การพัฒนาขนมจีนพร้อมบริโภค

นางสาวภาณิศา ชิณเครือ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญามหาบัณฑิต
สาขาวิชาเทคโนโลยีทางอาหาร ภาควิชาเทคโนโลยีทางอาหาร
คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2554

DEVELOPMENT OF READY-TO-EAT KANOM JEEN

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A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Master of Science Program in Food Technology

Department of Food Technology

Faculty of Science

Chulalongkorn University

Academic Year 2011

Thesis Title	DEVELOPMENT OF READY-TO-EAT KANOM JEEN
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Field of Study	Food Technology
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ภาณิศา ชิณเครือ : การพัฒนาขนมจีนพร้อมบริโภค. (DEVELOPMENT OF READY-TO-EAT KANOM JEEN) อ. ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร. สายวรุฬ ชัยวานิชศิริ, อ. ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ. ดร. กัลยา เลาหสงคราม, 84 หน้า.

ขนมจีนเป็นผลิตภัณฑ์อาหารเส้นจากข้าวที่นิยมบริโภคทั่วไป แต่เนื่องจากมีอายุการเก็บรักษาสั้น ที่อุณหภูมิห้อง งานวิจัยนี้จึงมีจุดประสงค์เพื่อพัฒนากระบวนการผลิตเพื่อเพิ่มอายุการเก็บรักษาของขนมจีน โดยศึกษาผลของการแช่แป้งในน้ำที่เติมกรดซิตริกหรือกรดแลกติกที่ความเข้มข้น 1 %, 2 % และ 3 % (w/w) ในขั้นตอนการนอนแป้งที่อุณหภูมิห้องต่อสมบัติทางเคมีและกายภาพของแป้งข้าวเจ้า พบว่า การแช่กรดทำให้แป้งข้าวมีปริมาณแอมิโลส โปรตีน ไขมัน ดัชนีความขาวและความหนืดลดลง และกำลังการพองตัวและการละลายที่อุณหภูมิ 75 ^{o}C ของแป้งข้าวเพิ่มขึ้น เมื่อนำน้ำแป้งที่ได้ไปผลิตเป็นขนมจีน พบว่าเมื่อเพิ่มความเข้มข้นของกรด ขนมจีนมีค่าแรงดึงสูงสุดและค่าการคืนตัวเพิ่มขึ้น แต่ค่าแรงกดสูงสุดและค่าความเหนียวลดลง โดยขนมจีนจากแป้งที่ผ่านการแช่ในกรดซิตริก 2% (w/w) มีค่าดัชนีความขาวและคะแนนความชอบโดยรวมสูงสุด เมื่อแปรสัดส่วนแป้งสุกต่อแป้งดิบในขั้นตอนการนึ่งและนวดเป็น 15:85, 20:80 และ 25:75 พบว่าสัดส่วนแป้งสุกต่อแป้งดิบ 15:85 ได้ขนมจีนที่มีค่าแรงกดสูงสุด จากการศึกษาผลของการเติมกรดซิตริก (0.25%, w/w) และเกลือ (7%, w/w) ในน้ำที่ใช้ในขั้นตอนการโรยเส้น พบว่าขนมจีนที่โรยเส้นในน้ำที่มีส่วนผสมของกรดซิตริกและเกลือสามารถลดค่า pH ของขนมจีนเป็น 3.88 โดยไม่มีผลต่อลักษณะเนื้อสัมผัสของขนมจีน จากการบรรจุขนมจีนที่ได้ในถุงลามิเนตที่เติมไนโตรเจนและให้ความร้อนที่อุณหภูมิ 85 ^{o}C และ 90 ^{o}C เป็นเวลา 1, 3 และ 5 นาที พบว่าขนมจีนภายหลังการให้ความร้อน มีค่าการคืนตัวและแรงกดสูงสุดลดลง และปริมาณจุลินทรีย์ทั้งหมดและยีสต์และราน้อยกว่า 250 และ 100 โคโลนี/กรัม โดยขนมจีนที่ผ่านการให้ความร้อนที่อุณหภูมิ 90^{o}C นาน 3 นาที มีอายุการเก็บรักษา 29 วัน ที่อุณหภูมิห้อง

ภาควิชา..เทคโนโลยีทางอาหาร……	ลายมือชื่อนิสิต…………………………………..
สาขาวิชา.เทคโนโลยีทางอาหาร.......	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก……..……
ปีการศึกษา.....2554......................	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม……..……

5272712623 : MAJOR FOOD TECHNOLOGY

KEYWORDS: RICE NOODLE / ACID-TREATED / PREGELATINIZED RICE FLOUR / HURDLE / SHELF-STABLE / PASTEURIZATION / NITROGEN

PANISA CHINKRUA : DEVELOPMENT OF READY-TO-EAT KANOM JEEN. ADVISOR : ASSOC. PROF. SAIWARUN CHAIWANICHSIRI, Ph. D., CO-ADVISOR : ASSOC. PROF. KALAYA LAOHASONGKRAM, Ph. D., 84 pp.

Kanom Jeen is a popular rice noodle product however, its storage shelf-life is short at room temperature. Thus, the objective of this study was to develop a process to extend its shelf – life with the acceptable quality. Firstly, the effect of acid (citric acid or lactic acid) during soaking on the physicochemical properties of rice flour was investigated. It was found that amylose, protein, and fat contents and viscosity of rice flour decreased while swelling power and solubility at 75 ^{O}C increased after acid treatment. Kanom Jeen prepared from acid - treated rice flour had higher tensile strength and springiness but lower hardness and stickiness than those of control sample. Kanom Jeen prepared from rice flour treated with 2% (w/w) citric acid had the highest whiteness index and overall liking score. Secondly, during steaming and kneading steps, the ratio of gelatinized to ungelatinized rice flour was varied at 15:85, 20:80 and 25:75. It was found that the gelatinized rice ratio at 15:85 gave the highest hardness Kanom Jeen. Next, the effect of adding citric acid (0.25%, w/w) and salt (7%, w/w) in the boiling water during cooking was studied and the results showed that the pH of Kanom Jeen was reduced to 3.88 without affecting the textural characteristics. After that, the sample was kept in PE/AL/PE – laminated pouch with nitrogen gas flushing and heated at 85^{O}C and 90^{O}C for 1, 3 and 5 min. The result showed that springiness and tensile strength of samples decreased whereas total aerobic plate count and yeast and moulds in sample were lower than 250 cfu/g and 100 cfu/g, respectively. The Kanom Jeen pasteurized at 90^{O}C for 3 min could be stored up to 29 days at room temperature.

Department : Food Technology	Student's Signature
Field of Study : Food Technology	Advisor's Signature
Academic Year : 2011	Co-advisor's Signature

ACKNOWLEDGEMENTS

I would like to gratefully acknowledge my advisor, Assoc. Prof. Dr. Saiwarun Chaiwanichsiri, and my co-advisor, Assoc. Prof. Dr. Kalaya Laohasongkram, for their guidance, support and encouragement all the time of research and writing of this thesis. I also wish to specially thank my thesis examiners, Prof. Dr. Vanna Tulyathan, Dr. Thanachan Mahawanich, and Dr. Kanitha Tananuwong, for their valuable suggestions.

The financial support from the THE 90th ANNIVERSARY OF CHULALONGKORN UNIVERSITY FUND (Ratchadaphiseksomphot Endowment Fund), The Thailand Research Fund - Master Research Grants and Burapaprosper Co., Ltd., Chonburi (Thailand) are particularly acknowledged. I am grateful to Mathnisium (The Math Workout Center) for great experience in mathematical teaching and their support.

I would like to thank all staffs and friends at Food Technology Department, Chulalongkorn University for their help and encouragement.

Especially, I am heartily thankful to my father, mother and brother for their care, morale and unremittingly support and also my best friends at Nawaminthrachinuthit Triamudomsuksanomklao School for cheerfulness.

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CHAPTER I

INTRODUCTION

Kanom Jeen is a traditional rice noodle product, which has widely consumed in Thailand (Naivikul, 2004; Keatkrai and Jirapakkul, 2010). Fresh Kanom Jeen has better odor and color but less elastic texture than fermented Kanom Jeen (Sribuathong *et al*., 2004). Acids, which are produced by lactic acid bacteria during fermentation, is the main factor in making good characteristics of Kanom Jeen (Naivikul, 2004; Sribuathong *et al*., 2004; Oupathumpanont *et al*., 2009). In this study, acid treatment is chosen to imitate the fermentation step by using organic acids which are also found in natural fermentation and added to foods as acidulant or preservative. Moreover, this fresh noodle has high water activity (more than 0.95) and short shelf – life at ambient temperature (Kittiya, 2007). Drying and freezing can be used to preserve the noodle products but texture of rehydrated product becomes harder (Hou *et al*., 2010). Nowadays, the consumer demands more natural and fresh like foods, which only mild preservation techniques are applied. Hurdle technology is a combination of different preservative factors or techniques used to control microbial spoilage and food poisoning (Leistner and Gorris, 1995). Therefore, this study aims to develop a process for making acceptable Kanom Jeen by combining the acidification, heating and packaging condition to extend its shelf – stable at room temperature.

CHAPTER II

LITERATURE REVIEW

2.1 RICE

Rice, seed of monocot plant *Oryza sativa* L., is a staple food in Asia and mostly consumed as white grain (Naivikul, 2004). The quality and chemical compositions of rice depend on growth environment, cultivar, genotype, location of rice and storage time (Zhou *et al*., 2002; Zhou *et al*., 2003).

