chili

Recipe of Pad-mhee Korat is not uniform since it is inherited from family to family and the recipe is adjusted by the preference of each person. (nlovecooking, 2012)

Modified Starch

Native rice flour has poor ability to resist to shear force and low elastic gel forming ability (Pitiphunpong and Suwannaporn, 2009). Modified starch could improve rice noodle quality and starch functionalities (Yu G. 2013; Hitishi K. 2014)

Modified starch is the native Starch that is changed the properties. Physical or chemical agent changes of the starch properties causes the molecule structure change. There are several methods to change molecule structure. The methods could be classified mainly as follows:

1. Chemical modified starches
2. Physical modified starch
3. Biological modified starch; starch with molecule structure change within the starch and/or external structure change with biological method

1. Starch changed molecule structure by chemical agent (Chemicals modified starches)

Group 1: Derivertization

Chemical attaches some group in the starch molecule in form of single molecule or more, causing the starch molecule to be larger i.e.

1.1) Etherification reaction type
- 1.1.1) Hydroxyethylated Starches
- 1.1.2) Hydroxypropylated Starches
- 1.1.3) Cyanoethyl starch

1.2) Carboxymethyl starch or negative starch

1.3) Carbonic Starches or positive starch
- 1.3.1) Tertiary aminoalkyl starch ether
- 1.3.2) Quaternary ammonium starch ether

1.4) Esterification reaction type
- 1.4.1) Starch acetate
- 1.4.2) Succinate and Substitues Succinated Starches
- 1.4.3) Starch phosphate monoester

1.5) Cross linking type reaction
- 1.5.1) Di-starch adipate
- 1.5.2) Di-starch phosphate
- 1.5.3) Di-starch glyceral

Group 2): Converted starch

The starch molecules are cut between glucose unit or breaking the glucose unit i.e.

2.1) Acid Conversion or Acid Modified Starch
2.2) Oxidized Hypochlorite - Modified Starch
2.3) Pyroconversion or Pyrodextrins
2.4) Enzyme conversion starch

From the principle and technology on structural change of the molecule of starch in main groups, it could be classified base on its function

Group 3): Combination Starches

3.1) Hydroxypropylated with Cross-Linked Starches
3.2) Hydroxypropylated with Oxidized Starches
3.3) Cross-Linked with Oxidized Starches
3.4) Acid Converted with Hydroxypropylated Starches
3.5) Oxidized with Acetylated Starches

2. Molecule changed structure by physical mean (Physicals modified starch)

It causes change without using chemical but uses the heat and/or dynamic energy. The starch of this group includes:

2.1) Pregelatinized starch
2.2) Granular cold water soluble starch
2.3) Annealing starch
2.4) Heat treatment starch
2.5) Mechanical milling starch

3. Molecule changed structure by biological mean (Biological modified starch)

The products from biological technology i.e. High amylase starch and Waxy starch (High Amylopectin ie Waxy corn). Change of the proportion of amylase and amylopectin shall change the properties of the starch (TTSA, 2011)

From the information above, the modified starch that suitable to added into frozen noodle are acetylated starches because of its properties on the frozen starch product.

Type of study modified starch

3 types of Modified starches are used to improve Korat noodle, Succinic Anhydride (SA), Octenyl Succinic Acid (OSA) and Acetylated (AC), with 3 concentrations, 5%, 10% and 15%. Modification does not alter the appearance of the starch but can improve the desired properties of the starch. The purposes of this modification are to enhance its properties particularly in specific applications such as to improve the increase in water holding capacity, heat resistant behavior, reinforce its binding, minimized syneresis of starch and improved thickening (Adzahan, 2002; Miyazaki et al., 2006).

1. Succinic Anhydride (SA)

Succinic anhydride, also called dihydro-2,5-furandione, is an organic compound with the molecular formula $C_4H_4O_3$. This colorless solid is the acid anhydride of succinic acid. Manufacture processing, hydrogenation of maleic anhydride or fumaric acid; heating of succinic acid at elevated temperature and pressure, by treating succinic acid with diketene, succinyl chloride or acetic anhydride, or by reacting diethyl ester with boron chloride. (Succinic anhydride, 2015)

2. Octenyl Succinic Anhydride (OSA)

A common modification of starch is esterfication with anhydrous octenyl succinic acid (OSA). The properties of the OSA starch make it interesting for used in egg yolk protein stabilized food emulsions, such as mayonnaise. The interactions between different components in a product have a great impact on factors such as texture and stability (De Kruif and Turnier, 2001). OSA can increase viscosity and decrease gelatinization temperature (Bao *et al*, 2003). OSA starch may give heat- (He *et al*, 2008) and freeze-thaw stability (Song *et al*, 2006), and may also be used as a partial replacement for fat, as it may give a sense of fattiness (BeMiller and Whistler, 1997).

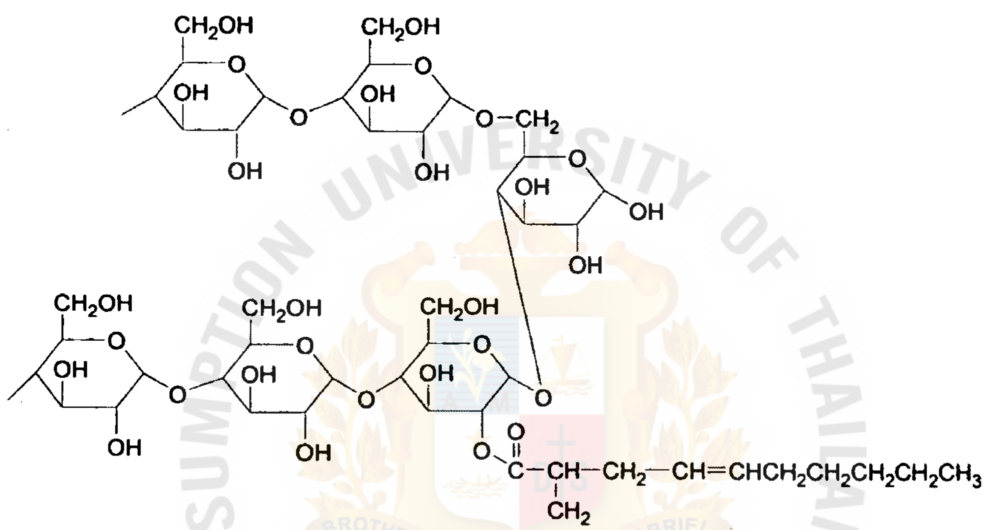


Figure2: Structure of Octenyl succinic anhydride

3. Acetylated starch (AC)

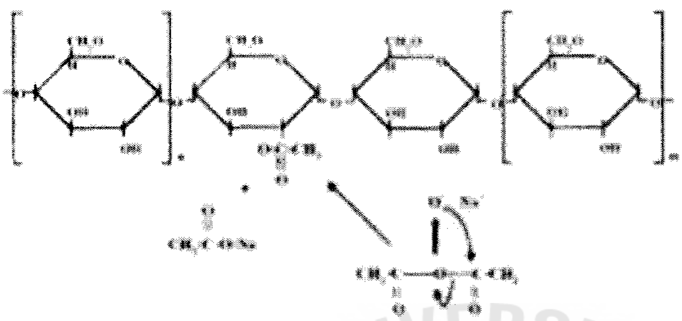
Acetylated starches are chemical modification; esterification with acetic acid, acetic anhydride, ketene, vinyl acetate, or a combination of these reagents. Acetylation replaces hydroxyl groups in the native starch with acetyl groups. According to Rutenberg and Solarek (1984), introduction of these acetyl groups reduces the bond strength between starch molecules and thereby alters the properties. Normally, the resultant acetylated starch will possess good stability at low temperatures and prevent syneresis. (Aning A. et al, 2012)

Acetylated starches

Starch Acetate

Reaction

Substituted with Acetyl in starch



Properties

Reduced on temperature increase, more viscosity, reduced reversion rate, not causing pressing of water outside gel (Syneresis)

Figure3: Reaction of substituted with Acetyl in starch of starch acetate

Materials and Methods

Materials

1. Chainat rice flour (purchased from different sources)
2. Acetylated starch (AC) (Siam modified starch Co., Ltd., Thailand)
3. Succinic anhydride(SA) (Siam modified starch Co., Ltd., Thailand)
4. Octanyl succinic anhydride (OSA) (Siam modified starch Co., Ltd., Thailand)
5. Distilled water
6. Water
7. NaOH 1 N
8. 95% alcohol
9. Acetic acid
10. Iodine
11. Rice bran oil

Equipments

1. Noodle production equipment (see Appendix B-1)
2. Atlas Marcato Pasta Maker Machine Model 150
3. Balance
4. Brush
5. Rapid Visco Analyser (Brabender RVA)
6. Moisture can
7. Desiccator
8. Porcelain dish
9. Furnace
10. Microscope
11. HunterLab CIE L*a*b* system (model Miniscan EZ, Hunter associates Laboratory, Inc.) in coorperates with EasyMatch QC software
12. Texture analyzer model TA.XTPlus (Texture Technologies Corp and by Stable Micro System)

Methods

1. **The study of physicochemical properties of rice flour and modified starch.**

1.1. Preparation of rice flour

Milled rice flour was sieve by standard sieve. The 80 mesh flour was collected into ziplock bag for further used.

1.2. Physicochemical properties

1.2.1. Moisture content determination

Empty alumium can and the lid were dried in the oven at 105°C for 3 hours and cooled down in desiccator for 1 hour to cool. The dried alumium can and lid then weighed. Known weight of sample (approximately 3 grams of sample) was weighed and put in alumium can then dry in oven for 3 hours at 105°C. After drying, the alumium can with partially covered lid was transferred to the desiccators for 1 hour to cool down. Then the dish was reweighed again. All samples were done in duplicate. To measure the moisture (%) as the formula:

$$\%\text{Moisture content} = \frac{(Wt. of\ flour\ before\ drying - Wt. of\ flour\ after\ drying)}{Wt. of\ flour\ before\ drying}\ x\ 100$$

1.2.2. ash content determination

Porcelain crucible was heated at 525 ± 25 °C for 1.5 hour then cooled down in desiccator 30 minutes. Crucible was weighted. Flour sample was weighted 5-10 grams(W1) and put into crucible. Porcelain crucible was burnt with Bunsen burner until no smoke obtained. Then further heat at 525 ± 25 °C for 2.5 hour then cooled down in desiccator 30 minutes. Crucible was weighted as ash residue. All samples were done in duplicate.

1.2.3. Amylose content determination

0.0400 gram of sample was weighed to the 100ml volumetric flask. 9ml NaOH 1N and 1ml 95% alcohol were added and shake gently and cover the volumetric flask with aluminum foil. Sample was kept overnight. Sample was diluted until 100ml with distilled water and take 5ml sample into 100ml volumetric flask. 70ml distilled water, 1ml acetic acid 1N, 2ml iodine were added and shake gently. Sample was kept 20 minutes before measuring the absorbance. Turn on the absorbance machine, and allow 15 minutes warm up. Then, set the wave length (620nm) and put the sample into the cuvette to measure the absorbance. All samples were done in duplicate.

1.3. Light microscopic method

Small drop of distilled water solution was dropped into glass slide, and put small amount of flour sample was dispersed into solution and add one drops of iodine. A cover slide is then placed in top the solution to observe the flour granule under the microscope with 40x objective lens and a micrometer eye piece (Dino Capture version 2.0). Some picture (10 pictures each sample) were taken using Dino Capture Software, approximately 10 granules were selected randomly. These step were repeated with iodine. Sample was done in duplicate.

1.4. Swelling power determination

An empty aluminum can and the lid were dried in the oven at 105°C for 3 hours and transferred to the desiccator for 15 minutes to cool. The dried aluminum can and lid then weighed. Centrifuge tubes were weighted. 0.5 grams of sample (4 digits) was weighed to centrifuge tube, add 15 ml distilled water and heat in water bath at 80°C for 30 minutes. Centrifuge tube was cooled down for 15 minutes then centrifuged at 4000 rpm for 20 minutes. Supernatant was collected in aluminum can and dried in the oven for 3 hours at 105°C, and for the sediment in the centrifuged tube was weighed. After drying, the aluminum can with partially covered lid was transferred to the desiccators for 15 minutes to cool. Then the dish was reweighed again. All samples were done in duplicate. To measure the swelling power (%) we use the formula

$$\text{Swelling Power (\%)} = \frac{\text{weight of sediment}}{\text{weight of flour} - \text{weight of dried solids in supernatant}} \times 100$$

1.5. Color measurement

The color measurement was done with HunterLab CIE L*a*b* system (model Miniscan EZ, Hunter associates Laboratory, Inc.) in coorperates with EasyMatch QC software. D65/10was used as standard light source and angle of observer throughout the measurement. 25 grams of samples were poured onto the plastic petri dish and tested for at least 5 spots of sample petri dish (middle, top, left, bottom, right). All samples were done in duplicate. L*a*b* values were recorded as the interpretation of L* (lightness;0 = dark to 100 = bright), a* (+ = red to - = green) and b* (+ = yellow to - = blue).

1.6. Pasting properties of rice flour and modified starch

3 grams of rice flour sample (dry weight) was mixed 25 grams of distilled water in canister. The measurement was done under the standard profile method of RVA. All samples were done in duplicate

Table3: Profile of RVA condition

Time	Type	Value
00:00:00	Temp	50 °C
00:00:00	Speed	960 rpm
00:00:10	Temp	160 rpm
00:01:00	Temp	50 °C
00:04:42	Temp	95 °C
00:07:12	Temp	95 °C
00:11:00	Temp	50 °C
00:13:00	End	
Idle Temperature: 50 ± 1°C Time between Readings: 4 s		

2. **The study preliminary test on 'Korat' noodle production.**

2.1. The preliminary test of different ratio on quality of Korat noodle

Rice flour was weighed and mixed with water at different ratio flour : water (36:64, 38:62, 40:60). Flour was soaked in water for 3 hours by stirring for 1 minute in every 15 minutes. After 3 hours, 40 grams slurry was poured in beaker. Frame was placed cloth. Slurry was poured in frame. Paddle was used to equalize the thickness. The cloth was placed on the pot filled with boiling water. Cover the cloth with lid. Slurry was steamed for 3 minutes. After 3 minutes, noodle was removed and put on PP plastic. Brush with rice bran oil 1/3 teaspoon on both sides. Let noodle expose to the air for 15 minutes at room temperature.

Then age the noodle at 10°C overnight. Noodle was cut into 0.6 cm strip. The strips were dried at 45°C until completely dried. Samples were kept in ziplock bag in dried condition. Sensory evaluation was determined.

Noodle was boiled in 500 ml for 8 minutes. Samples were soaked in room temperature for 1 minute. Then it was left to dry on tray for 15 minutes. Noodle was arranged in 3 digit code randomly. Sample was served with drinking water. 30 panelists were asked to evaluate the samples with 9 points hedonic scale test in accordance with given questionnaire (See Appendix B-2)

80 mesh rice flour +water

36:64 ← 38:62 → 40:60

↓

soak 3 hrs (stir 1 min every 15 mins)

↓

pour in beaker 40 g

↓

pour on cloth

↓

steam it with boiling water for 3 min

↓

remove noodle then press on PP plastic

↓

brush with rice bran oil 1/3 teaspoon on both sides

↓

expose to the air for 15 mins at room temperature

↓

Aging at 10 C, overnight

↓

cut into 0.5 cm slices

↓

Air dry 45 C, until dry

Figure4: Process of noodle production to study different ratio on quality of Korat noodle

2.2. Sensory evaluation of Korat noodle

Method of sensory evaluation was the same as the method 2.1. the preliminary test of different ratio on quality of Korat noodle. 30 panelists were asked to evaluate the samples with 9 points hedonic scale test in accordance with given questionnaire (See Appendix B-2)

2.3. The study of appropriate amount of slurry

The different amount (40 g and 50 g) of rice slurry has been used to produce rice sheet. 50 grams flour is mixed with 75 ml water to be 40% slurry. It was soaked for 3 hours by stir 1 minute in every 15 minutes. After 3 hours, 40 grams slurry and 50 grams were poured in beaker. Frame was placed cloth. Slurry was poured in frame. Paddle was used to equalize the thickness. The cloth was placed on the pot filled with boiling water. Cover the cloth with lid. Slurry was steamed for 3 minutes. After 3 minutes, noodle was removed and put on PP plastic. Brush with rice bran oil 1/3 teaspoon on both sides. Let noodle expose to the air for 15 minutes at room temperature. Then age the noodle at 10℃ overnight. Noodle was cut into 0.6 cm strip. The strips were dried at 45℃ until completely dry. Aged noodle and noodle were taken photo. Sensory evaluation was determined. Method of sensory evaluation was the same as the method 2.1. the preliminary test of different ratio on quality of Korat noodle. 30 panelists were asked to evaluate the samples with 9 points hedonic scale test in accordance with given questionnaire (See Appendix B-2)

80 mesh rice flour +water
↓
soak 3 hrs (stir 1 min every 15 mins)
↓
pour in beaker 40 g ← → pour in beaker 40 g
↓
pour on cloth
↓
steam it with boiling water for 3 min
↓
remove noodle then press on PP plastic
↓
brush with rice bran oil 1/3 teaspoon on both sides
↓
expose to the air for 15 mins at room temperature
↓
Aging at 10 C, overnight
↓
cut into 0.5 cm slices
↓
Air dry 45 C, until dry