2.1.1 Chemical compositions of rice

2.1.1.1 Proteins

Milled rice kernel contains about 7 – 8 % (db.) proteins. Albumin and globulins in aleurone layer can be removed during wet – milling (Lim *et al*., 1999; Ellepola and Ma, 2006). Protein content is one of indirect indicator of cooking qualities because it acts as barrier of water diffusion during cooking of the grain and has effect on pasting and functional properties of rice flour by forming complexes with the starch granules (Lim *et al*., 1999; Ellepola and Ma, 2006; Mason, 2009). Rice flour, which has high protein content, tends to be lower in viscosity caused by protein complexes inhibiting the extent of swelling (Lim *et al*., 1999).

2.1.1.2 Lipids

Lipids, which are minor components, may partly form complex with the amylose chain (Lu *et al*., 2003; Mason, 2009). Complexes of these lipids are hard to remove from the starch and influence physico – chemical properties of rice noodle (Li and Yeh, 2001; Lu *et al*., 2003; Biliaderis, 2009). High lipid content decreased viscosity due to lipid complexes inhibited the extent of swelling (Li and Yeh, 2001; Biliaderis, 2009).

2.1.1.3 Carbohydrates

Rice contains compound granules, which have polyhedral shape. These granules are tightly packed, hard to separate and diameter of rice granules ranges from 3 – 8 μm (Reddy *et al*., 2008). Rice differs in the amylose content, which is an indicator to determine the quality of rice flour. Rice can be classified based on its amylose content as waxy (0 – 2%), very low (2 – 9%), low (10 – 20%), intermediate (20 – 25%) and high amylose (more than 25%) (Juliano, 1985). High amylose rice was suitable for producing rice noodle with high hardness and tensile strength (Bhattacharya, Zee, and Corke, 1999; Li and Yeh, 2001). Moreover, Lu *et al*. (2009) studied the effect of amylose content and rice cultivar on thermal properties of composite rice starch. The samples with different amylose content were prepared from mixing waxy Japonica rice starch (1.2%amylose) and Indica rice starch (19.8%amylose) at different ratio of 0:100, 30:70, 70:30, 85:15 and 100:0 corresponding to 1.2%, 6.8%, 14.2%, 17.0% and 19.8% amylose, respectively. The DSC thermograms showed two peaks (Figure 2.1), representing waxy Japonica rice starch and Indica rice starch. Increasing ratio of Indica starch to waxy Japonica rice starch (increasing amylose), caused a shift of the first peak to a higher temperature due to reduction of amylopectin content in the two different starch blends. While increasing ratio of waxy Japonica rice starch to Indica rice starch (decreasing amylose) resulted in a shift of second peak to a higher temperature due to the potential competition of starch granules in the mixture for water during hydration and swelling.

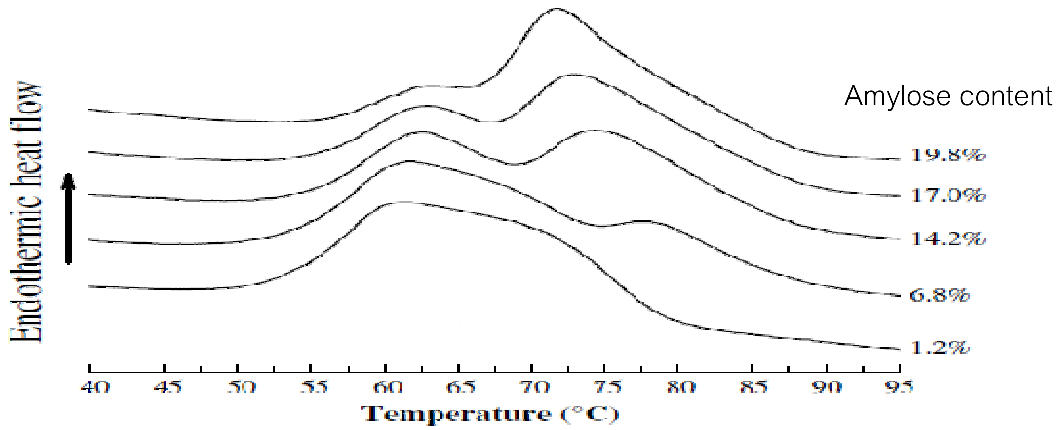


Figure 2.1 Comparison of thermal properties of composite rice starch.

Source : Lu *et al*. (2009)

2.1.2 Effect of acid - treatment on the properties of rice flour.

Acid - modified starches, which are normally prepared by treating the starch slurry (36 – 40% solid) with dilute acid such as HCl, H_2SO_4, or H_3PO_3 at temperature below the gelatinization point for a period of time, changed in physicochemical properties without substantial changes in the starch granule (Wang and Wang, 2001; Thirathumthavorn and Charoenrein, 2005; Gunaratne and Corke, 2007). Acid - hydrolysis reduces starch chain length randomly (Singh and Ali, 2000; Thirathumthavorn and Charoenrein, 2005; Sandhu, Singh, and Lim, 2007). After acid - treatment, swelling power decreased but solubility at below the gelatinization temperature and gel strength increased. However, Gunaratne and Corke (2007) found that swelling power at 85 ^{O}C of corn starch treated with 0.1M HCl at 50^{O}C for 1.5 h increased. It might be because hydrogen bonding between adjacent starch polymers was disrupted by acid. While at higher concentration (0.5M and 1.0M HCl), swelling power decreased because amorphous region in starch granules was more destroyed by acid hydrolysis. Furthermore, Tavares *et al*. (2010) found that amylose content and viscosity of the rice flour modified with 3% lactic acid at 40^{O}C for 1 h decreased due to depolymerization of glucose chain by acid.

Thirathumthavorn and Charoenrein (2005 and 2006) found that HCl concentrations (0.25 - 1.00 N) had more profound effect on degree of polymerization and viscosity of rice starch than hydrolysis time (0 - 6 hours). Besides, Hirashima, Takahashi, and Nishinari (2005) found that shear viscosity of the corn starch pastes, increased at $3.6 < pH < 5.6$ and decreased at pH below 3.6 regardless of type of organic acid used. They explained that the changes in viscosity might be due to the change in size of starch granules. The temperatures of gelatinization (onset, peak, and conclusion temperatures) increased with hydrolysis time, while the gelatinization enthalpy decreased because acid primarily attacked the amorphous regions in the granules (Thirathumthavorn and Charoenrein, 2005).

2.2 KANOM JEEN

Kanom Jeen can be divided into two distinct categories based on processing method as fresh Kanom Jeen and fermented Kanom Jeen (Thai Industrial Standards Institute [TISI.], 2006). The difference in processing method between fresh Kanom Jeen and fermented Kanom Jeen is natural fermentation in soaking or sedimentation step. Fresh Kanom Jeen has slightly fermented flavor, bright white color and less elastic texture while fermented Kanom Jeen has stronger fermented flavor and more elastic texture (Naivikul, 2004; Sribuathong *et al*., 2004).

2.2.1 Fermented Kanom Jeen process.

Fermented Kanom Jeen process includes several steps as shown in Figure 2.2.

Broken rice

↓

Cleaning and steeping in water

↓

Wet - milling and filtering

↓

Water - elimination

↓

Steaming

↓

Kneading and adjustment of water

↓

Extruding through a die into boiling water

↓

Cooling in cold water and shaping

↓

Kanom Jeen

Figure 2.2 Flow diagram of fermented Kanom Jeen process.

Source : Chavanan et *al*. (1992)

1. Milling or grinding : Broken rice was cleaned and then wet – milled by stone mill. Particle size of starch after milling is a key factor affecting the properties and application of rice flour (Park, Kim, and Kim, 2001; Chaing and Yeh, 2002). Small particle size could absorb water quickly and result in low pasting temperature and high peak viscosity as measured by RVA (Mason, 2009). Furthermore, rice noodle prepared from wet – milled rice flour was firmer and more elastic than that prepared from dry – milled rice flour due to lower damaged starch (Suksomboon, 2007).

2. Soaking : For fermented Kanom Jeen process, rice slurry after milling is left to precipitate at room temperature. The rice sediment is fermented for 1 – 2 days

with water washing 2 – 3 times per day by adding water to the precipitate, then left to precipitate and remove the supernatant. While fresh Kanom Jeen process does not have this step (Chavanan et *al*., 1992).

3. Water elimination : For traditional method, flour sediment is put in a cotton bag and a weight was placed on the bag overnight to remove excess water (Naivikul, 2004; Keatkrai and Jirapakkul, 2010). Machine, such as hydraulic press, and filter press can be used to drain water (Oupathumpanont *et al*., 2009). Rice cake obtained has moisture content about 42 – 44%.

4. Steaming : Rice cake is moulded into ball shape and precooked by steaming at 100°C for 20 min or putting in boiling water to enable surface gelatinization (Chavanan *et al*., 1992). The degree of pregelatinization of flour affects noodle texture. Over - gelatinization may give noodle which is easy to break while under - gelatinization will be difficult to make noodle (Lalana, 1989).

5. Kneading : The partially - gelatinized rice ball is kneaded to uniformly distribute the gelatinized rice flour throughout the dough before adjusting its moisture content (Chavanan *et al*., 1992).

6. Extruding : The kneaded dough is extruded through a die and dropped into boiling water (90-95°C). Temperature of water affects the texture of noodle as too low temperature gives tender noodles while too high temperature gives easy to break noodles. The sufficiently cooked noodles will float to the surface (Naivikul, 2004).

7. Cooling and shaping : After cooking, the noodles are then transferred to cold water for cooling. Noodles are collected and shaped into Kanom Jeen (Naivikul, 2004).

2.2.2 Properties of fermentation rice flour.

Protein, lipid, and ash contents of fermented rice flour were lower than the native one. RVA viscosity (except peak and setback) and gelatinization temperature were also lower but gelatinization enthalpy was higher (Lu *et al*., 2003). Change in compositions and properties of rice flour might be due to the fermentation of starch (Lu *et* al., 2003; Reddy *et al*., 2008). Lactic acid bacteria are the major microbial population found (Keatkrai and Jirapakkul, 2010). In Kanom Jeen process, fermentation step occurs during soaking and sedimentation (Naivikul, 2004). Niyomvit *et al*. (1985) reported that the optimum pH and acidity of fermented rice slurry in Kanom Jeen process should be 3.00 – 3.50 and 0.95 – 1.10% (as % lactic acid), respectively. Moreover, increasing fermentation time resulted in rice flour with lower pH and protein content but higher amylose and ash contents. Texture of Kamon Jeen became soft and elastic (Niyomvit *et al*., 1985).