Figure5: Process of noodle production to study appropriate amount of slurry

3. **The study of effect of modified starch on quality of 'Korat' noodle.**

3.1. The Production of modified starch added Korat noodle

Modified starch was added to rice slurry for 5%, 10% and 15%. Modified starch replaced amount of rice flour in slurry. Modified starch was weighed and poured in beaker containing rice flour. Flour and modified starch was stirred clockwise to mix For 1 minute. Water was added into container. For no modified starch added treatment, 50 grams rice flour is mixed with 75 ml water. For 5% modified starch added treatment, 2.5 grams modified starch 47.5 grams rice flour is mixed with 75 ml water. For 10% modified starch added treatment, 5 grams modified starch 45 grams rice flour is mixed with 75 ml water. For 15% modified starch added treatment, 7.5 grams modified starch 42.5 grams rice flour is mixed with 75 ml water. Slurry was soaked for 3 hours by stir 1 minute in every 15 minutes. After 3 hours, 40 grams slurry was poured in beaker. Frame was placed cloth. Slurry was poured in frame. Paddle was used to equalize the thickness. The cloth was placed on the pot filled with boiling water. Cover the cloth with lid. Slurry was steamed for 3 minutes. After 3 minutes, noodle was removed and put on PP plastic. Brush with rice bran oil 1/3 teaspoon on both sides. Let noodle expose to the air for 15 minutes at room temperature. Then age the noodle at $10^{\circ}C$ overnight. Noodle was cut into 0.6 cm strip. The strips were dried at $45^{\circ}C$ until completely dry. Cook loss properties, rehydration ratio properties, color, percentage of yield, thickness of noodle, sensory evaluation, texture analysis have been determined.

flour + modified starch

↓

stir clockwise for 1 min

↓

add water

↓

soak 3 hrs (stir 1 min every 15 mins)

↓

pour in beaker 40 g

↓

pour on cloth

↓

steam it with boiling water for 3 min

↓

remove noodle then press on PP plastic

↓

brush with rice bran oil 1/3 teaspoon on both sides

↓

expose to the air for 15 mins at room temperature

↓

Aging at 10 C, 2 hrs

↓

cut into 0.5 cm slices

↓

Air dry 45 C, overnight

Figure6: Modified starch added noodle production

3.2. The study of cook loss properties

5 grams of samples was weighed. Noodle was boiled in 500 ml. Noodle sample with addition of 15% modified starch was boiled for 6 minutes, with that of 10% modified starch added noodle was boil for 7 minutes and with that of 5% modified starch added noodle and no modified starch added noodle were boiled for 8 minutes. Rinse cooked noodle with 50 ml distilled water. Cooking water and rinsing water was collected in beaker. Dried out the water at $105^{\circ}C$ until dry. The residue was weighed. The %cook loss was calculated as the formula. All samples were done in duplicate.

$$cooking\ loss\ (\%) \frac{weight\ of\ drined\ residue\ in\ cooking\ water\ (g)}{weight\ of\ noodles\ before\ cooking\ (g)} x\ 100$$

3.3. The study rehydration ratio properties

High rehydration ratio tends to make noodles sticky whereas low rehydration ratio can render the noodle to be hard with unrefined texture (Collado et al. 2001; Yoenyong-buddhagal & Noomhorm 2002). 5 grams of samples was weighed. Noodle was boiled in 500 ml. Noodle sample with addition of 15% modified starch was boiled for 6 minutes, with that of 10% modified starch added noodle was boil for 7 minutes and with that of 5% modified starch added noodle and no modified starch added noodle were boiled for 8 minutes. Rinse cooked noodle with 50 ml distilled water. Samples were soaked in Room temperature for 1 minute. Then it was left to dry on tray for 15 minutes. The cooked noodle was weighed. The rehydration ratio was calculated as shown in the formula below (Cham, 2010). All samples were done in duplicate.

$$\text{Rehydration ratio} = \frac{dried\ noodle - cooked\ noodle}{dried\ noodle}\ x\ 100$$

3.4. The study of percentage of yield determination and thickness measurement

Fresh noodle was weighed then dried in 105°C until completely dry. Dried noodle was weighed. Percentage of yield was calculated by the formula.

$$\%yield = \frac{fresh\ noodle}{dried\ noodle} x100$$

Thickness measurement, fresh noodle and dried noodle were measured by using screw gauge micrometer. Samples of random duplication of both replications were selected. Top edge, middle and bottom edge of noodle strip from the center of noodle sheet were measured.

3.5. Color measurement

3.5.1. Fresh noodle

The color measurement was done with HunterLab CIE L*a*b* system (model Miniscan EZ, Hunter associates Laboratory, Inc.) in coorperates with EasyMatch QC software. D65/10was used as standard light source and angle of observer throughout the measurement. 10 grams fresh noodle was rearranged on petri dish and tested for at least 5 spots of sample petri dish (middle, top, left, bottom, right). All samples were done in duplicate. L*a*b* values were recorded as the interpretation of L* (lightness;0 = dark to 100 = bright), a* (+ = red to - = green) and b* (+ = yellow to - = blue).

3.5.2. Dried noodle

The color measurement was done with HunterLab CIE L*a*b* system (model Miniscan EZ, Hunter associates Laboratory, Inc.) in coorperates with EasyMatch QC software. D65/10was used as standard light source and angle of observer throughout the measurement. 10 grams dried noodle was grinded and poured petri dish and tested for at least 5 spots of sample petri dish (middle, top, left, bottom, right). All samples were done in duplicate. L*a*b* values were recorded as the interpretation of L* (lightness;0 = dark to 100 = bright), a* (+ = red to - = green) and b* (+ = yellow to - = blue).

3.6. Texture analysis

7 strips of noodle were selected randomly from the whole noodle sheet. Noodle strips were boiled in 500 ml. Noodle sample with addition of 15% modified starch was boiled for 6 minutes, with that of 10% modified starch added noodle was boil for 7 minutes and with that of 5% modified starch added noodle and no modified starch added noodle were boiled for 8 minutes. Samples were soaked in Room temperature for 1 minute. Then it was left to dry on tray for 15 minutes. The test was conducted using Texture analyzer model TA.XTPlus (Texture Technologies Corp and by Stable Micro System) with Comparison of elasticity (or 'tensile strength') of noodles test methods & analysis in Pasta & rice categories.

Table 4: Texture analysis condition of Korat noodle

Item	**Data**
Load cell (kg)	5 kg
probe name	A/spr
Test mode	Tension
Pre-test speed	3 mm/s
test speed	3 mm/s
Post-test speed	5 mm/s
Target Mode	Distance 50 mm
Trigger force	Auto force 5 g
Data acquisition Rate	200 pps
Measurement condition	Test must be conducted within 5 minutes/ sample Room temperature
Sample Preparation	7 strips of noodle were selected randomly from the whole noodle sheet. Noodle was boiled in 500 ml. Noodle sample with addition of 15% modified starch was boiled for 6 minutes, with that of 10% modified starch added noodle was boil for 7 minutes and with that of 5% modified starch added noodle and no modified starch added noodle were boiled for 8 minutes. Samples were soaked in Room temperature for 1 minute. Then it was left to dry on tray for 15 minutes.

3.7. Sensory evaluation

Noodle was boiled in boiling water. Noodle sample with addition of 15% modified starch was boiled for 6 minutes, with that of 10% modified starch added noodle was boil for 7 minutes and with that of 5% modified starch added noodle and no modified starch added noodle were boiled for 8 minutes. Samples were soaked in Room temperature for 1 minute. Then it was left to dry on tray for 15 minutes. Noodle was arranged in 3 digit code randomly. Sample was served with drinking water. 30 panelists were asked to evaluate the samples with 9 points hedonic scale test in accordance with given questionnaire (See Appendix B-2)

Result and Discussion

1. The study of physicochemical properties of rice flour and modified starch.

1.1. Physicochemical properties

1.1.2 moisture content and ash content

From table 5: moisture content result, AC, SA and OSA modified starch had no significant different among themselves but significant higher moisture content than native rice flour ($p \geq 0.05$). Modified starch was processed with water in starch modification then dried out moisture later. While rice flour was controlled moisture content to less than 13% since harvest and further dry milling. Thus rice flour would have low moisture content. For ash content result, AC, SA and OSA modified starch had no significant different among themselves but significant higher ash content than native rice flour. Ash content indicated mineral in sample. The result showed that modified starch contained significantly higher ash content than rice flour. It indicated that modified starch had mineral than rice flour ($p \leq 0.05$) The functional group of modified starch; acetyl group in AC, succinic anhydride in SA and octenyl succinic anhydride in OSA represented as mineral in starch. While rice flour had ash content concentrated in bran. Thus the high ash indicated bran contamination. Good quality flour should have least bran thus least ash

From table 6, amylose content of Chainat 1 rice flour considered high amylose content among other rice varieties. Amylose content had positive correlation to quality of noodle since amylose content. The higher amylose content, the higher tensile strength will be. Amylose content play important role in retrogradation of noodle, water binding capacity of flour (Huaisan et al, 2009). Especially, retrogradation strengthen noodle structure. Amylose content has effect on the quality and structure of noodle. RVA peak, crytallinity, enthalpy of gelatinization decrease when amylose content increase. Set back increase with amylose content. , (The Science of Rice Starches and Korean Rice Cake, 2012.)

Table5: Moisture content and ash content of Native rice flour and Modified starch; AC, SA and OSA (mean ± SD)

Sample	Moisture content (%)	Ash content (%)
F1	9.23 ± 0.15^{b}	4.43 ± 0.07^{b}
AC	11.91 ± 0.07^{a}	4.87 ± 0.02^{a}
SA	11.70 ± 0.09^{a}	4.96 ± 0.05^{a}
OSA	11.61 ± 0.08^{a}	4.87 ± 0.10^{a}

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

1.1.2 Amylose content of Native rice flour

Table6: Amylose content of Native rice flour (mean ± SD)

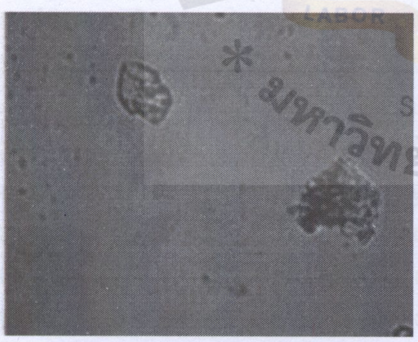
Sample	Amylose content (%)
F1 80 mesh	26.20 ± 0.14

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

1.2. Starch granule morphology

From figure A, Chracteristic of rice flour was circular shape and big particle. The flour particle sample was 80 mesh particle size thus it attached together and form large particle. Starch granule is angular shape with electron microscope observation or 2000x magnificant (Xiaoyan et al, 2006) Iodine solution added to test for the starch. The presence of amylose turned iodine to be dark blue color. The reaction occurred when iodine fit inside the coils of amylose. The iodine charge transfers between iodine and starch. The energy affects on the adsorption spectrum in visible light region. The blue color strength depended on the concentration of amylose content. While iodine content showed red brown color in presence of amylopectin.

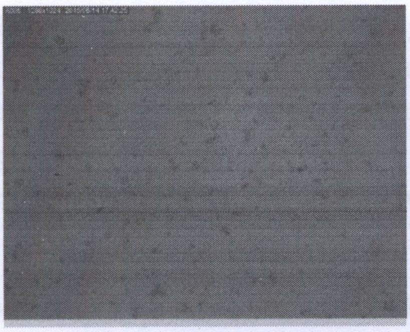
From the figure C, D and E, 3 types of modified starch had circular shape and much smaller particle size comparing to the native rice flour. The particle size of modified starch was small due to the process of modification. Moreover, the modified starch samples were commercial modified starch thus the particle size would be small to ease the application. Moreover, Xiaoyan et al, 2006 reported that modified starch had the porous and damage surface area observed under electron microscope due to the modification process.


A

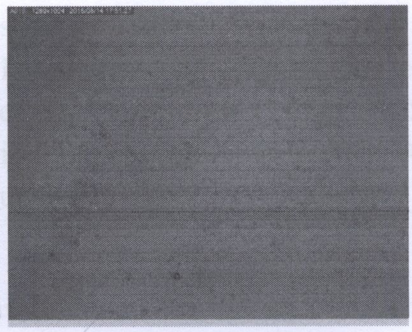

B

Figure 7: Microscopic Granule Examination of rice flour without Iodine at 40x magnification (A)

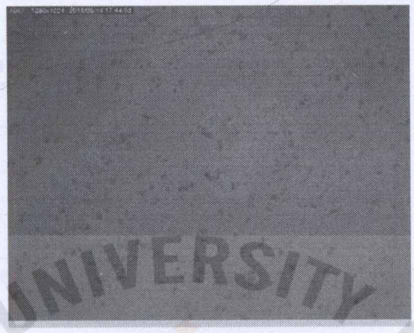
Figure 8: Microscopic Granule Examination of rice flour with Iodine at 40x magnification (B)



C



D



E

Figure 9: Microscopic Granule Examination of AC at 40x magnification (C)

Figure 10: Microscopic Granule Examination of SA at 40x magnification (D)

Figure 11: Microscopic Granule Examination of OSA at 40x magnification (E)

1.3. Swelling power

Native starch granules are insoluble in cold water but swell in warm water. The hydrogen bonds are broken and link with water. The swollen granules disperse in suspension which is reversible until the heating temperature reach gelatinization temperature which is irreversible. The cooked product is called a starch paste. Starch paste can be classified in two phases; dispersed phase of swollen granules (swelling power) and a continuous phase when amylase leach out from starch granule(solubility). Swelling power and solubility showed interaction between starch chains within the amorphous and crystalline regions. The interaction is influenced by amylose content, amylose and amylopectin structure, and other factors. (Schoch 1964). Swelling power indicates the water holding capacity of starch. (Asmeda, 2014). Hauisan et al, 2009 reported that less swelling power influenced loosely pack, soft starch gel. Swelling power indicated

From the result, modified starch had significantly higher swelling power than native rice flour ($p \leq 0.05$). Modified starch had bulky groups into starch molecules leads to structural reorganization. This repulses between starch molecules and ease water spread within the amorphous regions of starch granules which increase in swelling capacity. The structural reorganization may also weaken the starch granules resulting in enhances the leaching of amylose from the granule and emulsifier properties of modified starch introduced hydrophilic part thus increases starch solubility (Aning, 2012). OSA had significant highest swelling power (8.20 ± 0.31) (p≤0.05). Hence, OSA had highest water holding capacity. OSA increased highest viscosity of paste. Native rice flour had least swelling power thus least water holding capacity (5.47 ± 0.47). The largest molecule of substitution group of OSA introduced the largest OSA had highest molecular weight of substitution group than AC and SA. Thus OSA created more reorganization starch structure.

Table7: swelling power of Native rice flour and Modified starch; AC, SA and OSA (mean ± SD)

Sample	Swelling power (%)
F1 80 mesh	5.47 ± 0.47[c]
AC	6.51 ± 0.15[b]
SA	6.99 ± 0.19[b]
OSA	8.20 ± 0.31[a]

Note: Means with the same superscripted letter are not significantly different (p≥0.05)

1.5 Color measurement

The superficial appearance and color of food are the first parameters of quality evaluated by consumers, and are thus critical factors for acceptance of the food item by the consumer. Although there are different color spaces, the most used of these in the measuring of color in food is the L*, a*, b* color space due to the uniform distribution of colors and because it is very close to human perception of color. Where L* indicate brightness (=100) and darkness (=0), a* indicate redness (+) and greenness (-), b* indicate yellowness (+) and blueness (-). Brightness is very important for rice flour because brightness is one of the aspects which determine the quality of rice flour. There was research reported that the noodle color was result of polyphenol oxidase (PPO) which concentrated in seed coat. Both flour and noodle L* are correlated with protein, ash and starch damage (Miskelly, 1984).

From the results, rice flour had least L* (87.91 ± 0.12). AC and SA had highest L* (92.02 ± 0.22, 92.44 ± 0.15 respectively). While L* of OSA had no significant different from L* of AC (91.56 ± 0.14, 92.02 ± 0.22 respectively). Thus rice flour had least brightness while modified starch had brighter color. Modified starch was modified with acid thus color would be brighter from acid bleach. Moreover, small particle size of modified starch reflected light more than big particle rice particle resulting in whiter color.

Rice flour had negative sign on a* which meant the studied rice flour (F1) had green shade (-0.12 ± 0.01) while AC, SA and OSA had positive sign on a* which meant they had redness shade. However, AC had the most redness shade (0.21 ± 0.01). F1 had most yellowness (6.78 ± 0.05) while SA had least yellowness (1.92 ± 0.04). AC, SA and OSA were modified by acid which acid would bleach the native starch to be brighter.