2.3 HURDLE TECHNOLOGY

Hurdle technology is a concept for the mild preservation of foods in a stable product. An appropriate combination of hurdles with low intensity achieves microbial stability and safety. This method is widely used in food design for making shelf stable products, which have high moisture (a_w > 0.90) (Leistner and Gorris, 1995; Leistner, 2000). Mild heating has less effect on sensory and qualities of products. Moreover, shelf stable products still contain viable bacterial spores and spoilage bacteria that are inhibited by a decrease of a_w and pH of products (Leistner and Gorris, 1995; Leistner, 2000; Blackburn and McClure, 2002). The example of hurdle technology, such as reduced a_w and mild heating in addition to a modified atmosphere in package, has also been used in non – fermented food during storage. The hurdles used in this work are as follows.

2.3.1 pH

Most microorganisms grow at pH values around 7.0, whereas a few of them grow below 4.0. Pathogenic bacteria tend to be more sensitive to pH than moulds and yeasts (Walker, 1998; Jay, 2000). Organic acids are used for washing and sanitizing raw material to reduce pathogen load and to increase product shelf - life (Jay, 2000). The depressions of pH below the optimum growth range can inhibit metabolic growth of microbial by the undissociated acid molecules. Acids work most effectively as the pH approaches or falls below their pK_a values. The undissociated acid molecules diffused into the intracellular environment of the bacterial cell from the external environment and release their dissociated protons $[H^+]$ and anions $[A^-]$ inside the cells. The accumulation of $[H^+]$ caused pH of the bacterial cell to decrease which thereby became inhibitory effect. $[A^-]$ inside the cell regulated the pH gradient across the cell membrane and the energy of the cell was almost exhausted for further activity. (Leistner and Gorris, 1995; Jay, 2000; Vermeulen *et al*, 2007; Holdsworth and Simpson, 2008).

2.3.2 Water activity (a_w)

Water activity is the water available for microorganisms in the environment to use. Reduce in water activity below the optimum value increases the lag phase but decreases the growth rate and amount of final population. Reduction of a_w is performed by elimination of water (i.e. drying) or addition of humectants. Salt (NaCl) is added in most food as a flavor enhancer, seasoning agent and preservative. Potassium chloride (KCl) has similar functional properties to NaCl and is added in meat products. Potassium lactate is used to enhance flavor and extend shelf – life in meat and poultry products (Leistner and Gorris, 1995; Jay, 2000).

2.3.3 Pasteurization

Degree of heating depends on pH and water activity of products. For high-acid products (pH less than 4.5), a relatively mild pasteurization process is necessary to stabilize the product and inactivate moulds and yeasts because *C. botulinum* cannot grow. For low - acid products (pH greater than 4.5), it is necessary to apply heat sufficient to inactivate spores of *C. botulinum* (Leistner and Gorris, 1995; Jay, 2000; Holdsworth and Simpson, 2008).

2.3.4 Packaging

Modified atmosphere packaging (MAP) is a process that consists of altering the chamber or package atmosphere by flushing with varying mixtures of CO_2, N_2, and/or O_2. The initial gas concentration cannot be readjusted during storage. The vacuum or MAP methods alter the concentrations of O_2 and CO_2 in different ways. Nitrogen gas, which is inert gas, inhibits the growth of the bacteria and moulds and is used to exclude the air particularly oxygen (Appendini and Hotchkiss, 2002; Jääskeläinen *et al*., 2004; McMillin, 2008; Nobile *et al*., 2009; Syafila, Handajani and Prayascitra, 2010).

2.3.5 Examples of Hurdle technology in noodle products.

Oraphan (2004) studied the preservation of Sen lek (rice noodle) in pouch by steeping dried noodle in 0.4% citric acid solution to adjust pH to lower than 4.5 and pasteurizing at 65^{O}C for 30 min and found that pasteurized Sen lek could be stored at 35 ^{O}C and 45 ^{O}C for 15 and 9 days.

Kittiya (2007) studied the preservation of Kanom Jeen made from fermented rice flour and pregelatinized fermented rice flour in pouch by pasteurizing at 65^{O}C for 30 min and found that firmness of pasteurized Kanom Jeen was not different from the fresh one. The shelf - life at 35 ^{O}C and 45 ^{O}C was 13 and 5 days.

Korrakot (2007) studied the preservation of strip rice noodle in pouch by pasteurizing at 90^{O}C for 5 min and found that pasteurized rice noodle had lower hardness of texture than the control one and could be stored at 4 ^{O}C for 8 weeks.

Nobile *et al*. (2009) studied the effect of chitosan and modified atmosphere packaging on shelf - life of amaranth based pasta and found that the product containing chitosan and packed in the modified atmosphere packaging of CO_2 and N_2 at the ratio of 30 : 70 could be stored in refrigerator for 2 months.

CHAPTER III

MATERIALS AND METHODS

3.1 MATERIALS

Broken rice was provided from Burapaprosper Co., Ltd., Chonburi (Thailand). Citric acid and lactic acid (food grade) (Shanghai raise chemical Co., Ltd., China) were purchased from CT Chemical Co., Ltd. (Thailand). Salt (Thai Refined Salt Co., Ltd., Thailand) was purchased from local supermarket in Bangkok. Polyethylene (PE) / Aluminum (Al) / PE laminated bags (Janjaras Chem Supply Co., Ltd., Thailand) were bought from local retailers.

3.2 METHODS

3.2.1 Effect of citric acid and lactic acid on chemical and physical properties of rice flour

Broken rice was cleaned and soaked in water at room temperature overnight. Water was drained out and the soaked rice was ground with water using a double-disc stone mill (ratio of rice : water of 1 : 2). The slurry was centrifuged at 750 g for 15 min using a basket centrifuge (Owner Foods Machinery, Thailand). The sediment was soaked in citric acid or lactic acid solution (ratio of sediment : acid solution of 1 : 2) for 2 hours at room temperature. The concentration of acid solution was varied at 1%, 2% and 3% (%w/w). After 2 h, the rice slurry was centrifuged and supernatant was analyzed for pH (Eutech pH meter, model Cyberscan pH100 Bench, Singapore) and %total titratable acidity (AACC, 2000 as described in Appendix B.1). Thereafter, the pH of rice slurry was adjusted to 7.0 by washing with water. The rice slurry was centrifuged at 750 g for 15 min, then the sediment was dried in a tray dryer at 45 $\pm$ 5^{O}C until its moisture content was about 10 – 12%. The dried sediment was pulverized by a blender (Philips, model HR2021/75, Thailand) and sieved through a 100 - mesh screen before storing in PE / Al / PE laminated bag at $4^{o}C$ until used.

The flour samples were analyzed for crude protein, crude lipid and ash contents for all the rice flour were determined following approved methods of AACC 46-12, 30-10 and 08-01 (AACC, 2000), amylose content (Juliano, 1971), color by color meter (Minolta, model Chroma Meter CR 400 Series, Japan) reported as whiteness index by calculating from equation : whiteness index = $100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{½}$ (Zhu *et al*., 2009), swelling power and solubility at $75^{O}C$ (modified method of Li and Yeh (2001) as described in Appendix B.2), pasting properties (Rapid Visco Analyzer, Newport Scientific Instruments & Engineering, model 4D, Australia) according to the method 61-02 (AACC, 2000) and thermal properties by Differential Scanning Calorimetry (Perkin Elmer, model Diamond DSC, U.S.A.) (modified method of Ndife, Sumnu, and Bayindirli, (1998) as described in Appendix B.3) : the gelatinization temperatures (onset temperature: T_o, peak temperature: T_p and conclusion temperature: T_c) and enthalpy change (ΔH) were recorded and granule morphology by scanning electron microscope (SEM) (JEOL, JSM - 5410LV microscope, Tokyo, Japan as described in Appendix B.4) and light microscopy (Olymphus, model CH30RF200, Japan).

The experiment was carried out in duplicate. The analysis was done in 3 replicates according to completely randomized design (CRD). Analysis of variance (ANOVA) was performed for multiple treatments data and differences between means were tested for statistical significance at $p = 0.05$ level by Fischer's Least Significant Difference (LSD). SPSS 15.0 for Windows software was used to perform the statistical analysis.

3.2.2 Effect of citric acid and lactic acid on chemical and physical properties of Kanom Jeen

Rice slurry prepared as described in section 3.2.1 was used to produce Kanom Jeen by the modified method of Lalana (1989) (Figure 3.1, Appendix F).

Rice slurry (after adjusting pH to 7.0)

↓

Centrifuge by basket centrifuge at speed 750 g for 15 min

15% of rice sediment | 85% of rice sediment

↓

Steam at 100 ^{O}C for 10 minutes

↓

Knead and adjust moisture content to 50%.

↓

Extrude through a die into recieving boiling water containing 7% salt (w/w) (90-95^{o}C) and cook for 20 seconds

↓

Pick up the cooked noodle and cool in ice-water (~4 ^{O}C) containing 7% salt (w/w) for 20 seconds.

↓

Kanom Jeen

Figure 3.1 The Kanom Jeen process

After 1 day stored in PE / Al / PE bags, the Kanom Jeen was analyzed for pH, titratable acidity, color as in section 3.2.1, textural properties by a Texture Analyzer (Stable Micro System, model TA-XT2i, England) as described in Appendix B.5 and sensory qualities (color, odor, taste, texture and overall liking) using 30 untrained panelists and hedonic 5 - point scale with 1 for dislike very much and 5 for most like score (Appendix D). The experiment was carried out in duplicate. The analysis of pH, total titratable acidity and color was done in 3 replicates according to CRD. The textural measurement was done in 20 replicates according to CRD. Sensory evaluation was done in 2 replicates according to randomized complete block design (RCBD).