Table 8: Color analysis of rice flour and modified starch (mean ± SD)

Trt	F1	AC	SA	OSA
L*	87.91 ± 0.12^{c}	92.02 ± 0.22^{ab}	92.44 ± 0.15^{a}	91.56 ± 0.14^{b}
a*	-0.12 ± 0.01^{d}	0.21 ± 0.01^{a}	0.02 ± 0.02^{c}	0.13 ± 0.02^{b}
b*	6.78 ± 0.05^{a}	2.31 ± 0.03^{b}	1.92 ± 0.04^{c}	2.31 ± 0.03^{b}

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

2. The physicochemical properties of rice flour and modified starch.

2.1. The study of pasting properties by Rapid Visco Analyser (Brabender RVA)

The Rapid Visco Analyser (RVA) is a cooking stirring viscometer with ramped temperature and viable shear profile optimized for testing viscous properties. Mixture of flour sample and water was gelatinized by heat then retrogradated while machine measures rheological value. Peak value indicates highest viscosity of sample. Though value indicates lowest viscosity of sample. Breakdown value indicated heat and sheer resistant of sample to gelatinize. High breakdown value indicates that the flour is not resistant to heat and sheer force. Final viscosity indicates viscosity of gel. Low viscosity value indicates soft gel that a high amylose content in flour, but high viscosity value indicated that a high amylopectin content in flour (Sang et al., 2008). Setback value indicates retrogradation value. The higher setback value, tend to prone syneresis (Budijanto 2012, Newport Scientific 1998). Peak time value indicates the time it takes flour to increasing the viscosity to highest viscosity or the time that all starch gelatinizes. Pasting temperature is the temperature indicating an initial increase in viscosity or gelatinization temperature.

Amylose will inhibit starch granules development by forming a complex fat, which resulted in the low peak viscosity at high pasting temperatures. Asides of high amylose content in flour is due to the low water binding capability which is characterized by low power swelling, that affect the value of the viscosity and peak time to be low.

Native rice flour at 80 mesh had least peak value (576.33 cP) indicated least highest viscosity. Native rice flour has poor ability to resist to shear force and low elastic gel forming ability (Pitiphunpong and Suwannaporn, 2009). Modified starch is the native Starch that is changed the properties. Physical or chemical agent changes of the starch properties resulting in the molecule structure changing.

Moreover, from figure 12, F1 100 mesh (709.67 cP) had significant higher viscosity than F1 80 mesh (576.33 cP). Small flour size had significantly higher peak and trough than large size flour particle ($p \leq 0.05$) which agreed with Asmeda et al, 2014 that peak and trough had negatively correlation with particle size.

For pure modified starch paste, acetylated modified starch (AC) had the lowest peak value (2612.33 cP), trough (1017.33 cP) and final viscosity (1505 cP). AC had least viscosity which would increase least viscosity in rice slurry. Viscosity had positive correlation swelling power. AC had least swelling power comparing to OSA and SA which contributed to least viscosity. Succinate anhydride modified starch (SA) had peak viscosity (6001.67 cP) higher than peak of AC but less than peak of OSA but SA had highest trough (5087.33 cP), highest final viscosity value (6263.67 cP). SA can increase high viscosity of rice slurry comparing to native rice flour. Viscosity had positive correlation to swelling power. SA had swelling power significant lower than native rice flour ($p \leq 0.05$). Octenyl succinate anhydride modified starch (OSA) had high peak value (7492.67 cP), less trough and final viscosity value than SA but higher than AC (3465.67 cP, 4452 cP respectively). OSA can increase high viscosity of rice slurry. Viscosity had positive correlation to swelling power. OSA gave significant highest swelling power ($p \leq 0.05$).

For modified starch added paste, OSA10% (89 cP), OSA15% (59.67 cP), SA10% (63 cP) and SA15% (65.33 cP) added paste had significant higher of breakdown value than native rice starch 80 mesh (26.33 cP) and 100 mesh (12.33 cP) ($p \geq 0.05$). High breakdown value indicated low ability to resist heat and sheer force. Thus these modified starch added reduced heat and sheer resistant ability of gelatinization of rice flour which desirable. The high ability to resist heat and sheer force of paste required more time and energy to gelatinize.

The amount of modified starch added alter characteristic differently. For AC added, adding 5% of AC could not significantly increase viscosity of paste as the peak value, trough and final viscosity ($p \geq 0.05$). Moreover, adding 10% AC does not significantly increased viscosity of paste due to final viscosity value ($p \geq 0.05$) but significantly increase peak viscosity of paste ($p \leq 0.05$). Adding 15% AC significantly increased peak viscosity of paste (957 cP) comparing to other modified starch in the same concentration (SA; 2156.33 cP and OSA; 2512 cP) ($p \leq 0.05$). Nevertheless, Final viscosity value of adding 5%, 10% and 15% AC were not significantly different ($p \geq 0.05$). Moreover, AC added paste needed shorter time to reach peak viscosity and higher temperature to become paste comparing to SA and OSA added paste. For OSA added, adding OSA significantly increase viscosity of paste as peak and final viscosity were significantly increasing ($p \leq 0.05$). Higher of OSA added paste had higher viscosity respectively ($p \leq 0.05$). For SA added, adding SA significantly increased viscosity of paste as peak and final viscosity were significantly increasing ($p \leq 0.05$). Higher of OSA added paste had higher viscosity respectively ($p \leq 0.05$). Moreover, SA added paste had significantly higher viscosity comparing to AC added paste and OSA added paste in the same concentration ($p \leq 0.05$). Thus 15% SA added paste has highest viscosity statistically as final viscosity 2512 and peak 1206.67. However, high viscosity result high setback value which tended to syneresis.

Adding modified starch decreased peak time and pasting temperature .The incorporation of a bulky group enhances the overall pasting capacity of the starches and destroys their ordered structure, so the modified starches tend to paste more extensively at lower temperature and need shorter time (Xiaoyan et al, 2006).

Table 9: Data of Rapid Visco Analyzer

Sample	Peak (cP)	Trough (cP)	Breakdown (cP)	Final Viscosity (cP)	Setback (cP)	Peak Time (mins)	Pasting Temp (°C)
Fl 80 mesh	576.33^{j}	550^{j}	26.33^{fgh}	862.67^{k}	312.67^{i}	7^{a}	92.37^{cd}
Fl 100 mesh	709.67^{i}	697.33^{h}	12.33^{h}	1107^{i}	409.67^{h}	6.11^{d}	89.98^{ef}
AC	2612.33^{c}	1017.33^{e}	1595^{b}	1505^{g}	487.67^{g}	4.07^{f}	72.03^{i}
SA	6001.67^{b}	5087.33^{a}	914.33^{c}	6263.67^{a}	1176.33^{b}	4.33^{e}	71.73^{i}
OSA	7492.67^{a}	3465.67^{b}	4027^{a}	4452^{b}	986.33^{c}	4.18^{f}	69.27^{j}
Fl-80-AC 5%	618.33^{j}	601^{ij}	17.33^{gh}	881.33^{jk}	280.33^{i}	6.31^{c}	93.17^{bc}
Fl-80-AC 10%	700.67^{i}	656.67^{hi}	44^{ef}	957^{jk}	300.33^{i}	6.31^{c}	94^{ab}
Fl-80-AC 15%	759.67^{i}	704.67^{h}	55^{e}	976^{j}	271.33^{i}	6.44^{c}	94.6^{a}
Fl-80-OSA 5%	837.67^{h}	795.67^{g}	42^{efg}	1272.33^{h}	476.67^{gh}	6.93^{a}	92.05^{cd}
Fl-80-OSA 10%	1116.33^{f}	1027.33^{e}	89^{d}	1709^{f}	681.67^{e}	6.96^{a}	89.1^{fg}
Fl-80-OSA 15%	1450^{d}	1390.33^{c}	59.67^{e}	2156.33^{d}	766^{d}	6.76^{b}	80.88^{h}
Fl-80-SA 5%	740.33^{i}	700.67^{h}	39.67^{efg}	1305^{h}	604.33^{f}	7^{a}	91.07^{de}
Fl-80-SA 10%	1007^{g}	944^{f}	63^{e}	1938.33^{e}	994.33^{c}	7^{a}	88.05^{g}
Fl-80-SA 15%	1206.67^{e}	1141.33^{d}	65.33^{de}	2512^{c}	1370.67^{a}	7^{a}	81.42^{h}

Note:

F = whole grain rice flour

AC = Acetylated Modified Starch

SA = Succinate Anhydride Modified Starch

OSA = Octenyl Succinic Anhydride Modified Starch

Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

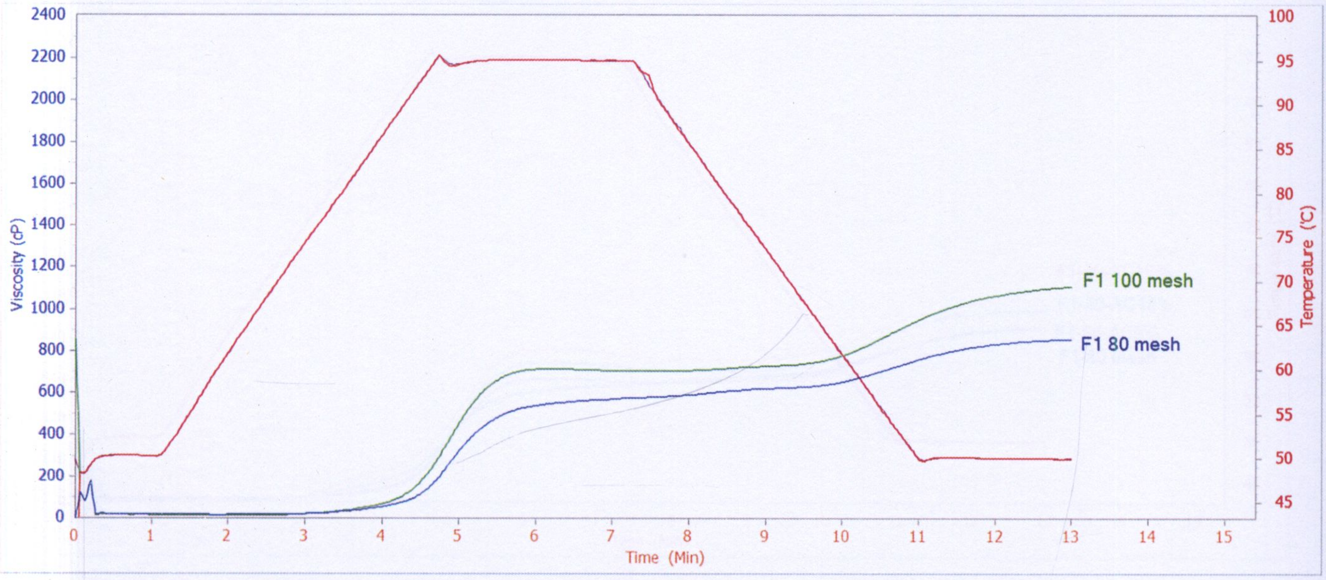


Figure 12: RVA graph of 100 mesh and 80 mesh particle size of flour

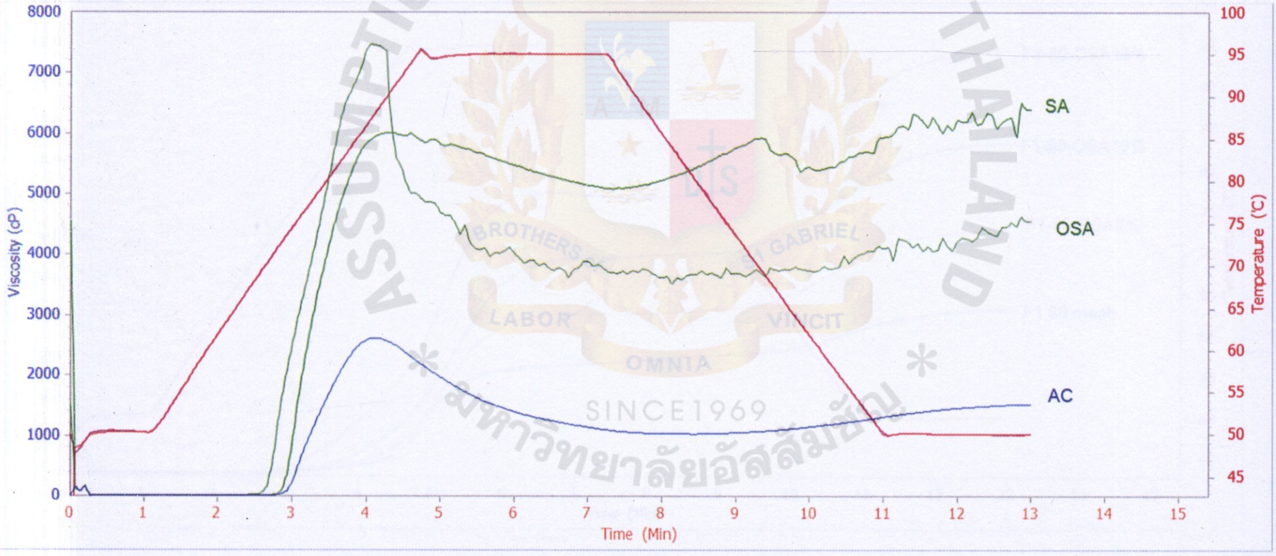
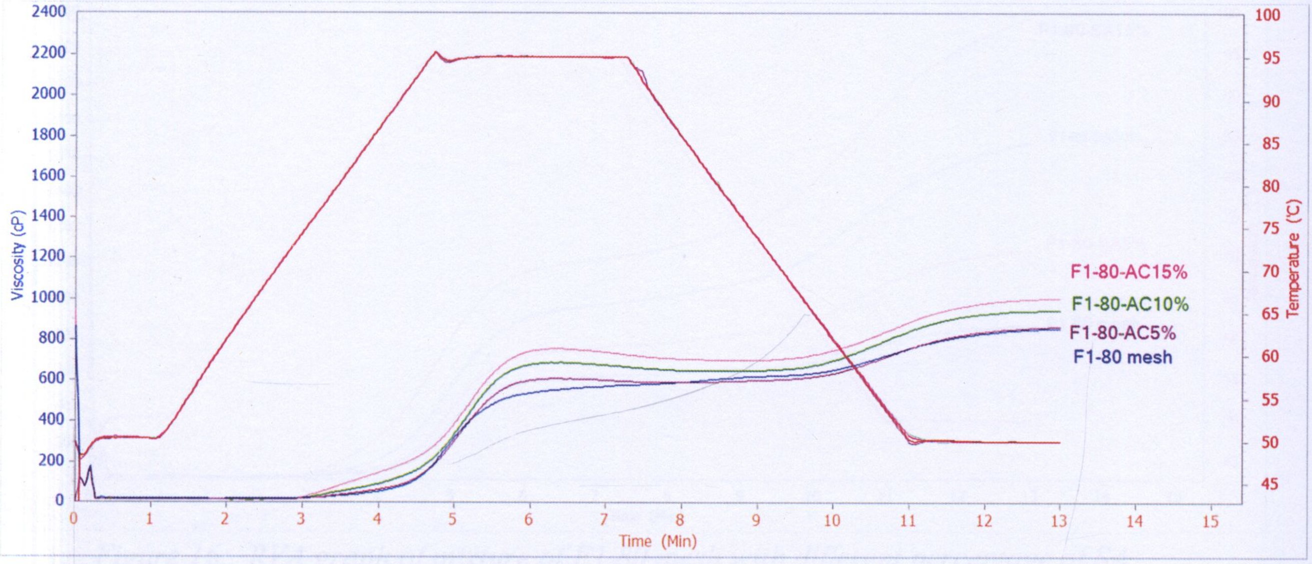
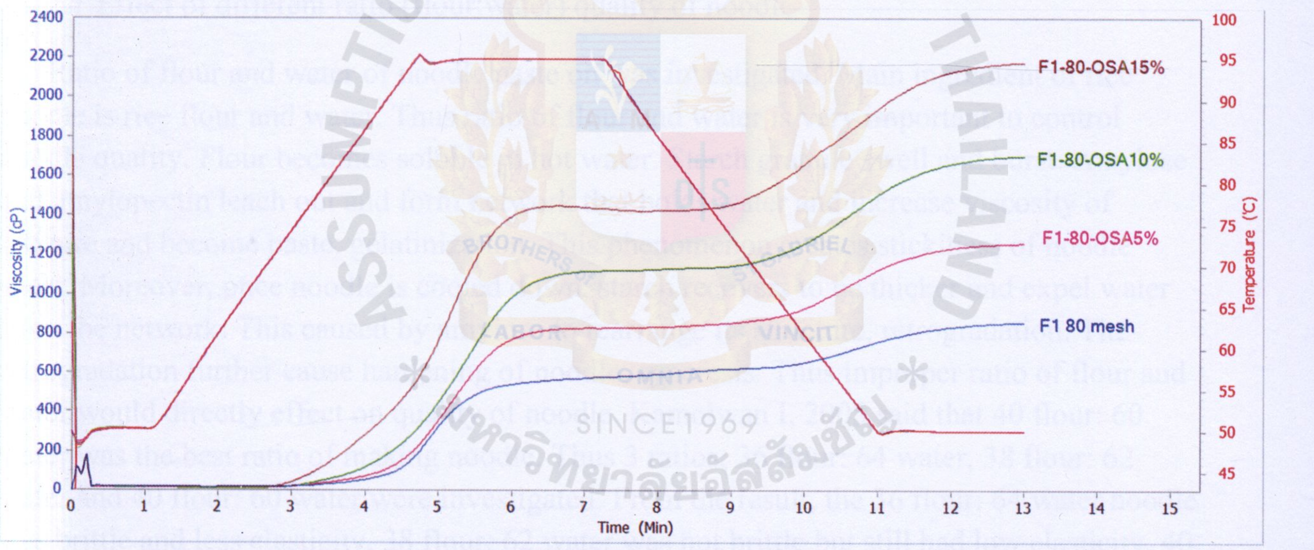


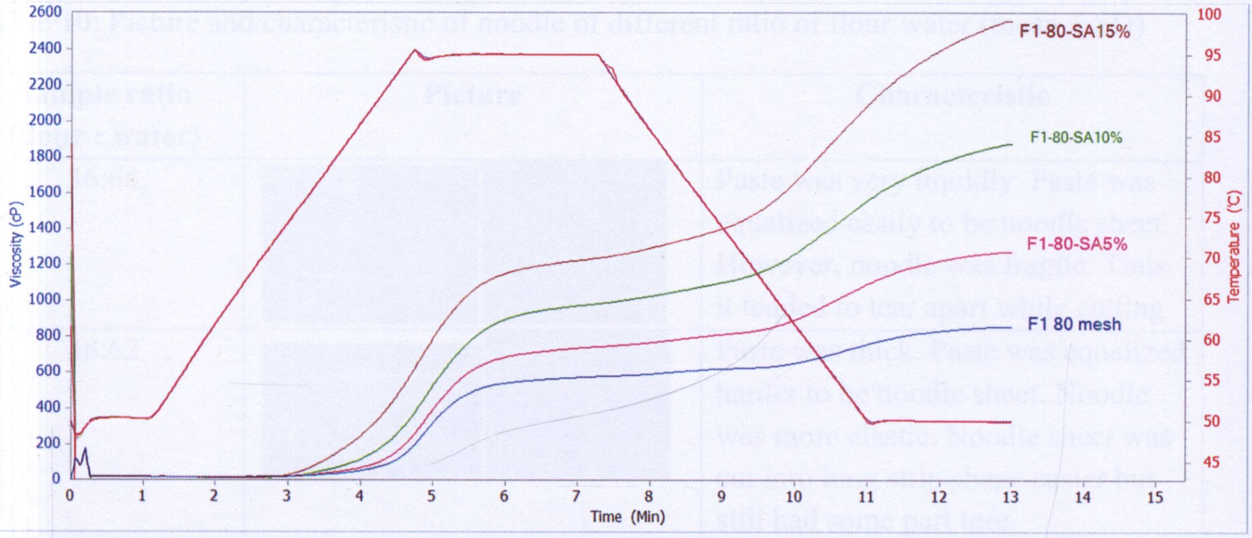
Figure 13: RVA graph of Modified Starch



1. *Figure 14: RVA graph of mixture of F1 80 mesh with different percentage of AC*



1. *Figure 15: RVA graph of mixture of F1 80 mesh with different percentage of OSA*



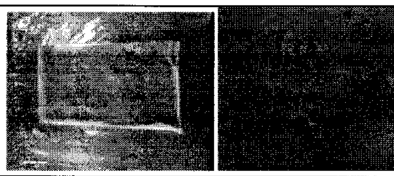
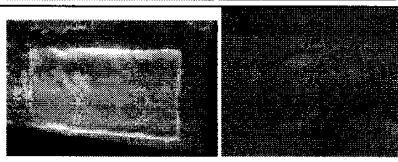
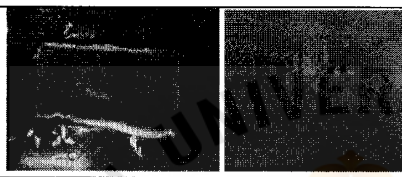
1. *Figure 16: RVA graph of mixture of F1 80 mesh with different percentage of SA*

2. **The preliminary test on 'Korat' noodle production.**

2.1 Effect of different ratio (flour:water) quality of noodle

Ratio of flour and water of noodle paste on was investigated. Main ingredient of rice noodle is rice flour and water. Thus ratio of flour and water is very important to control noodle quality. Flour becomes soluble in hot water. Starch granule swell and burst. Amylose and amylopectin leach out and form network that holds water and increase viscosity of mixture and become paste, gelatinization. This phenomenon creates stickiness of noodle sheet. Moreover, once noodle is cooled down, starch recovers to be thicker and expel water from the network. This caused by amylose to rearrange its structure, retrogradation. The retrogradation further cause hardening of noodle, syneresis. Thus improper ratio of flour and water would directly effect on quality of noodle. Kamolwan I, 2005 said that 40 flour: 60 water was the best ratio of making noodle. Thus 3 ratios; 36 flour: 64 water, 38 flour: 62 water and 40 flour: 60 water were investigated. From the result, the 36 flour: 64 water noodle was brittle and less elasticity. 38 flour: 62 water was not brittle but still had low elasticity. 40 flour: 60 water had the most elasticity of noodle. Amount of flour indicated amount of amylose that further retrogradatation and give the noodle elasticity. However, too much amylose gave rigid and tough noodle. Thus appropriate amount of rice flour was important for noodle production

Table 10: Picture and characteristic of noodle of different ratio of flour:water (mean ± SD)

Sample ratio (flour : water)	Picture	Characteristic
36:64		Paste was very liquidly. Paste was equalized easily to be noodle sheet. However, noodle was fragile. Thus it tended to tear apart while cutting
38:62		Paste was thick. Paste was equalized harder to be noodle sheet. Noodle was more elastic. Noodle sheet was cut into long strip shape easier but still had some part tore.
40:60		Paste was thick. Paste was equalized harder to be noodle sheet. Noodle was elastic. Thus noodle sheet was cut into long strip shape easier.

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

2.2 Sensory evaluation

Samples; 36 flour: 64 water, 38 flour: 62 water and 40 flour: 60 water were investigated on sensory evaluation. Sensory evaluation tests 8 attributes using 9 point hedonic scale. For the result, the color, opacity, softness, stickiness, flavor of samples were not significantly different ($p \geq 0.05$). The Elasticity of the samples was significantly different ($p \geq 0.05$). 40 flour: 60 water sample had the highest preference on elasticity, thickness and overall liking (4.8±2.24, 5.3±1.56 and 4.4±2.02 respectively). The preference of elasticity, thickness, overall liking, and the indifference of other attribute made 40 flour: 60 water ratio suitable to be further investigated.

Table 11: Sensory liking score of noodle of different ratio of flour:water using 9 point hedonic scale (mean ± SD)

Attributes	**36:64**	**38:62**	**40:60**
Color	5.4±2.08^a	5.1±2.06^a	5.4±1.87^a
Opacity	5.0±2.04^a	4.8±1.94^a	5.0±1.93^a
Softness	4.1±1.70^a	3.6±2.13^a	4.2±2.37^a
Stickiness	3.7±1.67^a	4.0±2.41^a	3.7±1.70^a
Elasticity	3.0±1.30^b	3.4±1.59^b	4.8±2.24^a
Flavor	4.7±1.78^a	4.4±2.32^a	4.4±1.74^a
Thickness	4.0±2.14^b	4.0±2.31^b	5.3±1.56^a
Overall liking	4.3±2.01^b	4.2±2.43^b	4.4±2.02^a

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

2.3 Appropriate amount of slurry

From the preference of ratio of the sensory evaluation, the amount of slurry was further investigated. Sensory evaluation tests 8 attributes using 9 point hedonic scale. For the result, color, opacity, softness, stickiness, elasticity, flavor, overall liking of samples were not significantly different ($p \geq 0.05$). While thickness of 40 grams paste sample was significantly different from 50 grams paste sample ($p \leq 0.05$). 40 grams paste sample had significantly higher preference in thickness of over 50 grams paste sample (5.32±1.56, 3.55±1.79 respectively) ($p \leq 0.05$). The higher preference score of thickness and the indifference of other attributes made the 40 grams paste suitable for noodle production. The amount of paste affected directly to thickness of noodle which further affected on elasticity of noodle since thicker noodle would resist more shear force to tear noodle.

Table 12: Sensory liking score of noodle of different amount of slurry using 9 point hedonic scale (mean ± SD)

Attribute	40:60(40g)	40:60 (50g)
Color	5.4±1.87[a]	5.3±1.86[a]
Opacity	5.0±1.93[a]	4.7±1.96[a]
softness	4.2±2.37[a]	4.2±2.27[a]
stickiness	3.7±1.70[a]	3.9±2.33[a]
elasticity	4.8±2.24[a]	4.5±1.79[a]
Flavor	4.4±1.74[a]	4.6±2.26[a]
thickness	5.3±1.56[a]	3.6±1.79[b]
overall liking	4.4±2.02[a]	4.4±2.28[a]

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

3. **The effect of modified starch on quality of 'Korat' noodle.**

3.1 Cook loss properties

Cooking loss is an important attribute in noodles as it evaluates the amount of irrecoverable solids in cooking water. It is important that the structural integrity of noodles need to be maintained throughout the cooking process (Rachel T. et al, 2014) High cooking loss is unacceptable as there can be high amount of solubilized starch present, which leads to cloudy boiling water and 'sticky' mouth feel with lower tolerance (Chakraborty et al. 2003; Chen et al. 2002; Jin et al. 1994).

From the result, rice flour had highest cook loss value (14.34 ± 0.11). It determined that rice flour had weak unity of noodle so it lost highest amount of irrecoverable solids in cooking water. The less stickiness of native rice flour and rearrangement of big particles (80 mesh) of rice flour could not hold the structure of noodle.

AC5% (12.87 ± 0.13), SA5% (11.59 ± 0.16) and OSA5% (12.04 ± 0.37) had significant cook loss value lower than F1(14.34 ± 0.11). AC10% (10.67 ± 0.33), SA10% (10.60 ± 0.32) and OSA10% (10.15 ± 0.21) had significant cook loss value lower than AC5% (12.87 ± 0.13), SA5% (11.59 ± 0.16) and OSA5% (12.04 ± 0.37). AC15% (9.44 ± 0.38), SA15% (7.30 ± 0.26) and OSA15% had significant cook loss value lower than AC10% (10.67 ± 0.33), SA10% (10.60 ± 0.32) and OSA10% (10.15 ± 0.21) ($p \leq 0.05$). The result showed that adding modified starch significantly reduced the cook loss value comparing to no modified added noodle ($p \leq 0.05$). Modified starch had thickening properties. Thus modified starch would be able to hold the structure of noodle better than rice flour. From 1.2 rheological properties result, 3 modified starch samples improved the break down value over rice native flour which indicated shear force and heat resistant. Moreover, modified starch increase stickiness which would hold the flour particles together through the cooking. Moreover, Chen Z, 2003 reported that used acetylated starches to improve quality of noodle. Acetylated starches can decrease cooking loss value.

SA15% had lowest cook loss value (7.30 ± 0.26). Adding SA modified starch 15% prevent the loss of irretrievable solid in cooking water and unitize the noodle structure. From 1.2 rheological properties, SA15% had highest breakdown value (65.33) which indicated shear force and heat resistant.

Table 13: Cook loss value of noodle samples with different modified starch and concentration added (mean ± SD)

Trt	Cook loss (%)
F1	14.34 ± 0.11^{a}
AC5%	12.87 ± 0.13^{b}
AC10%	10.67 ± 0.33^{d}
AC15%	9.44 ± 0.38^{ef}
SA5%	11.59 ± 0.16^{c}
SA10%	10.60 ± 0.32^{d}
SA15%	8.30 ± 0.26^{g}
OSA5%	12.04 ± 0.37^{c}
OSA10%	10.15 ± 0.21^{de}
OSA15%	9.00 ± 0.23^{f}

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

3.2 Rehydration ratio properties

Rehydration Ratio is ability of dried noodle to absorb water to be soft noodle (Rachel T, 2014). High rehydration ratio tends to make noodles sticky whereas low rehydration ratio can render the noodle to be hard with unrefined texture (Collado et al. 2001; Yoenyong-buddhagal & Noomhorm 2002).

From the result, modified starch added noodle increase the rehydration ratio since no modified starch added noodle had significantly lowest rehydration ratio (0.96 ± 0.03) ($p \leq 0.05$). No modified starch added noodle resulted in hard noodle. The AC10% and AC15%

had the highest rehydration ratio value (1.90 ± 0.09, 2.06 ± 0.15 respectively). AC10% and AC15% absorb highest amount of water. From the 1.1 RVA result, AC modified starch tended to require shorter time than OSA and SA to gelatinize. Thus with 10% or 15% concentration AC added noodle alter the gelatinize time of noodle. AC10% and AC15% noodle were overcook in the time that other samples were properly cook. Thus AC10% and AC15% noodle absorb too much water and became too soft and easy to tear. Rehydration ratio of AC5%, SA5%, SA10%, SA15%, OSA5%, OSA10%, and OSA15% was not significantly different. This indicated that 5% adding of AC and 5%,10%, 15% adding SA, OSA absorb same amount of water from cooking process. Modified starch had emulsifier properties which would react with water better than native rice flour. Moreover, the network of amylose retrogradation with bulky group of modified starch functional group would trap more water than rice flour. Small particle size of starch increase water absorption index (Nura M. et al, 2011).

Table 14: Rehydration ratio value of noodle sample with different modified starch and concentration added (mean ± SD)

Trt	Rehydration ratio (%)
F1	0.96 ± 0.03^{d}
AC5%	1.63 ± 0.01^{c}
AC10%	1.90 ± 0.09^{ab}
AC15%	2.06 ± 0.15^{a}
SA5%	1.63 ± 0.06^{c}
SA10%	1.67 ± 0.06^{bc}
SA15%	1.84 ± 0.07^{bc}
OSA5%	1.64 ± 0.02^{c}
OSA10%	1.69 ± 0.06^{bc}
OSA15%	1.78 ± 0.06^{bc}

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

3.3 Yield and thickness

Yield of noodle calculated from dried noodle with fresh noodle. From the yield result table 15, every treatment was not significantly different ($p \geq 0.05$). Adding modified starch did not effect on the yield of noodle.

Fresh noodle and dried noodle were measured by using screw gauge. From result of fresh noodle thickness, the thickness of no modified starch added noodle F1 had the most thickness (1.34 ± 0.02). The native rice flour particle size was bigger than modified starch. The big particles (80 mesh) of flour arrange itself loosely while small particle size of modified starch pack tightly. The thinnest noodle samples were AC15%, SA10%, SA15% and OSA15% (1.03 ± 0.04, 1.01 ± 0.04, 0.92 ± 0.03 and 0.91 ± 0.03 respectively). The adding of modified starch made the thinner noodle. The more of modified starch adding, the thinner noodle were.

Modified starch had the smaller particle size comparing to the native rice flour. The particle packed more organized. Thus there was no free space to increase thickness.

From dried noodle table 15, no modified added noodle was not significant different with AC5, SA5% and OSA5%. Adding 5% modified starch could not affect thickness of dried noodle. AC10%, SA10% and OSA10% had no significant different among them but had significantly thicker than AC15%, SA15% and OSA15%. The small particle size of modified starch arranged particles more tightly than the larger particle size of rice flour.

From yield and thickness result, thickness of different concentration of modified starch added noodle had significant different while yield that calculated from fresh and dried weight had no significant different. Thus the difference of thickness was not the weight of particle but the rearrangement of unorganized particle created free space that increased the thickness.

Table 15: Yield, thickness of fresh and dried noodle samples with different modified starch and concentration added (mean ± SD)

Trt	Yield (%)	Thickness (mm)	
		fresh	dried
F1	40.29 ± 0.11^{a}	1.34 ± 0.02^{a}	0.96 ± 0.01^{a}
AC5%	41.57 ± 0.22^{a}	1.07 ± 0.04^{b}	0.95 ± 0.02^{a}
AC10%	43.72 ± 3.75^{a}	1.03 ± 0.04^{b}	0.88 ± 0.01^{b}
AC15%	43.03 ± 1.53^{a}	0.92 ± 0.02^{c}	0.75 ± 0.02^{c}
SA5%	43.37 ± 0.21^{a}	1.06 ± 0.04^{b}	0.95 ± 0.02^{a}
SA10%	41.91 ± 0.80^{a}	1.01 ± 0.04^{bc}	0.86 ± 0.01^{b}
SA15%	41.13 ± 0.13^{a}	0.92 ± 0.03^{c}	0.76 ± 0.02^{c}
OSA5%	41.63 ± 0.90^{a}	1.09 ± 0.05^{b}	0.98 ± 0.01^{a}
OSA10%	41.28 ± 2.52^{a}	1.04 ± 0.04^{b}	0.87 ± 0.01^{b}
OSA15%	42.01 ± 0.44^{a}	0.91 ± 0.03^{c}	0.76 ± 0.02^{c}

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

3.4 Color measurement

Color of noodle plays important role for consumer evaluating of noodle quality. Rice flour had high protein content among the different types of flours. Protein in starch is unwanted, as by heating it will initiate Maillard reactions, which cause discoloration and flavor formation (starch, 2014). Fresh rice noodle is expected to maintain white color. High quality noodle should be consistent and long with white color while dried noodle should be slightly yellow transparent characteristic (Rachel T, 2014). The most used of these in the measuring of color in food is the L*, a*, b* color space due to the uniform distribution of colors and because it is very close to human perception of color. Where L* indicate brightness and darkness, a* indicate redness and greenness, b* indicate yellowness and blueness. Brightness is very important for rice noodle because brigthness is one of the aspects *which determine the quality of rice noodle. Both flour and noodle L* are correlated with* protein, ash and starch damage. Brightness stability measurement of noodle got darkening over time. It is correlated with polyphenol oxidase activity which PPO concentrated in seed coat. Noodle color stability is also affected by non-PPO background darkening. The mechanism is still unidentified (noodle-noodle darkening). Thus color stability of noodle depended on time of oxidation to be occurred. Moreover, noodle was covered by oil which increase oxidation rate.