The suitable type and concentration of acid for further study was chosen based on the overall liking score, hardness, stickiness, springiness, tensile strength, and whiteness index.

3.2.3 Effect of gelatinized rice ratio on chemical and physical properties of Kanom Jeen

The rice slurry was prepared as described in section 3.2.1 using the type and concentration of acid chosen in section 3.2.2. The ratio of gelatinized rice to ungelatinized rice was varied at 15:85, 20:80 and 25:75. Gelatinized rice was prepared by steaming the rice sediment at 100 $^{\circ}$C for 10 minutes. The Kanom Jeen samples were prepared by the process shown in Figure 3.1.

The Kanom Jeen samples were analyzed for pH, total titratable acidity, color and textural properties as in section 3.2.2 and water activity by a water activity analyzer (Novasina, Model ms1 Set aw, Switzerland). The experiment was carried out in duplicate. The analysis was done in 3 replicates according to CRD and the data of pH, total titratable acidity, color, water activity, and textural properties were analyzed as in section 3.2.1.

The suitable gelatinized rice ratio for further study was chosen based on the hardness, stickiness, springiness, tensile strength, and whiteness index.

3.2.4 Effect of citric acid in receiving boiling water on chemical and physical properties of Kanom Jeen

Kanom Jeen was prepared by the process shown in Figure 3.1 using the chosen conditions in sections 3.2.2 and 3.2.3. Kanom Jeen dough was pressed through the mould into the receiving boiling water containing 0.25% (w/w) citric acid with or without 7% (w/w) salt (acidic brine or acidic water). Kanom Jeen from the receiving boiling water containing 7% (w/w) salt (brine) was used as control sample.

The samples were analyzed for pH, total titratable acidity, color, and textural properties as in section 3.2.2 and water activity as section 3.2.3. The experiment was carried out in duplicate. The analysis was done in 3 replicates according to CRD and the data of pH, total titratable acidity, color, water activity and textural properties were analyzed as in section 3.2.1.

The suitable component in receiving boiling water for further study was chosen based on the hardness, stickiness, springiness, tensile strength, and whiteness index of Kanom Jeen.

3.2.5 Effect of pasteurization temperature and time on chemical and physical properties of Kanom Jeen

Kanom Jeen was prepared by the process shown in Figure 3.1 using the chosen condition in sections 3.2.2 - 3.2.4.and pasteurized by the process shown in Figure 3.2.

Kanom Jeen (30g.)

↓

Pack of sample in 18 cm. x 21 cm. PE / Al / PE bags

↓

Seal with nitrogen flushed at rate of 80 bar/min for 1 min.

(initial temperatre at the center of product is 30 $\pm$ 5^{O}C)

↓

Heat in 95^{O}C water bath till the center temperature reaches 85^{O}C

or 90^{O}C then hold for 1, 3 or 5 min

↓

Cool under tap water to decrease center temperature to 25 - 30 ^{O}C.

↓

Pasteurized Kanom Jeen

Figure 3.2 The pasteurization process of Kanom - Jeen

The experiment was carried out in duplicate. The samples were analyzed for textural and sensory properties as in section 3.2.2 and microbiological quality including aerobic plate counts, yeast and mould counts and *E. coli* using 3M pertrifilm^{TM} (as described in Appendix B.6). The textural measurement was done in 20 replicates according to CRD.

The suitable temperature and time for further study were chosen based on the overall liking score, hardness, stickiness, springiness, and tensile strength with microbiological qualities up to Announcement of the Thai Food and Drug (Thai Food and Drug Administration, 2006).

3.2.6 The shelf – life study of pasteurized Kanom Jeen

Kanom Jeen sample was prepared by the process shown in Figure 3.1 using the chosen conditions in sections 3.2.2 - 3.2.4 and pasteurized by the process shown in Figure 3.2 with the chosen condition in section 3.2.5. The sample was stored at 30 $\pm$ 5 ^{O}C until it spoiled based on microbial qualities.

The sample was taken everyday for the analysis of pH, total titratable acidity, color, water activity, textural characteristics, sensory qualities, and microbiological quality (except *E. coli* was analyzed only on first day of storage). The analysis of pH, total titratable acidity, and color were done in 3 replicates. Textural measurement was done in 7 replicates (due to limitation of product).

CHAPTER IV

RESULTS AND DISCUSSION

4.1 EFFECT OF CITRIC ACID AND LACTIC ACID ON CHEMICAL AND PHYSICAL PROPERTIES OF RICE FLOUR

Native rice flour sample contained 6.62% protein, 0.55% fat, 0.48% ash and 26.78% amylose (dry basis) (Table 4.1). Based on the amylose content, this rice flour could be classified as high amylose content (amylose content more than 25%), which is suitable for noodle making (Juliano, 1985).

Acid treatment was found to affect chemical compositions of the flour (protein, fat and amylose), except ash content. Protein, fat and amylose content were significantly lower than that of native rice flour ($p \leq 0.05$), which might be due to the acid hydrolysis and dissolution during soaking (Chiang and Yeh, 2002; Lu *et. al.,* 2003; Ohishi *et al.,*2007; Taraves *et. al.*, 2010). Furthermore, Table 4.1 also shows that chemical composition of rice flour samples varied depending on types and concentration of acids. Citric acid - treated rice flour contained significantly ($p \leq 0.05$) lower amounts of protein, fat, and amylose than those of lactic acid - treated samples. Table 4.2 shows that pH of supernatants of rice slurry treated with citric acid and lactic acid after soaking for 2 h was lower than that of samples treated with lactic acid. This is because citric acid, which is triprotic acid (pK_a = 3.09, 4.75 and 5.41), can dissociate in solution and release more amount of hydrogen ions than lactic acid, which is monoprotic (pK_a = 3.86) (Hirashima *et al.*, 2005). Besides, the amounts of protein, fat, and amylose tended to decrease with increasing acid concentration.

Table 4.1 Effect of citric acid and lactic acid on chemical compositions of rice flour

Sample		Compositions (% dry basis)			
		Protein	Fat	Ash^{ns}	Amylose
Native		6.62 ± 0.06^{f}	0.55 ± 0.02^{f}	0.48 ± 0.03	26.78 ± 1.23^{c}
Citric acid	1%	6.31 ± 0.08^{e}	0.50 ± 0.01^{e}	0.48 ± 0.01	23.93 ± 2.21^{a}
	2%	5.10 ± 0.01^{c}	0.39 ± 0.01^{b}	0.46 ± 0.01	23.53 ± 1.98^{a}
	3%	4.67 ± 0.01^{a}	0.44 ± 0.01^{d}	0.47 ± 0.02	23.40 ± 1.89^{a}
Lactic acid	1%	6.69 ± 0.07^{f}	0.50 ± 0.01^{e}	0.47 ± 0.00	26.02 ± 1.13^{bc}
	2%	6.14 ± 0.02^{d}	0.41 ± 0.01^{c}	0.48 ± 0.01	24.65 ± 0.42^{ab}
	3%	4.89 ± 0.03^{b}	0.37 ± 0.02^{a}	0.49 ± 0.02	23.95 ± 2.36^{ab}

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$)

ns is not significantly different ($p>0.05$)

% Titratable acidity of supernatants of rice slurry after soaking for 2 h was presented in terms of citric acid and lactic acid based on the type of acid used in the solution (Table 4.2). It was found that % titratable acidity increased with increasing acid concentration. After acid treatment, the whiteness indices of all samples were lower than that of native rice flour (Table 4.2). The samples became more yellowish (b* values increased, data shown in Appendix C.1).

Table 4.2 Effect of citric acid and lactic acid on pH and % titratable acidity of supernatants of rice slurry after soaking for 2 h and whiteness Index of rice flour

Acid	Concentration			pH	% Titratable acidity*	Whiteness Index
	% w/w	mol / L	pH*			
Native	0	0	7.12	7.13 $\pm$ 0.01^{g}	0.00 $\pm$ 0.00^{a}	96.89 $\pm$ 0.12^{b}
Citric acid	1%	0.05	2.97	3.64 $\pm$ 0.00^{e}	0.50 $\pm$ 0.05^{c}	95.39 $\pm$ 1.21^{a}
	2%	0.10	2.86	3.05 $\pm$ 0.00^{b}	0.69 $\pm$ 0.05^{d}	94.86 $\pm$ 1.00^{a}
	3%	0.16	2.65	2.69 $\pm$ 0.00^{a}	0.93 $\pm$ 0.05^{f}	94.97 $\pm$ 0.20^{a}
Lactic acid	1%	0.11	3.19	3.65 $\pm$ 0.00^{f}	0.42 $\pm$ 0.05^{b}	94.49 $\pm$ 0.07^{a}
	2%	0.22	3.03	3.52 $\pm$ 0.00^{d}	0.65 $\pm$ 0.05^{d}	95.73 $\pm$ 1.36^{ab}
	3%	0.33	2.94	3.42 $\pm$ 0.00^{c}	0.83 $\pm$ 0.05^{e}	95.53 $\pm$ 1.50^{a}

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$)

* initial pH of acid solution (before soaking)

* for citric acid - treated sample % titratable acidity as citric acid, for lactic acid - treated sample % titratable acidity as lactic acid

Swelling power at 75 ^{O}C of all acid - treated samples was higher than that of native rice flour regardless of type and concentration of acid (Table 4.3). Increase in swelling power at 75 ^{O}C due to the less amounts of protein and fat contents. Both protein and fat in rice flour inhibited swelling of starch granule. (Chiang and Yeh, 2002; Phothiset and Charoenrein, 2007). For this reason, acid - treated samples were led to easier swell than native sample. Moreover, this may be caused disruption of hydrogen bonding between starch polymer chains by acid (Gunaratne and Corke, 2007; Ohishi *et al.,* 2007). However, the result was different from the previous studies on the effect of acid treatment on corn starch (Sandhu *et al.*, 2007) and maize (Gunaratne and Corke, 2007) using HCl. The difference might be due to the difference effect of inorganic acid and organic acid on starch.