From fresh noodle L* result, the L* or brightness of F1, AC5%, AC10%, SA10%, OSA5%, OSA10% had no significant different ($p \geq 0.05$). From the 3.5 thickness result, 15% modified starch added had significant thinner than no modified starch added, 5% and 10% modified starch added. More surface area of thin noodle would accumulate the darken color faster than thick noodle in the same rate of darkening. The oxidized noodle would slightly change the color to be more brownness (less brightness).

For dried noodle L* result, AC10%, AC15%, SA10%, SA15%, OSA10% and OSA15% had no significant different and highest L* or highest brightness ($p \leq 0.05$). From the 1.6 color measurement result, AC, SA and OSA had significantly higher brightness than native rice starch F1. Thus adding modified starch 10% and 15% increase brightness of noodle.

However, there would no significant different among all samples with human eyes since the result showed small different value of both fresh and dried noodle. Thus for human perception, adding modified starch did not change the natural color of noodle.

Table 16: Color measurement of fresh noodle of noodle samples with different modified starch and concentration added (mean ± SD)

trt	F1	AC5%	AC10%	AC15%	SA5%	SA10%	SA15%	OSA5%	OSA10%	OSA15%
L*	32.55± 0.18 ^{ab}	33.08 ± 0.68^{a}	31.55 ± 1.24 ^{ab}	30.63 ± 0.45 ^{b}	30.89 ± 0.76 ^{b}	31.65 ± 0.75 ^{ab}	30.61 ± 0.45 ^{b}	33.21 ± 0.45 ^{a}	32.242 ± 0.36 ^{ab}	30.76 ± 0.38 ^{b}
a*	-0.88 ± 0.01 ^{b}	-0.88 ± 0.01 ^{b}	-0.87 ± 0.03 ^{b}	-0.79 ± 0.02 ^{a}	-0.91 ± 0.02 ^{bc}	-0.90 ± 0.02 ^{b}	-0.86 ± 0.02 ^{b}	-0.97 ± 0.02 ^{c}	-0.96 ± 0.01 ^{c}	-0.91 ± 0.02 ^{bc}
b*	0.90 ± 0.07^{cde}	1.32 ± 0.04^{ab}	1.38 ± 0.13 ^{a}	0.96 ± 0.08 ^{cde}	0.84 ± 0.17^{de}	1.06 ± 0.12^{abcd}	1.02 ± 0.12^{bcd}	1.20 ± 0.09^{abc}	1.21 ± 0.07^{abc}	0.64 ± 0.09^{e}

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

Table 17: Color measurement of dried noodle of noodle samples with different modified starch and concentration added (mean ± SD)

trt	F1	AC5%	AC10%	AC15%	SA5%	SA10%	SA15%	OSA5%	OSA10%	OSA15%
L*	27.35 ± 0.24^{b}	26.97 ± 0.23^{b}	28.77 ± 0.18^{a}	28.84 ± 0.28^{a}	26.97 ± 0.25^{b}	28.78 ± 0.37^{a}	29.02 ± 0.29^{a}	27.00 ± 0.37^{b}	28.77 ± 0.17^{a}	29.05 ± 0.16^{a}
a*	0.50 ± 0.03^{ab}	0.50 ± 0.03^{ab}	0.462 ± 0.02^{a}	0.46 ± 0.02^{a}	0.55 ± 0.01^{b}	0.48 ± 0.01^{a}	0.48 ± 0.01^{a}	0.55 ± 0.01^{b}	0.48 ± 0.01^{a}	0.51 ± 0.02^{ab}
b*	3.37 ± 0.17^{a}	2.85 ± 0.14^{c}	3.45 ± 0.20^{a}	3.48 ± 0.09^{a}	2.82 ± 0.13^{c}	3.33 ± 0.07^{ab}	3.47 ± 0.08^{a}	2.97 ± 0.12^{bc}	3.72 ± 0.15^{a}	3.41 ± 0.06^{a}

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

3.5 Texture analysis

Texture is an important attribute of cooked noodles. It determines consumer acceptance of the product and quality of noodle (Rachel T. et al, 2014). Texture analyzer is the objective measurement of noodle quality.

The test began with the upper arm moving away from lower arm at the pre-test speed of 1 mm/sec. As the pasta loop is extended the force increases and when the force equals the trigger force of 5 g the speed increased to 3 mm/s and data was recorded. The sample was extended and the force continued to increase until the sample could no longer support the applied force and the sample tore. In order to have a valid test result the sample should break in one of the two sections at the middle of the gauge length. The upper arm will continue to move to the target distance of 50 mm and then returned to the start position at the post test speed of 5 mm/s. Once the trigger force of 5g was attained the graph proceeds to plot the effect on the noodle under tension.

From table, elastic Limit/ tensile strength or force indicated force required to create tension in noodle. The elastic limit/tensile strength was exceeded the noodle tore as the maximum tension force. The cooking quality of noodles can also be determined based on the results of tensile strength as it indicates how the noodles can stay intact during cooking (Bhattacharya et al. 1999; Ross 2006). Hense tensile strength indicates firmness of noodle. F1, SA5%, SA10%, OSA5%, OSA10% and OSA15% required the significantly highest force to reach maximum tension force (31.87 ± 4.16 g , 27.87 ± 3.11 g, 34.38 ± 3.13 g, 29.07 ±2.63 g, 28.43 ±2.90 g, 25.95 ± 1.79 g respectively) ($p \leq 0.05$). Tensile strength indicated firmness of noodle. Adding modified starch had no significantly different in noodle firmness ($p \geq 0.05$). However, For the thickness effect on tensile strenght. Thin noodle tended to easy to tear. While thick noodle can resist more tear force. From 3.5 thickness result, no modified starch added noodle had no significant thicker than 5%, 10% and 15% modified starch added noodle. Thus SA5%, SA10%, OSA5%, OSA10% and OSA15% might increase firmness of noodle.

Elasticity is the measurement of distance the sample elongate when applied tension force- the greater the extension distance, the more extensible/elastic is the sample. The distance was in negative charge indicated the opposite force direction. Thus without charge, higher distance indicated higher elasticity. From elasticity result, SA10%, SA15%, OSA15% had sigificantly highest elasticity (-14.58 ± 1.10 mm, -15.26 ± 1.12 mm, -17.08 ± 1.59 mm) ($p \leq 0.05$). This indicated that SA10%, SA15%, OSA15% had sigificantly highest ability of deformed noodles to return to its initial shape and size when the force creating.

Table 18: Tensile strength and elasticity of noodle samples (mean ± SD)

Trt	Elastic Limit/tensile strength g Force	Elasticity mm Distance
F1	31.87 ± 4.16 [ab]	-6.26 ± 0.85[a]
AC5%	22.99 ± 1.63 [bc]	-10.49 ± 1.90 [bc]
AC10%	21.67 ± 2.40 [c]	-7.99 ± 0.59 [ab]
AC15%	8.50 ± 0.58 [d]	-10.49 ± 1.90 [a]
SA5%	27.87 ± 3.11 [abc]	-10.61 ± 1.34 [bc]
SA10%	34.38 ± 3.13 [a]	-14.58 ± 1.10 [cde]
SA15%	24.40 ± 1.81 [bc]	-15.26 ± 1.12 [de]
OSA5%	29.07 ±2.63 [abc]	-10.94 ± 1.50 [bc]
OSA10%	28.43 ±2.90 [abc]	-11.45 ± 0.94 [bcd]
OSA15%	25.95 ± 1.79 [abc]	-17.08 ± 1.59 [e]

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

From the graph, Force indicates tensile strength which assesses the capability of noodles to endure a longitudinal force without tearing. Time indicates elasticity as time has positive relation to the distance without charge that determine opposite force direction. The longer time, more distance noodle can stay shape without tearing. From figure 17, F1 require highest force but less time to tear noodle. It indicated that F1 require high force to tear noodle but noodle had less elasticity. OSA15% required less force but long time to tear noodle. It indicated that OSA15% required less force to tear noodle but noodle had more elasticity.
Thus modified starch improved quality of noodle by increase elasticity of noodle.

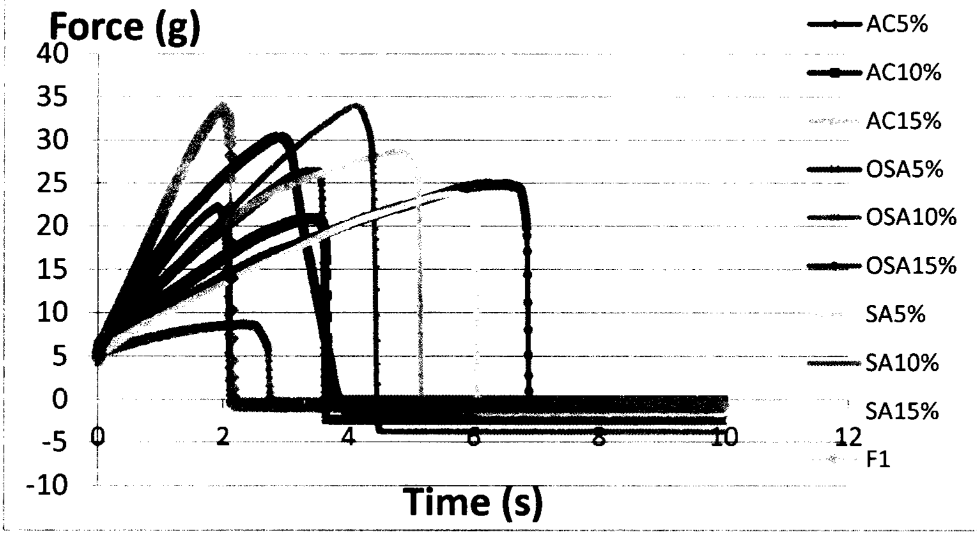


Figure 17: Tensile strength of noodle samples

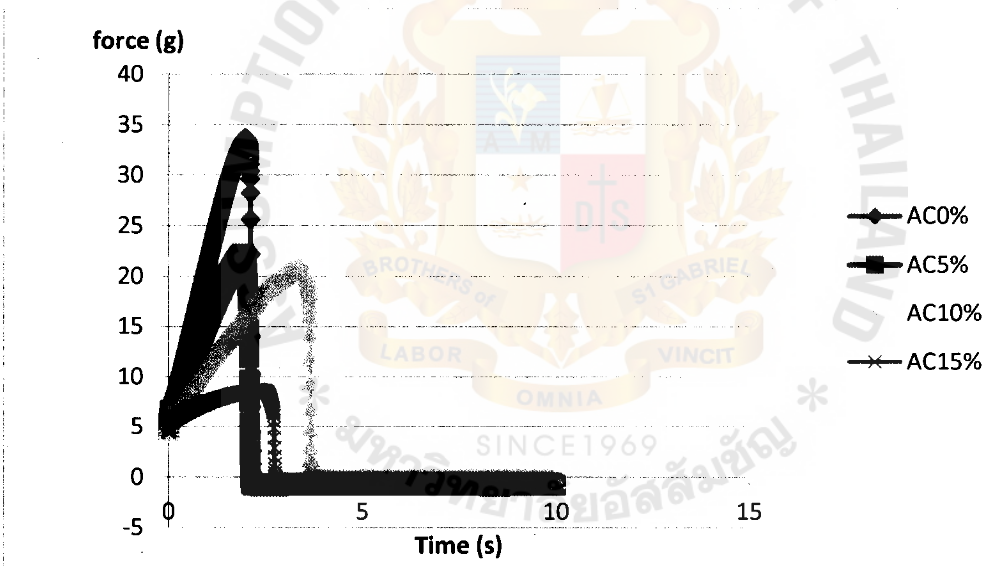


Figure 18: tensile strength of AC added noodle with no AC added noodle.

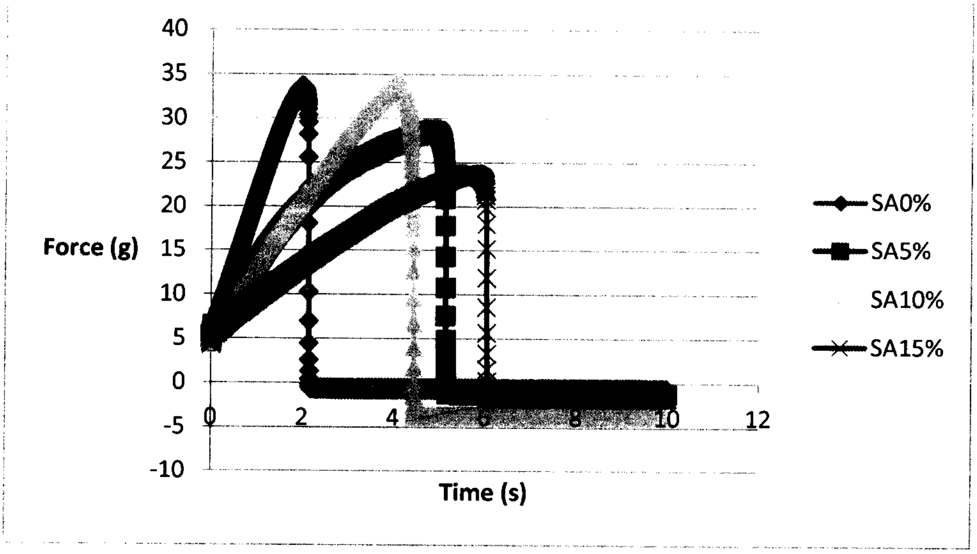


Figure 19: Tensile strength of SA added noodle with no SA added noodle.

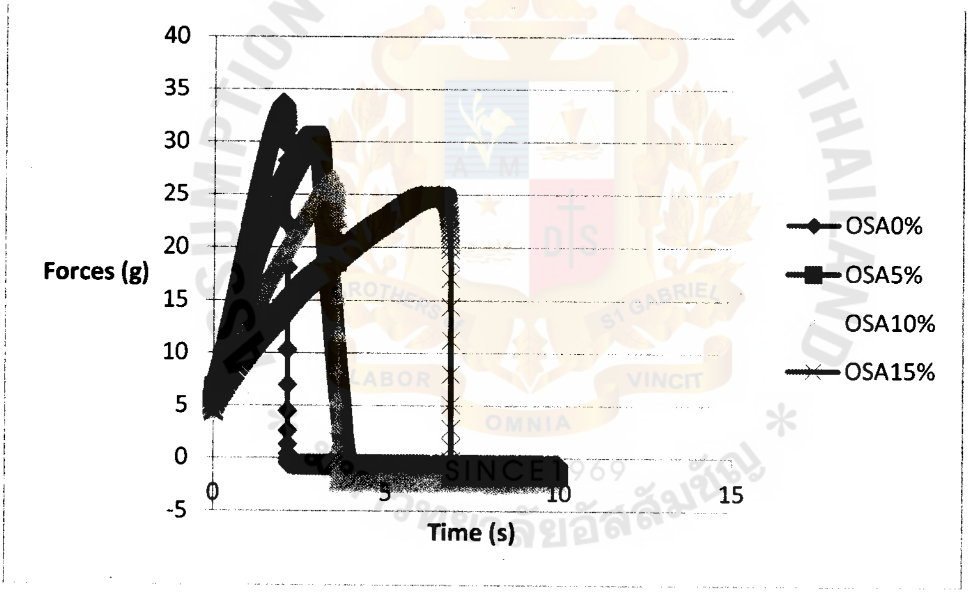


Figure 20: Tensile strength of OSA added noodle with no OSA added noodle.

3.6 Sensory evaluation

Sensory evaluation is subjective measurement of noodle quality according to consumer preference. Sensory evaluation on 7 attributes using 9 point hedonic scale. For the result, color; the most preference are SA5%, SA15%, OSA5%, OSA15% (6.5 ± 0.24, 7.2 ± 0.19, 6.6 ± 0.21, 7.0 ± 0.25 respectively). Opacity; the most preference are AC5%, SA15%, OSA5% OSA10%, OSA15% (6.0 ± 0.24, 6.7 ± 0.27, 6.3 ± 0.25, 6.3 ± 0.26, 6.8 ± 0.29 respectively). Softness; the most preference are SA15% and OSA10% (6.8 ± 0.23 and 6.0 ± 0.24 respectively). Stickiness; the most preference are SA15%, OSA15% (6.9 ± 0.21 and 7.4 ±

0.18). Elasticity; the most preference is OSA15% (7.7 ± 0.18). Flavor; the most preference are SA15%, OSA10% and OSA15% (6.3 ± 0.24, 6.3 ± 0.20 and 6.90 ± 0.19 respectively). Overall liking; the most preference is OSA15% (7.6 ± 0.16) ($p \leq 0.05$). The result showed that, OSA and SA modified starch had good properties to improve noodle characteristic. More concentration of OSA and SA added, more preference obtained.

The least preference of every attribute were F1, AC10% and AC15% (5.7± 0.33, 5.5 ± 0.35 and 4.9 ± 0.37 respectively). AC added noodle was over cook by the nature of AC modified starch. From the RVA result, AC modified starch required shorter time to gelatinize. Thus in the same time range of cooking, AC added noodle would be cooked before SA and OSA added noodle which contributed the noodle to be too soft. Thus for consumer vision, AC noodle was not good in any of the attribute indicated good noodle. Especially AC10% and AC15% that contain high concentration of AC, noodle became thinner than as the more modified starch added according to the 3.5 thickness result. The thinner noodle was easy to tear. Moreover, AC modified starch can soften the noodle (Aning A, 2012). Thus AC10% and AC15% noodle became easily to tear.

SA15% and OSA15% had the most preference on almost attribute. SA15% and OSA15% increase elasticity of noodle as showed in 3.5 texture analyzer result.

Table 19: Sensory liking score of noodle of noodle samples with different modified starch and concentration added using 9 point hedonic scale (mean ± SD)

	F1	AC 5%	AC10%	AC15%	SA5%	SA10%	SA15%	OSA5%	OSA10%	OSA15%
color	5.7± 0.33^{def}	6.0 ± 0.26^{cde}	5.5 ± 0.35^{ef}	4.9 ± 0.37^{f}	6.5 ± 0.24^{abcd}	6.3± 0.30^{bcde}	7.2 ± 0.19^{a}	6.6 ± 0.21^{bc}	6.2 ± 0.24^{bcde}	7.0 ± 0.25^{ab}
opacity	5.2 ± 0.28^{cd}	6.0 ± 0.24^{abc}	5.3 ± 0.30^{cd}	4.9 ± 0.36^{d}	5.7 ± 0.30^{bcd}	5.7 ± 0.31^{bcd}	6.7 ± 0.27^{a}	6.3 ± 0.25^{ab}	6.3 ± 0.26^{ab}	6.8 ± 0.29^{a}
softness	3.3 ± 0.31^{f}	4.6 ± 0.36^{cde}	4.1 ± 0.35^{ef}	3.7 ± 0.31^{ef}	4.5 ± 0.31^{de}	5.0 ± 0.31^{cd}	6.8 ± 0.23^{a}	5.5 ± 0.29^{bc}	6.0 ± 0.24^{ab}	5.2± 0.41^{bcd}
stickiness	3.2 ± 0.23^{d}	5.0 ± 0.32^{c}	3.7 ± 0.30^{d}	3.8 ± 0.29^{d}	5.0 ± 0.31^{c}	5.4 ± 0.26^{bc}	6.9 ± 0.21^{a}	5.9 ± 0.19^{b}	5.9 ± 0.24^{b}	7.4 ± 0.18^{a}
elasticity	3.6 ± 0.32^{e}	4.8 ± 0.27^{d}	3.6 ± 0.30^{e}	3.5 ± 0.37^{e}	4.3 ± 0.28^{de}	4.7 ± 0.30^{d}	6.9 ± 0.24^{b}	5.7 ± 0.25^{c}	5.8 ± 0.28^{c}	7.7 ± 0.18^{a}
flavor	3.8 ± 0.34^{e}	5.7 ± 0.27^{bc}	4.3 ± 0.34^{e}	4.5 ± 0.34^{de}	5.2 ± 0.26^{cd}	5.6 ± 0.32^{bc}	6.3 ± 0.24^{ab}	5.9 ± 0.24^{bc}	6.3 ± 0.20^{ab}	6.9 ± 0.19^{a}
overall liking	3.4 ± 0.28^{e}	5.2 ± 0.26^{d}	3.9 ± 0.31^{e}	3.8 ± 0.27^{e}	5.4 ± 0.25^{cd}	5.7 ± 0.31^{cd}	6.8 ± 0.20^{b}	6.1 ± 0.22^{c}	6.1 ± 0.18^{c}	7.6 ± 0.16^{a}

Note: Means with the same superscripted letter are not significantly different ($p \geq 0.05$)

Conclusion

1. The physicochemical properties of rice flour and Modified starch
   - Modified starch had significantly higher moisture content and ash content than rice flour.
   - Rice flour contained amylose content 26.20 ± 0.14 %.
   - Swelling power, OSA had the highest %swelling power (8.20 + 0.31).
   - Starch granule morphology, rice flour had big particle size while modified starch had small particle.
   - Brightness colors of 3 types of modified starch were not significant different but significant higher than rice flour.
   - Pasting properties, all three types of modified starch increase more viscosity of slurry. More modified starch add, more viscosity increase. Adding modified starch decrease peak time and pasting temp.

2. Preliminary test on 'Korat' noodle production

Appropriate ratio of noodle were (40 flour : 60 water) with 40 grams slurry

3. The effect of modified starch on quality of Korat noodle
   - Modified starch reduce cook loss, increase rehydration ratio of noodle
   - Modified starch had no effect on color of noodle.
   - Modified starch had no effect on yield of noodle.
   - Modified starch reduced thickness of noodle.
   - Texture analysis, OSA15% modified starch added has the most elasticity ($p \geq 0.05$). Modified starch increased elasticity of noodle but the thinner noodle obtained. Thinner noodle resulted in loss of tensile strength.
   - Sensory evaluation, OSA15% added noodle has highest preference of color, opacity, stickiness, elasticity, flavor and overall liking. No modified added had lowest preference of stickiness, elasticity and overall liking score.

Further study recommendations

1. Further study the effect of rice particle on quality of noodle
2. Further study on freeze thaw ability of modified starch added Korat noodle
3. Further study on frozen ready to eat 'Pad mhee Korat' of modified starch added Korat noodle

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Appendix A:

Statistic analysis in the physicochemical properties of rice flour and modified starch.

Appendix A-1: Statistic analysis in the physicochemical properties of rice flour and modified starch.

1. The physicochemical properties of rice flour and modified starch.

1.1. Physicochemical properties

1.1.1. Moisture content

```
Df Sum Sq Mean Sq F value    Pr(>F)
trt         3 19.149  6.3830  213.58 1.114e-08 ***
rep          3  0.069  0.0230    0.77    0.5392
Residuals    9  0.269  0.0299
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

LSD t Test for y
P value adjustment method: bonferroni

Mean Square Error:  0.02816654

trt,  means and individual ( 95 %) CI

          y   std.err replication       LCL       UCL
AC  11.909414 0.03386718           4 11.835623 11.983204
F1   9.226936 0.15286625           4  8.893869  9.560003
OSA 11.608894 0.03890038           4 11.524137 11.693650
SA  11.704448 0.04624093           4 11.603698 11.805198

alpha: 0.05 ; Df Error: 12
Critical Value of t: 3.152681
```

Least Significant Difference 0.374138

Means with the same letter are not significantly different.

Groups, Treatments and means

a	AC	11.91
a	SA	11.7
a	OSA	11.61
b	F1	9.227

1.1.2. **Ash content**

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	3	0.54381	0.181269	44.7169	0.0001689	***
rep	3	0.01288	0.004294	1.0593	0.4331706	
Residuals	6	0.02432	0.004054			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

LSD t Test for y

P value adjustment method: bonferroni

Mean Square Error: 0.004133856

trt, means and individual (95 %) CI

	y	std.err	replication	LCL	UCL
AC	4.957200	0.02180837	4	4.907866	5.006534
F1	4.428767	0.04149764	3	4.334892	4.522641

OSA 4.873333 0.05844317 3 4.741126 5.005541

SA 4.872033 0.01057896 3 4.848102 4.895965

alpha: 0.05 ; Df Error: 9

Critical Value of t: 3.364203

Least Significant Difference 0.1710015

Harmonic Mean of Cell Sizes 3.2

Means with the same letter are not significantly different.

Groups, Treatments and means

a	AC	4.957
a	OSA	4.873
a	SA	4.872
b	F1	4.429

1.1.3. **Amylose content**

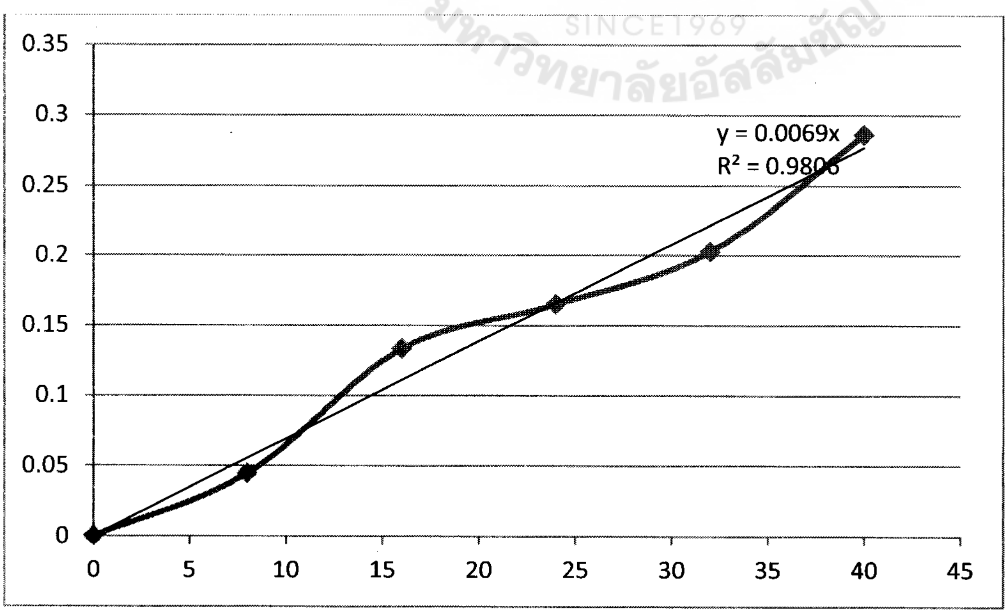

Figure 21: Standard curve of amylose content determination

1.4 Swelling power

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	4	11.5650	2.89125	43.7252	6.7e-06	***
rep	3	0.1689	0.05630	0.8515	0.5001	
Residuals	9	0.5951	0.06612			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

LSD t Test for y

P value adjustment method: bonferroni

Mean Square Error: 0.08062955

trt, means and individual (95 %) CI

	y	std.err	replication	LCL	UCL
AC	5.469117	0.2723784	3	4.852954	6.085279
F1_80	7.171150	0.0313792	4	7.100165	7.242135
OSA	8.195981	0.1797784	3	7.789294	8.602668
SA	6.989092	0.1116457	3	6.736531	7.241652

alpha: 0.05 ; Df Error: 9

Critical Value of t: 3.364203

Least Significant Difference 0.7552129

Harmonic Mean of Cell Sizes 3.2

Means with the same letter are not significantly different.

Groups, Treatments and means

a	OSA	8.196
b	F1_80	7.171
b	SA	6.989
c	AC	5.469

1.2. **Color measurement**

L*

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	3	194.838	64.946	148.1345	<2e-16	***
rep	14	3.333	0.238	0.5431	0.8922	
Residuals	42	18.414	0.438			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 0.3883438

trt, means

	y	std.err	replication
AC	92.01533	0.2177457	15
F1	87.90533	0.1240348	15
OSA	91.56467	0.1375184	15

SA 92.43667 0.1478148 15

alpha: 0.05 ; Df Error: 56

Critical Range

2 3 4

0.4558382 0.4794970 0.4950866

Means with the same letter are not significantly different.

Groups, Treatments and means

a SA 92.44

ab AC 92.02

b OSA 91.56

c F1 87.91

a*

Df Sum Sq Mean Sq F value Pr(>F)

trt 3 1.01222 0.33741 152.2462 <2e-16 ***

rep 14 0.04949 0.00354 1.5952 0.1208

Residuals 42 0.09308 0.00222

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 0.002545952

trt, means

	y	std.err	replication
AC	0.21466667	0.012222799	15
F1	-0.12333333	0.006946508	15
OSA	0.12666667	0.015543079	15
SA	-0.01666667	0.015481684	15

alpha: 0.05 ; Df Error: 56

Critical Range

2	3	4
0.03690861	0.03882423	0.04008650

Means with the same letter are not significantly different.

Groups, Treatments and means

a	AC	0.2147
b	OSA	0.1267
c	SA	-0.01667
d	F1	-0.1233

b*

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	3	239.227	79.742	3222.9303	<2e-16	***

```
rep        14   0.260   0.019    0.7515 0.7119
Residuals   42   1.039   0.025
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>
Duncan's new multiple range test
for y

Mean Square Error:  0.02320524

trt,  means

         y    std.err replication
AC  2.306667 0.03297426          15
F1  6.777333 0.05175461          15
OSA 2.314667 0.03214353          15
SA  1.920667 0.03726950          15

alpha: 0.05 ; Df Error: 56

Critical Range
      2         3         4
0.1114283 0.1172116 0.1210225

Means with the same letter are not significantly different.

Groups, Treatments and means
```

a F1 6.777

b OSA 2.315

b AC 2.307

c SA 1.921

1.5. **The study of Rapid Visco Analyser (Brabender RVA)**

Peak

Df Sum Sq Mean Sq F value Pr(>F)

trt 13 182075528 14005810 7127.3662 <2e-16 ***

rep 2 1962 981 0.4992 0.6127

Residuals 26 51092 1965

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 1894.786

trt, means

	y	std.err	replication
AC	2616.6667	14.745998	3
AC10%	700.6667	10.203485	3
AC15%	759.6667	18.853234	3
AC5%	618.3333	5.487359	3
F1_100mesh	709.6667	2.666667	3
F1_80mesh	576.3333	3.382964	3

OSA	7492.6667	81.495058	3
OSA10%	1116.3333	3.480102	3
OSA15%	1450.0000	15.373137	3
OSA5%	837.6667	11.170397	3
SA	6001.6667	18.021592	3
SA10%	1007.0000	24.419937	3
SA15%	1206.6667	12.547687	3
SA5%	740.3333	4.841946	3

alpha: 0.05 ; Df Error: 28

Critical Range

2	3	4	5	6	7	8	9
72.80324	76.49662	78.88441	80.58379	81.86276	82.86101	83.66007	84.31148

10	11	12	13	14
84.84975	85.29902	85.67680	85.99615	86.26706

Means with the same letter are not significantly different.

Groups, Treatments and means

a	OSA	7493
b	SA	6002
c	AC	2617
d	OSA15%	1450
e	SA15%	1207
f	OSA10%	1116
g	SA10%	1007

h	OSA5%	837.7
i	AC15%	759.7
i	SA5%	740.3
i	F1_100mesh	709.7
i	AC10%	700.7
j	AC5%	618.3
j	F1_80mesh	576.3

Trough

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	13	66341112	5103162	3697.6837	<2e-16	***
rep	2	924	462	0.3348	0.7185	
Residuals	26	35883	1380			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 1314.524

trt, means

	y	std.err	replication
AC	1028.0000	6.557439	3
AC10%	656.6667	8.685876	3
AC15%	704.6667	16.904963	3
AC5%	601.0000	6.350853	3

F1_100mesh 697.3333 3.527668 3

F1_80mesh 550.0000 4.163332 3

OSA 3465.6667 30.112751 3

OSA10% 1027.3333 16.148615 3

OSA15% 1390.3333 29.491995 3

OSA5% 795.6667 8.252946 3

SA 5087.3333 49.653242 3

SA10% 944.0000 29.022979 3

SA15% 1141.3333 14.310059 3

SA5% 700.6667 6.489307 3

alpha: 0.05 ; Df Error: 28

Critical Range

2 3 4 5 6 7 8 9

60.63940 63.71569 65.70454 67.11998 68.18527 69.01673 69.68229 70.22486

10 11 12 13 14

70.67320 71.04741 71.36207 71.62806 71.85370

Means with the same letter are not significantly different.

Groups, Treatments and means

a SA 5087

b OSA 3466

c OSA15% 1390

d SA15% 1141

e AC 1028

e	OSA10%	1027
f	SA10%	944
g	OSA5%	795.7
h	AC15%	704.7
h	SA5%	700.7
h	F1_100mesh	697.3
hi	AC10%	656.7
ij	AC5%	601
j	F1_80mesh	550

Breakdown

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	13	48185869	3706605	2154.0741	<2e-16	***
rep	2	4058	2029	1.1792	0.3235	
Residuals	26	44739	1721			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 1742.762

trt, means

	y	std.err	replication
AC	1588.66667	20.2758751	3

AC10%	44.00000	1.5275252	3
AC15%	55.00000	2.0816660	3
AC5%	17.33333	0.8819171	3
F1_100mesh	12.33333	1.3333333	3
F1_80mesh	26.33333	0.8819171	3
OSA	4027.00000	76.5919926	3
OSA10%	89.00000	19.0787840	3
OSA15%	59.66667	16.2924659	3
OSA5%	42.00000	7.6376262	3
SA	914.33333	33.5128499	3
SA10%	63.00000	5.1316014	3
SA15%	65.33333	1.8559215	3
SA5%	39.66667	2.1858128	3

alpha: 0.05 ; Df Error: 28

Critical Range

2	3	4	5	6	7	8	9
69.82158	73.36370	75.65370	77.28348	78.51007	79.46743	80.23377	80.85850

10	11	12	13	14
81.37473	81.80560	82.16790	82.47418	82.73399

Means with the same letter are not significantly different.