When starch molecules are heated in excess water, the crystalline structure is disrupted and water molecules become linked by hydrogen bonding to the exposed hydroxyl groups of amylose and amylopectin (Singh *et al.*, 2003). For this reason, acid - treated samples led to increase in granule swelling and solubility (Table 4.3). In addition to that reason, the increase in solubility of acid – treated rice flour samples might be due to depolymerization and structure weakening of granule after acid treatment (Gunaratne and Corke, 2007; Sandhu *et al.*, 2007). Acid concentration affected solubility of the treated samples. Solubility increased with increasing acid concentration regardless of type of organic acid used.

Table 4.3 Effect of citric acid and lactic acid on swelling power and solubility at 75^{O}C of rice flour

Sample		Swelling power (g/g dry basis)	Solubility (% dry basis)
Native		7.01 ± 0.04^{a}	2.58 ± 0.39^{a}
Citric acid	1%	7.14 ± 0.07^{b}	3.69 ± 0.32^{cd}
	2%	7.23 ± 0.06^{c}	3.52 ± 0.22^{bc}
	3%	7.15 ± 0.10^{b}	4.04 ± 0.21^{e}
Lactic acid	1%	7.12 ± 0.08^{b}	3.32 ± 0.38^{d}
	2%	7.17 ± 0.11^{b}	3.78 ± 0.18^{b}
	3%	7.13 ± 0.10^{b}	4.01 ± 0.33^{e}

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$)

Table 4.4 shows that all acid – treated samples had lower peak viscosity, trough, breakdown and final viscosity but higher pasting temperature than those of native rice flour. All pasting temperature of acid – treated samples were coincident with T_o which determined by DSC (Tale 4.5). In dilute starch paste, viscosity was primary governed by swelling characteristics (Reddy *et al*., 2008). But in this study, paste viscosity of rice flour was decreased after acid – treatment indicating less stability of swollen granule at stirring and heating. This might because acid hydrolysis reduces chains length of amylose and amylopectin (Singh and Ali, 2000; Thirathumthavorn and Charoenrein, 2005; Ohishi *et al*., 2007; Sandhu *et al*., 2007; Tavares *et al*.,2010). Moreover, pH of acid solution affected viscosity of rice flour by hydrogen ion which attacked the glycosidic oxygen atoms and hydrolysed the glycosidic linkages and shortened the chain length of amylose and amylopectin (Hirashima *et al*., 2005; Lawal *et al*., 2005). Setback of acid - treated samples was lower than that of native sample suggesting that rice noodle might exhibit less tendencies to retrograde (Bhattacharya *et al*., 1999). These results showed that solubility of acid - treated rice flour increased while peak viscosity, trough, final viscosity and setback decreased that agreed with the report of Bhattacharya *et al.* (1999). Furthermore, types and concentration of acid affected viscosity. Citric acid treatment reduced all RVA viscosities more than those of lactic acid. Besides types of acid, viscosity of all acid - treated rice flour samples tended to reduce with increasing acid concentration.

Table 4.4 Effect of citric acid and lactic acid on RVA pasting properties of rice flour

Sample		Pasting temperature (^{O}C)	Peak viscosity	Trough	Breakdown	Final viscosity	Setback
Native		70.20 ± 7.36^{a}	270.50 ± 2.74^{g}	177.67 ± 1.78^{f}	92.83 ± 3.93^{e}	344.50 ± 3.73^{g}	150.50 ± 7.06^{e}
Citric acid	1%	76.80 ± 1.49^{b}	202.50 ± 3.20^{f}	108.14 ± 2.88^{d}	94.36 ± 2.80^{e}	205.94 ± 3.23^{d}	97.80 ± 3.26^{c}
	2%	78.37 ± 2.44^{b}	174.65 ± 2.30^{d}	95.44 ± 1.01^{bc}	79.21 ± 3.04^{c}	189.42 ± 5.97^{c}	93.97 ± 6.41^{bc}
	3%	79.02 ± 3.42^{b}	140.56 ± 6.45^{a}	72.36 ± 3.30^{a}	68.91 ± 3.31^{ab}	159.61 ± 5.78^{a}	82.25 ± 2.67^{a}
Lactic acid	1%	78.70 ± 1.21^{b}	196.19 ± 5.21^{e}	112.30 ± 3.19^{e}	83.89 ± 2.37^{d}	236.50 ± 1.49^{f}	127.91 ± 0.68^{d}
	2%	77.35 ± 2.48^{b}	169.25 ± 0.39^{c}	98.58 ± 0.94^{c}	70.67 ± 0.61^{b}	217.86 ± 5.71^{e}	119.28 ± 4.77^{d}
	3%	79.17 ± 2.49^{b}	158.33 ± 3.20^{b}	92.14 ± 1.99^{b}	66.19 ± 3.12^{a}	183.06 ± 6.93^{b}	90.92 ± 6.91^{ab}

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$)

All data showed are in RVU except pasting temperature

Breakdown = Peak viscosity – Trough

Setback = Final viscosity – Trough

DSC thermograms showed two peaks in native rice flour (Figure C.1 in Appendix C), which may be due to the different cultivars in the flour. The first peak may be from low – medium amylose rice flour and the second peak is from high amylose rice flour (Lu *et al.*, 2009). Flour treated with 1% acid had two peaks while those treated at higher concentration (2% and 3%) had only one peak. Table 4.5 shows that both T_O and T_P of the first peak shifted to higher temperature while T_P of the second peak shifted to lower temperature. The change of T_O and T_P might be caused by the different mechanism of acid treatment on low – medium amylose rice flour and high amylose rice flour. T_O, T_P and enthalpy of acid – treated low – medium amylose rice flour increased with increasing acid concentration. For low – medium amylose rice flour, as acid can gradually degrade the surface of the starch granule before entering the inner region and breaking down the amorphous region. While the crystalline area is not freely accessible to the acid so it remains intact (Lawal *et al.*, 2005). Moreover, less amorphouss regions retained after acid treatment lead to increase in ratio of crystalline regions to amorphous regions (Sandhu *et al.*, 2007). For this reason, a higher degree of heat was required for creating gelatinization. While for high amylose rice flour, T_P of the second peak decreased corresponded to the increase in swelling power at 75^{O}C which led to gelatinization at lower temperature (Singh and Ali, 2000; Thirathumthavorn and Charoenrein, 2005). From this result, acid treatment degraded the surface of the starch granule and attacked amorphous regions of starch granule of low – medium amylose rice flour while reduce in protein and fat content rice flour which has effect on swelling power of starch of high amylose rice flour. Conclusion temperature of all samples was not significantly different ($p>0.05$) except sample treated with 1% lactic acid concentration. Moreover, range of gelatinization temperature of acid - treated rice flour tended to be narrow with no change in enthalphy of gelatinization.

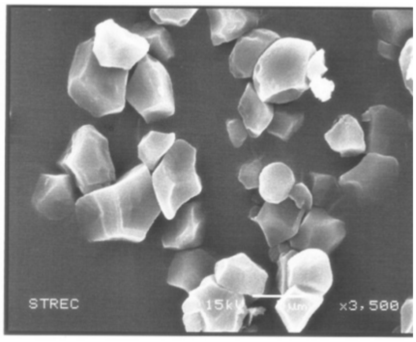
Starch granules of all rice flour samples had polygonal shape (Figure 4.1). The light micrographs taken under polarized light source (Figure 4.2) showed the birefringence of starch granule appeared in all rice flour samples indicating that starch granules were not destroyed after acid treatment.

Table 4.5 Effect of citric acid and lactic acid on thermal properties of rice flour

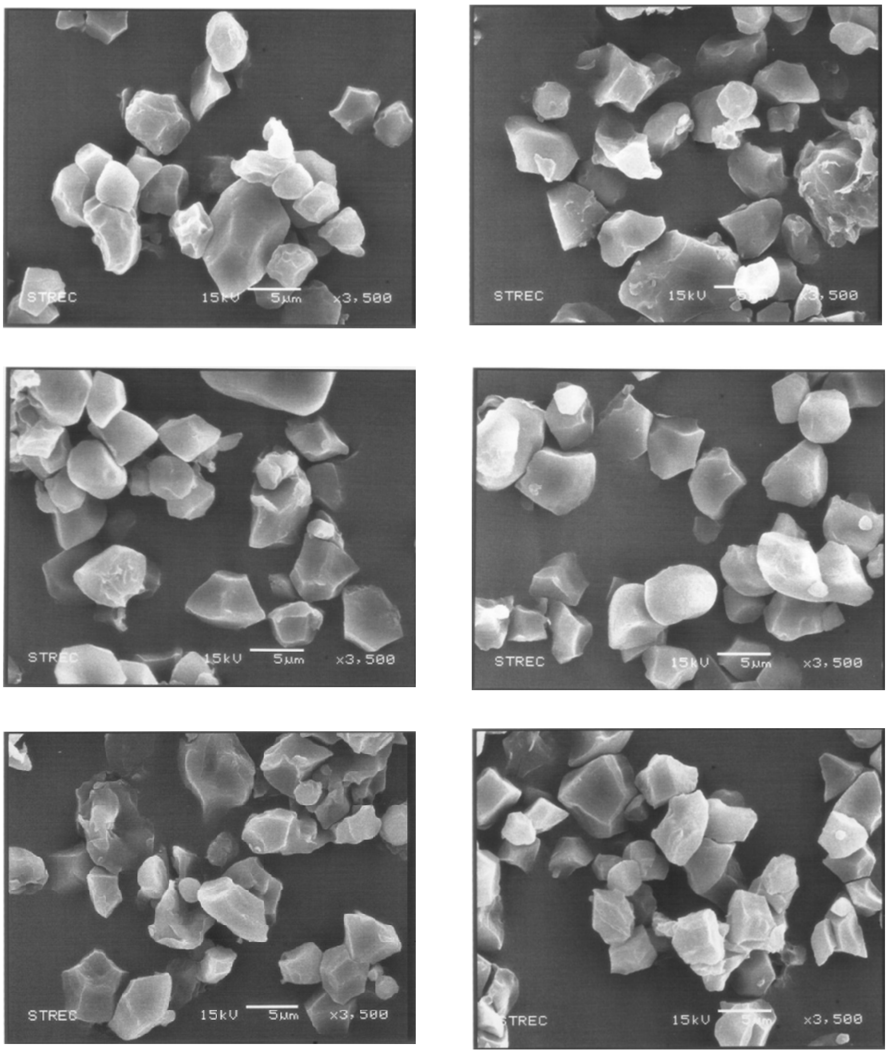
Sample		T_o (^{O}C)	T_{p1} (^{O}C)	T_{p2} (^{O}C)	T_c (^{O}C)	ΔT^* (^{O}C)	ΔH^{ns} (J/g)
Native		66.78 ± 0.22^{b}	70.74 ± 0.47^{b}	79.29 ± 0.02^{c}	83.81 ± 0.34^{ab}	17.03 ± 0.40^{c}	8.61 ± 0.15
Citric acid	1%	67.53 ± 0.50^{c}	71.19 ± 0.25^{b}	82.38 ± 2.33^{d}	83.40 ± 1.88^{ab}	15.86 ± 1.57^{c}	6.14 ± 1.37
	2%	69.20 ± 0.88^{c}	77.57 ± 0.48^{c}	-	84.45 ± 1.70^{ab}	15.26 ± 2.57^{bc}	7.19 ± 0.91
	3%	71.09 ± 0.97^{d}	77.22 ± 0.67^{c}	-	83.12 ± 1.37^{a}	12.03 ± 2.18^{a}	7.48 ± 1.43
Lactic acid	1%	65.76 ± 0.79^{a}	69.20 ± 0.60^{a}	78.91 ± 1.13^{bc}	86.77 ± 1.74^{c}	21.01 ± 1.43^{d}	7.85 ± 0.40
	2%	69.31 ± 0.83^{c}	77.95 ± 0.47^{c}	-	84.35 ± 0.31^{ab}	13.71 ± 0.90^{ab}	6.92 ± 1.33
	3%	70.64 ± 0.87^{d}	77.93 ± 0.64^{c}	-	84.93 ± 0.98^{b}	15.62 ± 1.64^{bc}	7.93 ± 1.11

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$)

$\Delta T^* = T_c - T_o$



Native rice flour



1%

2%

3%

Citric acid Lactic acid

Figure 4.1 SEM micrographs of native and rice flour treated with1%, 2% and 3% (w/w) acid concentration

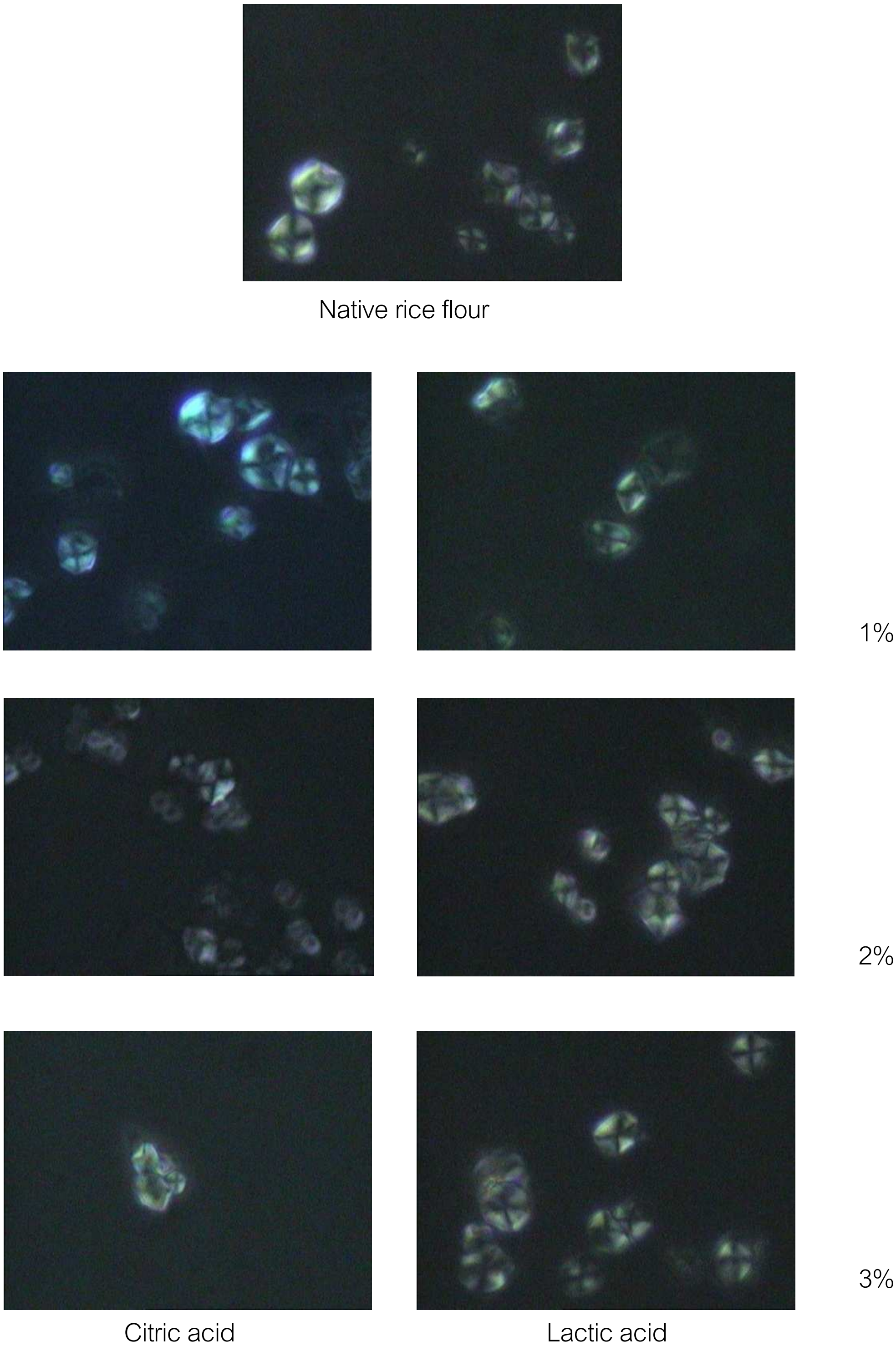


Figure 4.2 Light micrographs of native and rice flour treated with1%, 2% and 3% (w/w) acid concentration

4.2 EFFECT OF CITRIC ACID AND LACTIC ACID ON CHEMICAL AND PHYSICAL PROPERTIES OF KANOM JEEN

The fresh Kanom Jeen prepared from native rice flour was used as control sample. It was found that samples prepared from acid – treated rice flour had higher acidity but lower pH (Table 4.6). Increasing acid concentration resulted in an increase in acidity and decrease in pH of Kanom Jeen samples with citric acid showing higher effect than that of lactic acid. The % titratable acidity of Kanom Jeen was presented in terms of citric acid and lactic acid based on the type of acid used in the solution and for commercial samples (fermented Kanom Jeen) was presented in terms of lactic acid (Table 4.6). Whiteness index of samples prepared from acid – treated rice flour was increased due to a decrease in protein content of acid – treated rice flour (Ohishi *et al*., 2007). Increasing concentration of both acids gave Kanom Jeen with an increase in whiteness index.

Table 4.6 Effect of citric and lactic acid on pH, titratable acidity, and whiteness index of Kanom Jeen

Sample		pH	% Titratable acidity*	Whiteness Index
Native		7.44 ± 0.01^{j}	0.02 ± 0.00^{a}	67.76 ± 1.21^{a}
Citric acid	1%	4.76 ± 0.02^{i}	0.08 ± 0.00^{c}	71.26 ± 1.31^{bcd}
	2%	4.36 ± 0.02^{f}	0.08 ± 0.01^{c}	70.86 ± 1.30^{bc}
	3%	3.29 ± 0.01^{a}	0.12 ± 0.00^{d}	73.31 ± 0.46^{e}
Lactic acid	1%	4.93 ± 0.01^{h}	0.04 ± 0.01^{b}	70.49 ± 0.22^{bc}
	2%	4.41 ± 0.01^{g}	0.07 ± 0.00^{c}	71.64 ± 0.62^{cd}
	3%	4.16 ± 0.01^{e}	0.08 ± 0.01^{c}	71.92 ± 0.12^{d}
Commercial (fermeted Kanom Jeen)	1	3.88 ± 0.01^{d}	0.07 ± 0.00^{c}	69.09 ± 1.40^{a}
	2	3.65 ± 0.07^{b}	0.08 ± 0.01^{c}	74.52 ± 1.83^{e}
	3	3.92 ± 0.02^{c}	0.06 ± 0.01^{c}	73.02 ± 1.45^{e}

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$) * for citric acid - treated sample % titratable acidity as citric acid, for lactic acid - treated sample % titratable acidity as lactic acid

Table 4.7 shows that Kanom Jeen prepared from acid - treated rice flour had lower hardness and stickiness but higher springiness and tensile strength than that of control sample (native). Decrease in hardness and stickiness and increase in springiness might be caused by reduced protein and amylose content. Lower in protein which inhibited swelling of starch granule resulted in Kanom Jeen with softer texture and more flexible (Lu *et al*., 2003; Ohishi *et al*., 2007; Wu *et al*., 2010). Moreover, hardness of Kanom Jeen was correlated with the RVA setback values. The lower the setback values, the lower the retrogradation (Bhattacharya *et al*., 1999). While increase in tensile strength may be caused by a decrease in protein content of rice flour similar to fermented rice noodle (Lu *et* al., 2003). Type and concentration of acid were found to affect Kanom Jeen texture except tensile strength. Kanom Jeen had lower hardness and stickiness and higher springiness as acid concentration increased. Samples prepared from citric acid - treated rice flour show significant lower hardness than the ones prepared from lactic acid - treated rice flour ($p \leq 0.05$). Commercial Kanom Jeen provided the hardness of 13.45 – 15.19 N, stickiness of 0.35 – 0.37 N, springiness of 0.65 – 0.67 and tensile strength of 7.56 – 9.45 g. As compared to the commercial Kanom Jeen, Kanom Jeen prepared from acid – treated rice flour had lower stickiness, springiness and tensile strength except stickiness of Kanom Jeen made from 1% citric acid. Among six samples prepared from acid – treated rice flour, hardness of Kanom Jeen made from both 1% and 2% citric acid and lactic acid - treated rice flour were not significantly different from the commercial samples. It may be caused by the difference of ingredient and processing method.