Groups, Treatments and means

a	OSA	4027
b	AC	1589

c SA 914.3

d OSA10% 89

de SA15% 65.33

e SA10% 63

e OSA15% 59.67

e AC15% 55

ef AC10% 44

efg OSA5% 42

efg SA5% 39.67

fgh F1_80mesh 26.33

gh AC5% 17.33

h F1_100mesh 12.33

Final Viscosity

Df Sum Sq Mean Sq F value Pr(>F)

trt 13 93829477 7217652 1905.9457 <2e-16 ***

rep 2 2381 1190 0.3144 0.733

Residuals 26 98460 3787

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 3601.452

trt, means

	y	std.err	replication
AC	1531.6667	5.456902	3
AC10%	957.0000	14.640128	3
AC15%	976.0000	28.513155	3
AC5%	881.3333	8.685876	3
F1_100mesh	1107.0000	2.645751	3
F1_80mesh	862.6667	3.711843	3
OSA	4452.0000	55.293158	3
OSA10%	1709.0000	16.502525	3
OSA15%	2156.3333	36.752929	3
OSA5%	1272.3333	10.333333	3
SA	6263.6667	74.194190	3
SA10%	1938.3333	49.363729	3
SA15%	2512.0000	50.003333	3
SA5%	1305.0000	20.599353	3

alpha: 0.05 ; Df Error: 28

Critical Range

2	3	4	5	6	7	8	9
100.3713	105.4632	108.7552	111.0981	112.8613	114.2376	115.3392	116.2373

10	11	12	13	14
116.9794	117.5988	118.1196	118.5599	118.9334

Means with the same letter are not significantly different.

Groups, Treatments and means

a	SA	6264
b	OSA	4452
c	SA15%	2512
d	OSA15%	2156
e	SA10%	1938
f	OSA10%	1709
g	AC	1532
h	SA5%	1305
h	OSA5%	1272
i	F1_100mesh	1107
j	AC15%	976
jk	AC10%	957
jk	AC5%	881.3
k	F1_80mesh	862.7

Set back

```
Df Sum Sq Mean Sq  F value Pr(>F)
trt         13 48.549  3.7346 450.2375 <2e-16 ***
rep          2  0.001  0.0003   0.0383 0.9625
Residuals   26  0.216  0.0083
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Duncan's new multiple range test

for y

Mean Square Error: 0.007724868

trt, means

	y	std.err	replication
AC	4.066667	0.03849002	3
AC10%	6.311111	0.04444444	3
AC15%	6.444444	0.08888889	3
AC5%	6.311111	0.08012336	3
F1_100mesh	6.111111	0.05879447	3
F1_80mesh	7.000000	0.00000000	3
OSA	4.177778	0.05879447	3
OSA10%	6.955556	0.02222222	3
OSA15%	6.755556	0.09686442	3
OSA5%	6.933333	0.03849002	3
SA	4.333333	0.00000000	3
SA10%	7.000000	0.00000000	3
SA15%	7.000000	0.00000000	3
SA5%	7.000000	0.00000000	3

alpha: 0.05 ; Df Error: 28

Critical Range

2	3	4	5	6	7	8	9
0.1469996	0.1544570	0.1592783	0.1627096	0.1652920	0.1673076	0.1689210	0.1702363

10	11	12	13	14
0.1713232	0.1722303	0.1729931	0.1736379	0.1741849

Means with the same letter are not significantly different.

Groups, Treatments and means

a	F1_80mesh	7
a	SA10%	7
a	SA15%	7
a	SA5%	7
a	OSA10%	6.956
a	OSA5%	6.933
b	OSA15%	6.756
c	AC15%	6.444
c	AC10%	6.311
c	AC5%	6.311
d	F1_100mesh	6.111
e	SA	4.333
f	OSA	4.178
f	AC	4.067

Pasting temp

Df Sum Sq Mean Sq F value Pr(>F)

trt 13 3182.0 244.768 403.6122 <2e-16 ***

rep 2 0.8 0.391 0.6452 0.5328

Residuals 26 15.8 0.606

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 0.5910714

trt, means

	y	std.err	replication
AC	71.51667	0.29486343	3
AC10%	94.00000	0.00000000	3
AC15%	94.60000	0.34034296	3
AC5%	93.16667	0.52068331	3
F1_100mesh	89.98333	0.01666667	3
F1_80mesh	92.36667	0.01666667	3
OSA	69.26667	0.25873624	3
OSA10%	89.10000	0.80000000	3
OSA15%	80.88333	0.78333333	3
OSA5%	92.05000	0.25000000	3
SA	71.73333	0.29202359	3
SA10%	88.05000	0.52519838	3
SA15%	81.41667	0.67412495	3
SA5%	91.06667	0.29202359	3

alpha: 0.05 ; Df Error: 28

Critical Range

2	3	4	5	6	7	8	9
1.285851	1.351083	1.393257	1.423271	1.445860	1.463491	1.477604	1.489110

10	11	12	13	14
1.498617	1.506551	1.513224	1.518864	1.523649

Means with the same letter are not significantly different.

Groups, Treatments and means

a	AC15%	94.6
ab	AC10%	94
bc	AC5%	93.17
cd	F1_80mesh	92.37
cd	OSA5%	92.05
de	SA5%	91.07
ef	F1_100mesh	89.98
fg	OSA10%	89.1
g	SA10%	88.05
h	SA15%	81.42
h	OSA15%	80.88
i	SA	71.73
i	AC	71.52
j	OSA	69.27

Appendix B:

Noodle production equipment, questionnaire, statistic analysis, and sensory result in the preliminary test on 'Korat' noodle production.

Appendix B-1: Noodle production equipment

Figure 22: Noodle production equipment

Noodle production equipment consists of aluminum hoop, aluminum square frame, cheesecloth

Appendix B-2: questionnaire

Sensory evaluation of Korat noodle

Instruction:

1. Please rinse your mouth with water before starting or anytime during the test you need to.
2. Please test the samples in the order presented by pick up 1-2 noodle slice to test the stickiness and elasticity attributes and taste the rest of noodle slice for softness and flavor attribute.
3. Please rate the samples from most preferred or least preferred using the following numbers (9 point hedonic scale) in providing space

   1=dislike extremely (ไม่ชอบมากที่สุด) 2=dislike very much (ไม่ชอบมาก)

   3=dislike moderately (ไม่ชอบปานกลาง) 4=dislike slightly (ไม่ชอบเล็กน้อย)

   5=neither like nor dislike(บอกไม่ได้ว่าชอบหรือไม่ชอบ)

   6=like slightly (ชอบเล็กน้อย) 7=like moderately (ชอบปานกลาง)

   8=like very much (ชอบมาก) 9=like extremely (ชอบมากที่สุด)

Attributes				
Color (สี)				
opacity (ความขุ่นใส)				
Softness(เละ หรือ แข็งกระด้าง)				
Stickiness(ความเหนียวเกาะติด)				
Elasticity(ความยากง่ายในการฉีกขาด)				
Flavor (กลิ่นรส)				
Overall liking (ความชอบโดยรวม)				

Appendix B-3: Statistic analysis and sensory result in the preliminary test on 'Korat' noodle production.

1. The study preliminary test on 'Korat' noodle production

Trt 1: 36:64

Trt 2: 38:62

Trt 3: 40:60 50 g

Trt 4: 40:60 40 g

Attribute color

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
trt	3	1.489	0.4962	0.2346	0.8719
rep	21	192.239	9.1542	4.3277	3.23e-06 ***
Residuals	63	133.261	2.1153		

Attribute: opacity

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
trt	3	1.364	0.4545	0.1171	0.9498
rep	21	82.364	3.9221	1.0100	0.4651
Residuals	63	244.636	3.8831		

Attribute: softness

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
trt	1	1.00	1.0023	0.2204	0.6400
rep	1	1.29	1.2863	0.2828	0.5962
Residuals	85	386.61	4.5483		

Attribute: stickiness

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
trt	1	0.06	0.0568	0.0138	0.9069
rep	1	5.18	5.1836	1.2546	0.2658
Residuals	85	351.20	4.1318		

Attribute: Elasticity

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	3	51.307	17.1023	5.3091	0.002513	**
rep	21	57.830	2.7538	0.8549	0.644923	
Residuals	63	202.943	3.2213			

Mean Square Error: 3.104437

trt, means

	y	std.err	replication
1	2.954545	0.2750622	22
2	3.363636	0.3389917	22
3	4.454545	0.3821067	22
4	4.818182	0.4773500	22

alpha: 0.05 ; Df Error: 84

Critical Range

2	3	4
1.056440	1.111641	1.148227

Means with the same letter are not significantly different.

Groups, Treatments and means

a	4	4.818
a	3	4.455
b	2	3.364
b	1	2.955

Attribute: flavor

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	3	1.682	0.5606	0.1582	0.92404	
rep	21	126.955	6.0455	1.7055	0.05382	.
Residuals	63	223.318	3.5447			

Attribute: thickness

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	3	38.670	12.8902	2.9468	0.03953	*
rep	21	50.648	2.4118	0.5514	0.93500	
Residuals	63	275.580	4.3743			

Mean Square Error: 3.883658

trt, means

	y	std.err	replication
1	4.000000	0.4558423	22
2	4.000000	0.4923660	22
3	3.545455	0.3821067	22
4	5.318182	0.3315082	22

alpha: 0.05 ; Df Error: 84

Critical Range

2	3	4
1.181609	1.243351	1.284271

Means with the same letter are not significantly different.

Groups, Treatments and means

a	4	5.318
b	1	4
b	2	4
b	3	3.545

Attribute: overall liking

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
trt	3	0.58	0.1932	0.0407	0.989
rep	21	103.69	4.9378	1.0398	0.433
Residuals	63	299.17	4.7487		

Appendix C: Statistic analysis and sensory result in the effect of modified starch on quality of 'Korat' noodle.

Appendix C-1: Statistic analysis and sensory result in the effect of modified starch on quality of 'Korat' noodle.

1. The effect of modified starch on quality of 'Korat' noodle.

1.1 Cook loss properties

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	147.318	16.3687	57.504	2.736e-15	***
rep	3	0.836	0.2787	0.979	0.4172	
Residuals	27	7.686	0.2847			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 0.2840541

trt, means

	y	std.err	replication
AC10%	10.672758	0.3253306	4
AC15%	9.437915	0.3807658	4
AC5%	12.873015	0.1290772	4
F1	14.344518	0.1072078	4
OSA10%	10.149732	0.2097934	4
OSA15%	9.001005	0.2278742	4
OSA5%	12.035774	0.3697362	4
SA10%	10.604541	0.3197843	4

SA15%	8.299334	0.2641437	4
SA5%	11.586081	0.1627254	4

alpha: 0.05 ; Df Error: 30

Critical Range

2	3	4	5	6	7	8	9
0.7696605	0.8088343	0.8342285	0.8523544	0.8660394	0.8767570	0.8853677	0.8924153

10
0.8982641

Means with the same letter are not significantly different.

Groups, Treatments and means

a	F1	14.34
b	AC5%	12.87
c	OSA5%	12.04
c	SA5%	11.59
d	AC10%	10.67
d	SA10%	10.6
de	OSA10%	10.15
ef	AC15%	9.438
f	OSA15%	9.001
g	SA15%	7.299

1.2 Rehydration ratio properties

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	2.99890	0.33321	15.8940	1.23e-08	***
rep	3	0.05668	0.01889	0.9013	0.4534	
Residuals	27	0.56605	0.02096			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 0.02075766

trt, means

	y	std.err	replication
AC10%	1.9002510	0.093007853	4
AC15%	2.0594704	0.152804934	4
AC5%	1.6302093	0.008039644	4
F1	0.9621882	0.026051971	4
OSA10%	1.6885953	0.062465758	4
OSA15%	1.7808205	0.061953376	4
OSA5%	1.6412290	0.019971580	4
SA10%	1.6729158	0.055219325	4
SA15%	1.8399480	0.068051029	4
SA5%	1.6339783	0.057722002	4

alpha: 0.05 ; Df Error: 30

Critical Range

2	3	4	5	6	7	8	9
0.2080597	0.2186494	0.2255141	0.2304140	0.2341134	0.2370107	0.2393384	0.2412435

10
0.2428246

Means with the same letter are not significantly different.

Groups, Treatments and means

a	AC15%	2.059
ab	AC10%	1.9
bc	SA15%	1.84
bc	OSA15%	1.781
bc	OSA10%	1.689
bc	SA10%	1.673
c	OSA5%	1.641
c	SA5%	1.634
c	AC5%	1.63
d	F1	0.9622

1.3 Color measurement

1.3.1 Fresh noodle

L*

Df Sum Sq Mean Sq F value Pr(>F)

```
trt        9  91.005 10.1117  2.6211 0.01035 *
rep        9  51.770  5.7522  1.4911 0.16528
Residuals 81 312.477  3.8577
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test
for y

Mean Square Error:  4.047189

trt,  means

            y   std.err replication
AC10%  31.546 1.2408673          10
AC15%  30.630 0.4527300          10
AC5%   33.082 0.6789924          10
F1     32.550 0.1790407          10
OSA10% 32.242 0.3582575          10
OSA15% 30.759 0.3769098          10
OSA5%  33.210 0.4492092          10
SA10%  31.653 0.7456482          10
SA15%  30.613 0.4483750          10
SA5%   30.888 0.7616806          10

alpha: 0.05 ; Df Error: 90
```

Critical Range

2	3	4	5	6	7	8	9
1.787387	1.880863	1.942863	1.988230	2.023404	2.051741	2.075199	2.095019

10
2.112033

Means with the same letter are not significantly different.

Groups, Treatments and means

a	OSA5%	33.21
a	AC5%	33.08
ab	F1	32.55
ab	OSA10%	32.24
ab	SA10%	31.65
ab	AC10%	31.55
b	SA5%	30.89
b	OSA15%	30.76
b	AC15%	30.63
b	SA15%	30.61

a*

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	0.240145	0.0266828	7.0718	1.751e-07	***
rep	9	0.061505	0.0068339	1.8112	0.07864	.
Residuals	81	0.305625	0.0037731			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 0.004079222

trt, means

	y	std.err	replication
AC10%	-0.872	0.03213859	10
AC15%	-0.789	0.01870532	10
AC5%	-0.875	0.01447220	10
F1	-0.875	0.01127928	10
OSA10%	-0.963	0.01350309	10
OSA15%	-0.910	0.02255857	10
OSA5%	-0.968	0.01902046	10
SA10%	-0.895	0.01752776	10
SA15%	-0.860	0.01949359	10
SA5%	-0.908	0.02489087	10

alpha: 0.05 ; Df Error: 90

Critical Range

2	3	4	5	6	7	8
0.05674537	0.05971301	0.06168137	0.06312169	0.06423839	0.06513799	0.06588274

9	10
0.06651199	0.06705213

Means with the same letter are not significantly different.

Groups, Treatments and means

a AC15% -0.789

b SA15% -0.86

b AC10% -0.872

b AC5% -0.875

b F1 -0.875

b SA10% -0.895

bc SA5% -0.908

bc OSA15% -0.91

c OSA10% -0.963

c OSA5% -0.968

b*

Df Sum Sq Mean Sq F value Pr(>F)

trt 9 4.6721 0.51912 4.7845 4.038e-05 ***

rep 9 1.2058 0.13398 1.2348 0.2858

Residuals 81 8.7885 0.10850

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 0.1110477

trt, means

	y	std.err	replication
AC10%	1.377	0.13254810	10
AC15%	0.960	0.08071899	10
AC5%	1.316	0.03621540	10
F1	0.897	0.07337953	10
OSA10%	1.213	0.06706630	10
OSA15%	0.641	0.09345766	10
OSA5%	1.195	0.08917212	10
SA10%	1.060	0.12027746	10
SA15%	1.024	0.11959376	10
SA5%	0.844	0.17410852	10

alpha: 0.05 ; Df Error: 90

Critical Range

2	3	4	5	6	7	8	9	10
0.2960714	0.3115552	0.3218252	0.3293401	0.3351666	0.3398603	0.3437460	0.3470292	0.3498474

Means with the same letter are not significantly different.

Groups, Treatments and means

a	AC10%	1.377
ab	AC5%	1.316
abc	OSA10%	1.213
abc	OSA5%	1.195

abcd SA10% 1.06

bcd SA15% 1.024

cde AC15% 0.96

cde F1 0.897

de SA5% 0.844

e OSA15% 0.641

1.3.2 Dried noodle

L*

Df Sum Sq Mean Sq F value Pr(>F)

trt 9 39.804 4.4226 11.5868 2.817e-08 ***

rep 4 0.223 0.0558 0.1461 0.9636

Residuals 36 13.741 0.3817

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 0.349102

trt, means

	y	std.err	replication
AC10%	28.766	0.1789581	5
AC15%	28.842	0.2821950	5
AC5%	26.966	0.2267730	5
F1	27.346	0.2387802	5

OSA10% 28.776 0.1675291 5

OSA15% 29.046 0.1627452 5

OSA5% 26.998 0.3722016 5

SA10% 28.782 0.3663523 5

SA15% 29.016 0.2933871 5

SA5% 26.974 0.2544130 5

alpha: 0.05 ; Df Error: 40

Critical Range

2	3	4	5	6	7	8	9
0.7552464	0.7941076	0.8195280	0.8378516	0.8518328	0.8629068	0.8719120	0.8793786

10
0.8856619

Means with the same letter are not significantly different.

Groups, Treatments and means

a	OSA15%	29.05
a	SA15%	29.02
a	AC15%	28.84
a	SA10%	28.78
a	OSA10%	28.78
a	AC10%	28.77
b	F1	27.35
b	OSA5%	27
b	SA5%	26.97

b AC5% 26.97

a*