Table 4.7 Effect of citric and lactic acid on textural properties of Kanom Jeen

Sample		Hardness (N)	Stickiness (N)	Springiness	Tensile strength (g)
Native		12.31 ± 3.11[b]	0.34 ± 0.09[b]	0.46 ± 0.05[a]	5.68 ± 0.47[a]
Citric acid	1%	11.11 ± 2.10[ab]	0.39 ± 0.07[c]	0.54 ± 0.04[b]	6.07 ± 0.48[b]
	2%	13.44 ± 0.90[bc]	0.30 ± 0.01[a]	0.61 ± 0.06[cd]	6.23 ± 0.58[b]
	3%	6.78 ± 1.57[a]	0.29 ± 0.04[a]	0.62 ± 0.05[d]	6.31 ± 0.39[b]
Lactic acid	1%	16.54 ± 1.59[d]	0.30 ± 0.03[a]	0.58 ± 0.05[c]	6.18 ± 0.59[b]
	2%	15.17 ± 5.27[c]	0.30 ± 0.04[a]	0.61 ± 0.06[cd]	6.28 ± 0.39[b]
	3%	9.69 ± 3.95[a]	0.29 ± 0.04[a]	0.61 ± 0.05[cd]	6.35 ± 0.35[b]
Commercial	1	13.45 ± 1.19[bc]	0.37 ± 0.04[bc]	0.65 ± 0.05[d]	8.49 ± 0.35[d]
	2	15.19 ± 1.14[cd]	0.36 ± 0.04[b]	0.67 ± 0.04[d]	7.56 ± 0.40[c]
	3	13.65 ± 1.69[bc]	0.35 ± 0.05[b]	0.65 ± 0.04[d]	9.45 ± 0.45[e]

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$)

Odor Liking scores of Kanom Jeen from acid - treated rice flour were not significantly different from that of control sample while color, taste, texture, and overall liking scores were lower except samples from 2% (w/w) citric acid – treated rice flour (Table 4.8). These were corresponded to the higher whiteness index (Table 4.6) and lower hardness and stickiness (Table 4.7). Concentration of acid showed the significant effect on the color, taste, texture, and overall liking scores as they seemed to decrease with increasing acid concentration. But the effect of type of acid was not significantly different. Among six samples prepared from acid – treated rice flour, Kanom Jeen prepared from 2% citric acid – treated rice flour showed the highest scores in texture and overall, whereas 3% lactic acid – treated rice flour showed the lowest texture and overall liking scores. The overall liking score of Kanom Jeen made from both 1% and 2% citric acid and lactic acid - treated rice flour samples were not significantly different from the control as well. The results of hardness of those samples was agreed with the hardness of commercial Kanom Jeen which were not significantly different (Table 4.7). This implied that among type and concentration of acid used in this study, 2% (w/w) citric acid, which gave Kanom Jeen of pH lower than 4.5, the highest overall liking score and higher tensile strength than control sample, was the most appropriate condition for further study.

Table 4.8 Effect of citric acid and lactic acid on sensory scores of Kanom Jeen.

Sample		Color	Odor^{ns}	Taste	Texture	Overall
Control		3.67 ± 1.21^{c}	3.37 ± 1.31	3.17 ± 1.11^{ab}	3.30 ± 0.98^{bc}	3.37 ± 1.23^{bc}
Citric acid	1%	3.50 ± 0.86^{bc}	3.57 ± 0.82	3.57 ± 0.82^{b}	3.20 ± 1.06^{bc}	3.43 ± 0.90^{bc}
	2%	3.30 ± 1.02^{abc}	3.27 ± 0.94	3.27 ± 0.94^{ab}	3.53 ± 0.94^{bc}	3.63 ± 1.00^{c}
	3%	3.57 ± 0.50^{bc}	2.93 ± 0.98	2.93 ± 0.98^{a}	2.37 ± 0.94^{a}	2.73 ± 0.94^{a}
Lactic acid	1%	3.50 ± 1.25^{bc}	3.33 ± 1.18	3.33 ± 1.18^{ab}	3.07 ± 1.20^{b}	3.50 ± 1.20^{bc}
	2%	3.13 ± 0.82^{ab}	2.93 ± 0.89	2.93 ± 0.89^{a}	3.30 ± 0.77^{bc}	3.10 ± 1.06^{ab}
	3%	3.03 ± 0.89^{a}	3.17 ± 1.12	3.17 ± 1.12^{ab}	2.57 ± 0.77^{a}	2.90 ± 0.88^{a}

using five-point hedonic scales (5- most like; 4- like; 3- neither like nor dislike, 2- dislike; 1- dislike very much)

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$)

ns is not significantly different ($p>0.05$)

4.3 EFFECT OF GELATINIZED RICE RATIO ON CHEMICAL AND PHYSICAL PROPERTIES OF KANOM JEEN

The results showed that pH, % titratable acidity, whiteness index, water activity, stickiness, springiness, and tensile strength of Kanom Jeen were not significantly different ($p>0.05$) while hardness of Kanom Jeen were significant different ($p\leq0.05$) (Tables 4.9 and 4.10). The 20:80 gelatinized rice ratio gave the softest Kanom Jeen while Kanom Jeen prepared from 15:85 and 25:75 gelatinized rice ratio were not significantly different ($p>0.05$). Rice noodle, which used only rice as material, required some starch gelatinization to act as a binder because of a lack of functionality of wheat gluten which made a cohesive dough structure (Sozer *et al.*, 2009). Pregelatinized was used to improve the functional properties by giving body and texture of products and dough was easier to from as the amount of gelatinized rice starch increased (Sozer *et al.*, 2009). However increase gelatinized rice ratio from 20:80 to 25:75, decreased hardness of Kanom Jeen due to the swelling power and hydration capacity of gelatinized rice flour which were higher than native rice flour (Busarawan, 2004). For this reason, Kanom Jeen absorbed more water with increase in gelatinized rice ratio. Similarly the result of Lalana (1989) are showed that Kanom Jeen prepared from the mixture of pregelatinized rice flour and rice flour had lower resistance to compression as the amount of pregelatinized rice flour increased (from 15% to 40%). Moreover, the result of Sozer *et al*. (2009) showed that elasticity of rice pasta dough increased with increasing the amounts of gelatinized fraction from 0 to 50% and then decreased. The gelatinized rice ratio of 15:85 gave Kanom Jeen having the highest hardness was chosen for further study.

Table 4.9 Effect of gelatinized rice ratio on physicochemical properties of Kanom Jeen

Ratio of gelatinized to ungelatinized rice	pH^{ns}	% Titratable acidity^{ns} (as citric acid)	Whiteness index^{ns}	Water activity^{ns}
15:85	4.35 $\pm$ 0.03	0.10 $\pm$ 0.01	72.69 $\pm$ 1.11	0.975 $\pm$ 0.001
20:80	4.34 $\pm$ 0.03	0.10 $\pm$ 0.01	73.39 $\pm$ 0.87	0.975 $\pm$ 0.001
25:75	4.34 $\pm$ 0.03	0.10 $\pm$ 0.01	72.69 $\pm$ 0.65	0.975 $\pm$ 0.002

ns is not significantly different ($p>0.05$)

Table 4.10 Effect of gelatinized rice ratio on textural properties of Kanom Jeen

Ratio of gelatinized to ungelatinized rice	Hardness (N)	Stickiness^{ns} (N)	Springiness^{ns}	Tensile strength^{ns} (g)
15:85	11.64 ± 1.01^{b}	0.35 ± 0.03	0.65 ± 0.06	6.06 ± 0.45
20:80	10.67 ± 1.06^{a}	0.32 ± 0.02	0.63 ± 0.06	6.10 ± 0.50
25:75	11.25 ± 0.83^{ab}	0.35 ± 0.03	0.61 ± 0.04	6.05 ± 0.59

a, b,… Means having different superscripts in a column are significantly different ($p \leq 0.05$)

ns is not significantly different ($p>0.05$)

4.4 EFFECT OF CITRIC ACID IN RECEIVING BOILING WATER ON CHEMICAL AND PHYSICAL PROPERTIES OF KANOM JEEN

In this study, Kanom Jeen was cooked in water containing salt to control microbial load in finished products (Naivikul, 2004; Sribuathong *et al*., 2004) and Kanom Jeen cooked in 7% (w/w) brine was used as control sample. Kanom Jeen, which cooked in both acidic water and acidic brine, had lower pH and higher % titratable acidity (Table 4.11). On the contrary, only Kanom Jeen cooked in acidic water alone had lower whiteness index but higher water activity than the other samples (Table 4.11). This is due to the fact that salt could reduce water activity. Lower whiteness index might be due to the higher water activity of product (Marti, Pagani, and Seetharaman 2011). Moreover, Kanom Jeen cooked in acidic water had the lowest hardness (Table 4.12) which might be because amylopectin molecule swollen more in water having acidic condition (Ohishi *et al*., 2007). However, all Kanom Jeen samples were not significantly different in stickiness, springiness and tensile strength (p>0.05). Therefore, water containing both 0.25% (w/w) citric acid and 7% (w/w) salt was selected for further study because it can reduce pH of Kanom Jeen to 3.88 without affecting the textural characteristics except hardness that the higher values is required.