```
Df  Sum Sq   Mean Sq F value  Pr(>F)
trt        9 0.042018 0.0046687  2.8194 0.01289 *
rep        4 0.008708 0.0021770  1.3147 0.28308
Residuals  36 0.059612 0.0016559
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Duncan's new multiple range test
for y

Mean Square Error:  0.001708

trt,  means

          y     std.err replication
AC10%  -0.462 0.020346990         5
AC15%  -0.462 0.020346990         5
AC5%   -0.500 0.025690465         5
F1     -0.502 0.029732137         5
OSA10% -0.484 0.010295630         5
OSA15% -0.510 0.019235384         5
OSA5%  -0.548 0.014966630         5
SA10%  -0.482 0.013190906         5
SA15%  -0.484 0.009273618         5
SA5%   -0.548 0.009165151         5
```

alpha: 0.05 ; Df Error: 40

Critical Range

2	3	4	5	6	7	8
0.05282706	0.05554528	0.05732335	0.05860503	0.05958297	0.06035755	0.06098744

9	10
0.06150971	0.06194921

Means with the same letter are not significantly different.

Groups, Treatments and means

a	AC10%	-0.462
a	AC15%	-0.462
a	SA10%	-0.482
a	OSA10%	-0.484
a	SA15%	-0.484
ab	AC5%	-0.5
ab	F1	-0.502
ab	OSA15%	-0.51
b	OSA5%	-0.548
b	SA5%	-0.548

b*

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	4.1256	0.45840	5.4440	0.0001028	***
rep	4	0.3556	0.08889	1.0557	0.3924726	
Residuals	36	3.0313	0.08420			

```
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test
for y

Mean Square Error:  0.084672

trt,  means

          y    std.err replication
AC10%  3.446 0.19956453           5
AC15%  3.484 0.08981091           5
AC5%   2.846 0.14361755           5
F1     3.374 0.17362603           5
OSA10% 3.724 0.15390257           5
OSA15% 3.414 0.06169279           5
OSA5%  2.970 0.11920570           5
SA10%  3.328 0.07165194           5
SA15%  3.470 0.07543209           5
SA5%   2.822 0.13473678           5

alpha: 0.05 ; Df Error: 40

Critical Range
        2         3         4         5         6         7         8         9
0.3719482 0.3910867 0.4036059 0.4126301 0.4195156 0.4249693 0.4294043 0.4330815
```

10

0.4361760

Means with the same letter are not significantly different.

Groups, Treatments and means

a	OSA10%	3.724
a	AC15%	3.484
a	SA15%	3.47
a	AC10%	3.446
a	OSA15%	3.414
a	F1	3.374
ab	SA10%	3.328
bc	OSA5%	2.97
c	AC5%	2.846
c	SA5%	2.822

1.4 Yield, Thickness

Yield

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
trt	9	20.882	2.3202	0.4280	0.8889
rep	1	0.182	0.1820	0.0336	0.8587
Residuals	9	48.793	5.4215		

Thickness

Fresh noodle

```
          Df  Sum Sq  Mean Sq F value    Pr(>F)
trt        9 0.85307 0.094785 14.6013 1.086e-10 ***
rep        5 0.09983 0.019966  3.0756   0.01797 *
Residuals 45 0.29212 0.006492
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Duncan's new multiple range test
for y


Mean Square Error:  0.007839


trt,  means


               y    std.err replication
AC10%  1.0300000 0.03855732           6
AC15%  0.9200000 0.02463060           6
AC5%   1.0650000 0.03528456           6
F1     1.3416667 0.02468693           6
OSA10% 1.0383333 0.04190598           6
OSA15% 0.9066667 0.02752776           6
OSA5%  1.0900000 0.05329165           6
SA10%  1.0050000 0.03870831           6
SA15%  0.9200000 0.02670830           6
SA5%   1.0550000 0.03939120           6
```

alpha: 0.05 ; Df Error: 50

Critical Range

2	3	4	5	6	7	8	9
0.1026725	0.1079880	0.1114830	0.1140164	0.1159610	0.1175111	0.1187801	0.1198398

10
0.1207384

Means with the same letter are not significantly different.

Groups, Treatments and means

a	F1	1.342
b	OSA5%	1.09
b	AC5%	1.065
b	SA5%	1.055
b	OSA10%	1.038
b	AC10%	1.03
bc	SA10%	1.005
c	AC15%	0.92
c	SA15%	0.92
c	OSA15%	0.9067

Dried noodle

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	0.43044	0.047826	31.7641	<2e-16	***
rep	5	0.00403	0.000806	0.5351	0.7486	
Residuals	45	0.06776	0.001506			

```
---

Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Duncan's new multiple range test

for y


Mean Square Error:  0.001435667


trt,  means


          y     std.err replication
AC10%  0.8800000 0.011254629      6
AC15%  0.7533333 0.022010099      6
AC5%   0.9483333 0.015147424      6
F1     0.9583333 0.020723041      6
OSA10% 0.8650000 0.009219544      6
OSA15% 0.7566667 0.018012341      6
OSA5%  0.9833333 0.008027730      6
SA10%  0.8600000 0.009309493      6
SA15%  0.7633333 0.018196459      6
SA5%   0.9533333 0.015202339      6


alpha: 0.05 ; Df Error: 50


Critical Range

       2          3          4          5          6          7          8
0.04393906 0.04621382 0.04770951 0.04879370 0.04962591 0.05028927 0.05083235
```

9	10
0.05128587	0.05167042

Means with the same letter are not significantly different.

Groups, Treatments and means

a	OSA5%	0.9833
a	F1	0.9583
a	SA5%	0.9533
a	AC5%	0.9483
b	AC10%	0.88
b	OSA10%	0.865
b	SA10%	0.86
c	SA15%	0.7633
c	OSA15%	0.7567
c	AC15%	0.7533

1.5 Texture analysis

Tensile strength

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	4417.6	490.85	5.7557	2.348e-06	***
rep	21	2142.8	102.04	1.1965	0.2723	
Residuals	95	8101.6	85.28			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 88.31384

trt, means

	y	std.err	replication
AC10%	21.66917	2.3984659	12
AC15%	8.50250	0.5764601	8
AC5%	22.99125	1.6302984	8
F1	31.86656	4.1632718	11
OSA10%	28.42824	2.9049702	17
OSA15%	25.94750	1.7861389	16
OSA5%	29.07455	2.6344878	11
SA10%	34.37769	3.1320038	13
SA15%	23.40318	1.8107137	22
SA5%	27.87375	3.1095308	8

alpha: 0.05 ; Df Error: 116

Critical Range

2	3	4	5	6	7	8	9
7.825675	8.236033	8.508849	8.708982	8.864565	8.990254	9.094614	9.183061

10
9.259228

Harmonic Mean of Cell Sizes 11.3141

Different value for each comparison

Means with the same letter are not significantly different.

Groups, Treatments and means

a	SA10%	34.38
ab	F1	31.87
abc	OSA5%	29.07
abc	OSA10%	28.43
abc	SA5%	27.87
abc	OSA15%	25.95
bc	SA15%	23.4
bc	AC5%	22.99
c	AC10%	21.67
d	AC15%	8.502

Elasticity

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	1628.19	180.910	8.8759	1.352e-09	***
rep	21	424.58	20.218	0.9919	0.4804	
Residuals	95	1936.31	20.382			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Duncan's new multiple range test

for y

Mean Square Error: 20.35246

trt, means

	y	std.err	replication
AC10%	-7.990000	0.5902580	12
AC15%	-5.975000	1.1095865	8
AC5%	-10.493750	1.9024683	8
F1	-6.255182	0.8452152	11
OSA10%	-11.450588	0.9404674	17
OSA15%	-17.080000	1.5900236	16
OSA5%	-10.942727	1.4974986	11
SA10%	-14.579231	1.0985080	13
SA15%	-15.259091	1.1224320	22
SA5%	-10.608750	1.3387473	8

alpha: 0.05 ; Df Error: 116

Critical Range

2	3	4	5	6	7	8	9
3.756781	3.953777	4.084745	4.180820	4.255509	4.315847	4.365946	4.408406

10
4.444970

Harmonic Mean of Cell Sizes 11.3141

Different value for each comparison

Means with the same letter are not significantly different.

Groups, Treatments and means

a	AC15%	-5.975
a	F1	-6.255
ab	AC10%	-7.99
bc	AC5%	-10.49
bc	SA5%	-10.61
bc	OSA5%	-10.94
bcd	OSA10%	-11.45
cde	SA10%	-14.58
de	SA15%	-15.26
e	OSA15%	-17.08

1.6 Sensory evaluation

Color

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	130.87	14.5411	7.3461	1.529e-09	***
rep	29	166.67	5.7472	2.9035	3.568e-06	***
Residuals	261	516.63	1.9794			

Duncan's new multiple range test

for y

Mean Square Error: 2.356207

trt, means

	y	std.err	replication
1	6.033333	0.2603417	30

10	5.700000	0.3327005	30
2	5.500000	0.3482303	30
3	4.900000	0.3693735	30
4	6.533333	0.2432223	30
5	6.266667	0.2991687	30
6	7.166667	0.1862104	30
7	6.600000	0.2122675	30
8	6.166667	0.2448708	30
9	7.033333	0.2467412	30

alpha: 0.05 ; Df Error: 290

Critical Range

2	3	4	5	6	7	8	9
0.7800554	0.8211774	0.8486455	0.8688983	0.8847277	0.8975882	0.9083293	0.9174888

10
0.9254267

Means with the same letter are not significantly different.

Groups, Treatments and means

a	6	7.167
ab	9	7.033
abc	7	6.6
abcd	4	6.533
bcde	5	6.267
bcde	8	6.167

cde	1	6.033
def	10	5.7
ef	2	5.5
f	3	4.9

Elasticity

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	551.27	61.252	25.7297	<2e-16	***
rep	29	76.07	2.623	1.1018	0.3344	
Residuals	261	621.33	2.381			

Duncan's new multiple range test

for y

Mean Square Error: 2.404828

trt, means

	y	std.err	replication
1	4.833333	0.2673124	30
10	3.633333	0.3233564	30
2	3.633333	0.2974348	30
3	3.533333	0.3736534	30
4	4.300000	0.2760560	30
5	4.666667	0.3045001	30
6	6.866667	0.2384497	30
7	5.700000	0.2451835	30
8	5.800000	0.2812125	30

9 7.700000 0.1803572 30

alpha: 0.05 ; Df Error: 290

Critical Range

2	3	4	5	6	7	8	9
0.7880626	0.8296067	0.8573568	0.8778175	0.8938093	0.9068018	0.9176532	0.9269067

10
0.9349261

Means with the same letter are not significantly different.

Groups, Treatments and means

a	9	7.7
b	6	6.867
c	8	5.8
c	7	5.7
d	1	4.833
d	5	4.667
de	4	4.3
e	10	3.633
e	2	3.633
e	3	3.533

Flavor

Df Sum Sq Mean Sq F value Pr(>F)

trt 9 262.47 29.1633 13.2094 < 2e-16 *** rep 29 103.74 3.5771 1.6202 0.02697 *

Residuals 261 576.23 2.2078

Duncan's new multiple range test

for y

Mean Square Error: 2.344713

trt, means

	y	std.err	replication
1	5.700000	0.2718603	30
10	3.833333	0.3359096	30
2	4.300000	0.3429085	30
3	4.500000	0.3381831	30
4	5.233333	0.2612232	30
5	5.600000	0.3202011	30
6	6.300000	0.2404498	30
7	5.866667	0.2384497	30
8	6.333333	0.1996165	30
9	6.900000	0.1938716	30

alpha: 0.05 ; Df Error: 290

Critical Range

2	3	4	5	6	7	8	9
0.7781504	0.8191720	0.8465730	0.8667764	0.8825671	0.8953961	0.9061111	0.9152481

10

0.9231667

Means with the same letter are not significantly different.

Groups, Treatments and means

a	9	6.9
ab	8	6.333
ab	6	6.3
bc	7	5.867
bc	1	5.7
bc	5	5.6
cd	4	5.233
de	3	4.5
e	2	4.3
e	10	3.833

Opacity

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	106.0	11.7778	6.3988	3.299e-08	***
rep	29	250.6	8.6414	4.6948	3.439	

Duncan's new multiple range test

for y

Mean Square Error: 2.52069

trt, means

	y	std.err	replication
1	5.966667	0.2420380	30
10	5.233333	0.2823682	30
2	5.333333	0.3007016	30
3	4.933333	0.3649385	30
4	5.733333	0.3029864	30
5	5.733333	0.3141613	30
6	6.733333	0.2709427	30
7	6.266667	0.2534059	30
8	6.266667	0.2579019	30
9	6.800000	0.2892718	30

alpha: 0.05 ; Df Error: 290

Critical Range

2	3	4	5	6	7	8	9	10
0.8068233	0.8493564	0.8777671	0.8987149	0.9150875	0.9283892	0.9394990	0.9489727	0.9571831

Means with the same letter are not significantly different.

Groups, Treatments and means

a	9	6.8
a	6	6.733

ab 7 6.267

ab 8 6.267

abc 1 5.967

bcd 4 5.733

bcd 5 5.733

cd 2 5.333

cd 10 5.233

d 3 4.933

Softness

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	304.9	33.877	12.3837	2.542e-16	***
rep	29	148.5	5.121	1.8718	0.005735	**
Residuals	261	714.0	2.736			

Duncan's new multiple range test

for y

Mean Square Error: 2.974138

trt, means

	y	std.err	replication
1	4.633333	0.3635184	30
10	3.266667	0.3104810	30
2	4.066667	0.3455242	30
3	3.700000	0.3112821	30
4	4.500000	0.3060689	30

5	5.033333	0.3088106	30
6	6.766667	0.2283541	30
7	5.500000	0.2866774	30
8	6.000000	0.2397317	30
9	5.166667	0.4070735	30

alpha: 0.05 ; Df Error: 290

Critical Range

2	3	4	5	6	7	8	9
0.8763938	0.9225944	0.9534549	0.9762090	0.9939933	1.0084421	1.0205098	1.0308004

10
1.0397188

Means with the same letter are not significantly different.

Groups, Treatments and means

a	6	6.767
ab	8	6
bc	7	5.5
bcd	9	5.167
cd	5	5.033
cde	1	4.633
de	4	4.5
ef	2	4.067
ef	3	3.7
f	10	3.267

Stickiness

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	515.28	57.253	29.2589	<2e-16	***
rep	29	62.35	2.150	1.0987	0.3383	
Residuals	261	510.72	1.957			

Duncan's new multiple range test

for y

Mean Square Error: 1.976092

trt, means

	y	std.err	replication
1	5.000000	0.3216338	30
10	3.166667	0.2253137	30
2	3.733333	0.2953017	30
3	3.800000	0.2932184	30
4	4.933333	0.3104810	30
5	5.366667	0.2558885	30
6	6.866667	0.2075214	30
7	5.933333	0.1913854	30
8	5.900000	0.2414039	30
9	7.433333	0.1773582	30

alpha: 0.05 ; Df Error: 290

Critical Range

2	3	4	5	6	7	8	9
0.7143685	0.7520277	0.7771828	0.7957302	0.8102266	0.8220041	0.8318408	0.8402289

10
0.8474984

Means with the same letter are not significantly different.

Groups, Treatments and means

a	9	7.433
a	6	6.867
b	7	5.933
b	8	5.9
bc	5	5.367
c	1	5
c	4	4.933
d	3	3.8
d	2	3.733
d	10	3.167

Overall liking

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
trt	9	492.16	54.685	29.5541	<2e-16	***
rep	29	62.70	2.162	1.1684	0.259	
Residuals	261	482.94	1.850			

Duncan's new multiple range test

for y

Mean Square Error: 1.881494

trt, means

	y	std.err	replication
1	5.200000	0.2555139	30
10	3.433333	0.2823682	30
2	3.933333	0.3104810	30
3	3.766667	0.2741060	30
4	5.400000	0.2518894	30
5	5.700000	0.3149530	30
6	6.800000	0.2000000	30
7	6.100000	0.2215411	30
8	6.066667	0.1789711	30
9	7.566667	0.1638848	30

alpha: 0.05 ; Df Error: 290

Critical Range

2	3	4	5	6	7	8	9	10
0.6970600	0.7338068	0.7583524	0.7764504	0.7905956	0.8020877	0.8116860	0.8198709	0.8269643

Means with the same letter are not significantly different.

Groups, Treatments and means

a	9	7.567
b	6	6.8
c	7	6.1
c	8	6.067
cd	5	5.7
cd	4	5.4
d	1	5.2
e	2	3.933
e	3	3.767
e	10	3.433