Table 4.11 Physicochemical properties of Kanom Jeen cooked on different boiling water

Brine means 7% (w/w) salt, acidic water means 0.25% (w/w) citric acid and acidic brine

Water contains	pH	%Titratable acidity (as citric acid)	Whiteness index	Water activity
Brine (pH 7.12)*	4.34 ± 0.03^{c}	0.07 ± 0.01^{a}	73.39 ± 0.87^{b}	0.975 ± 0.001^{a}
Acidic water (pH 3.89)*	3.43 ± 0.01^{a}	0.12 ± 0.01^{b}	70.06 ± 1.40^{a}	0.980 ± 0.001^{b}
Acidic brine (pH 4.01)*	3.80 ± 0.01^{b}	0.11 ± 0.00^{b}	73.38 ± 2.34^{b}	0.975 ± 0.001^{a}

means 7% (w/w) salt and 0.25% (w/w) citric acid

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$)

* (pH of water)

Table 4.12 Textural properties of Kanom Jeen cooked on different boiling water

Water contains	Hardness (N)	Stickiness^{ns} (N)	Springiness^{ns}	Tensile strength^{ns} (g)
Brine	11.64 ± 1.01^{b}	0.35 ± 0.03	0.65 ± 0.06	6.06 ± 0.45
Acidic water	10.40 ± 1.61^{a}	0.34 ± 0.03	0.65 ± 0.05	6.20 ± 0.41
Acidic brine	12.00 ± 1.45^{b}	0.33 ± 0.03	0.61 ± 0.04	6.01 ± 0.08

a, b,... Means having different superscripts in a column are significantly different ($p \leq 0.05$), ns is not significantly different ($p>0.05$)

4.5 EFFECTS OF PASTEURIZATION TEMPERATURE AND TIME ON CHEMICAL AND PHYSICAL PROPERTIES OF KANOM JEEN

The effects of heating temperature (85 ^{O}C and 90 ^{O}C) and time (1, 3 and 5 min) on the qualities of Kanom Jeen are shown in Table 4.13. From the ANOVA (Appendix E; Table E.5), it was found that heating temperature and time and their interactions significantly affected springiness and tensile strength.

When increasing heating temperature and time, springiness and tensile strength of Kanom Jeen decreased especially at 90^{O}C for 5 min (Table 4.13). This is normal that noodle products tend to be softer with higher heating condition. However, in case of heating at 85^{O}C, time had no effect on all textural properties. For microbial qualities, the initial aerobic plate counts, yeast and mould counts of Kanom Jeen were 5 x 10^{3} cfu/g and less than 100 cfu/g, respectively. After heating, aerobic plate counts of all treatments decreased rapidly to less than 250 cfu/g and *E. coli* was not detected (data not shown). Therefore, lower pH to less than 4.5 and heating used in hurdle treated products created condition which was not suitable for microbial growth. Furthermore, color, taste and odor liking scores of all pasteurized Kanom Jeen samples were not significantly different from those of control sample while texture and overall liking scores (Table 4.14) were lower. These were corresponded to the lower springiness and tensile strength (Table 4.13). Temperature showed significant effect on the texture and overall liking scores. The texture and overall liking scores seemed to decrease with increasing temperature. However, heating time affected only the texture liking score when increasing heating time, texture score tended to decrease. Among six samples, it was found that Kanom Jeen pasteurized at 90^{O}C for 5 min showed the lowest texture and overall liking score. The overall liking score of Kanom Jeen, which pasteurized at 85^{O}C for 1 and 3 min and 90^{O}C for 1 min was not significantly different from the control sample. Thus, heating at 90^{O}C for 3 min, which was the maximum temperature and time without affecting the springiness and tensile strength was chosen for further study.

Table 4.13 Effect temperature and time on microbiological and textural properties of Kanom Jeen

Heat condition		Microbiological properties (colonies/g)		Textural properties			
Temperature (^{O}C)	Time (min)	Aerobic plate counts	Yeast and mould	Hardness^{ns} (N)	Stickiness^{ns} (N)	Springiness	Tensile strength (g)
0	0	5×10^{3}	<100	14.94 ± 3.31	0.29 ± 0.04	0.49 ± 0.04^{c}	6.33 ± 0.46^{b}
85	1	<250	<100	12.23 ± 2.92	0.31 ± 0.06	0.46 ± 0.05^{bc}	6.05 ± 0.11^{b}
	3	<250	<100	12.18 ± 2.60	0.29 ± 0.04	0.45 ± 0.06^{bc}	6.00 ± 0.20^{b}
	5	<250	<100	12.18 ± 2.86	0.29 ± 0.06	0.46 ± 0.05^{bc}	6.04 ± 0.53^{b}
90	1	<250	<100	12.10 ± 2.17	0.30 ± 0.04	0.44 ± 0.03^{b}	6.00 ± 0.31^{b}
	3	<250	<100	12.05 ± 2.96	0.30 ± 0.03	0.47 ± 0.04^{c}	5.89 ± 0.31^{b}
	5	<250	<100	10.57 ± 1.41	0.26 ± 0.08	0.39 ± 0.05^{a}	4.29 ± 0.29^{a}

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$)

ns is not significantly different ($p>0.05$)

Table 4.14 Effect of temperature and time on sensory scores of Kanom Jeen

Sample		Color^{ns}	Odor^{ns}	Taste^{ns}	Texture	Overall
Control		3.3 $\pm$ 0.7	3.5 $\pm$ 0.8	3.4 $\pm$ 0.9	3.8 $\pm$ 0.5^{c}	3.8 $\pm$ 0.5^{c}
	1	3.3 $\pm$ 1.2	3.1 $\pm$ 0.9	3.3 $\pm$ 0.8	3.6 $\pm$ 0.5^{bc}	3.5 $\pm$ 0.5^{bc}
85^{O}C	3	3.6 $\pm$ 1.2	3.3 $\pm$ 1.0	3.4 $\pm$ 0.9	3.4 $\pm$ 1.0^{b}	3.5 $\pm$ 0.8^{bc}
	5	3.2 $\pm$ 0.8	2.9 $\pm$ 0.9	3.2 $\pm$ 0.9	3.4 $\pm$ 0.7^{b}	3.2 $\pm$ 0.7^{b}
	1	3.4 $\pm$ 1.0	3.3 $\pm$ 1.1	3.5 $\pm$ 0.9	3.6 $\pm$ 1.0^{bc}	3.4 $\pm$ 0.5^{bc}
90^{O}C	3	3.2 $\pm$ 0.8	3.2 $\pm$ 0.8	2.9 $\pm$ 0.8	3.3 $\pm$ 0.6^{b}	3.2 $\pm$ 0.7^{ab}
	5	3.4 $\pm$ 0.7	3.0 $\pm$ 0.6	3.0 $\pm$ 0.8	2.9 $\pm$ 0.7^{a}	2.9 $\pm$ 0.7^{a}

using five-point hedonic scales (5- most like; 4- like; 3- neither like nor dislike, 2- dislike; 1- dislike very much)

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$)

ns is not significantly different ($p>0.05$)

4.6 THE SHELF – LIFE STUDY OF PASTEURIZED KANOM JEEN

The shelf - life study of Kanom Jeen pasteurized at 90^{O}C for 3 min stored at 30 $\pm$ 5 ^{O}C was shown in Figures 4.3 – 4.5. The pH, % total acidity, water activity, whiteness index, textural characteristics, aerobic plate count and yeast and moulds of samples were analyzed. After storage, % titratable acidity slightly increased (Figure 4.3) which might be due to the activity of microorganism. Foods which are rich in carbohydrate, microorganism will usually utilize carbohydrate and produce acid (Lu *et* al., 2003; Reddy *et* al., 2008). However, the pH was not noticeably different. Furthermore, the hardness, whiteness index and springiness decreased and stickiness increased during storage (Figures 4.3 – 4.4). However, tensile strength seemed to change insignificantly ($p>0.05$) (Figure 4.4). In addition, color, odor, taste, and overall liking scores of the samples decreased during prolonged storage with no change in texture score (Figure 4.4). It might be due to the growth of microorganism in foods caused spoilage by producing an unacceptable odor and flavor. Similar results were also reported in Kanom Jeen (Kittiya, 2007) and Sen Lek (Oraphan, 2005). From microbial analysis (Table 4.15), total aerobic plate count and yeast and moulds of sample were lower than 250 cfu/g and 100 cfu/g, respectively and *E.coli* was also not detected (data is not shown) for the first 13 days of storage. According to the Thai Food and Drug Administration, this type of product must not exceed 1 x 10^4 cfu/g total aerobic plate count and 100 cfu/g in yeast and moulds. Total aerobic plate count reached 6 x 10^3 cfu/g after 29 days while yeast and moulds were more than 100 cfu/g (120 cfu/g) which exceeded the limit for the ready – to – eat product standard (Thai Food and Drug Administration, 2006). Therefore, lowering pH, nitrogen flushing and heating could extend shelf – life of Kanom Jeen to 29 days while the control sample spoiled within 4 days (Table 4.15).

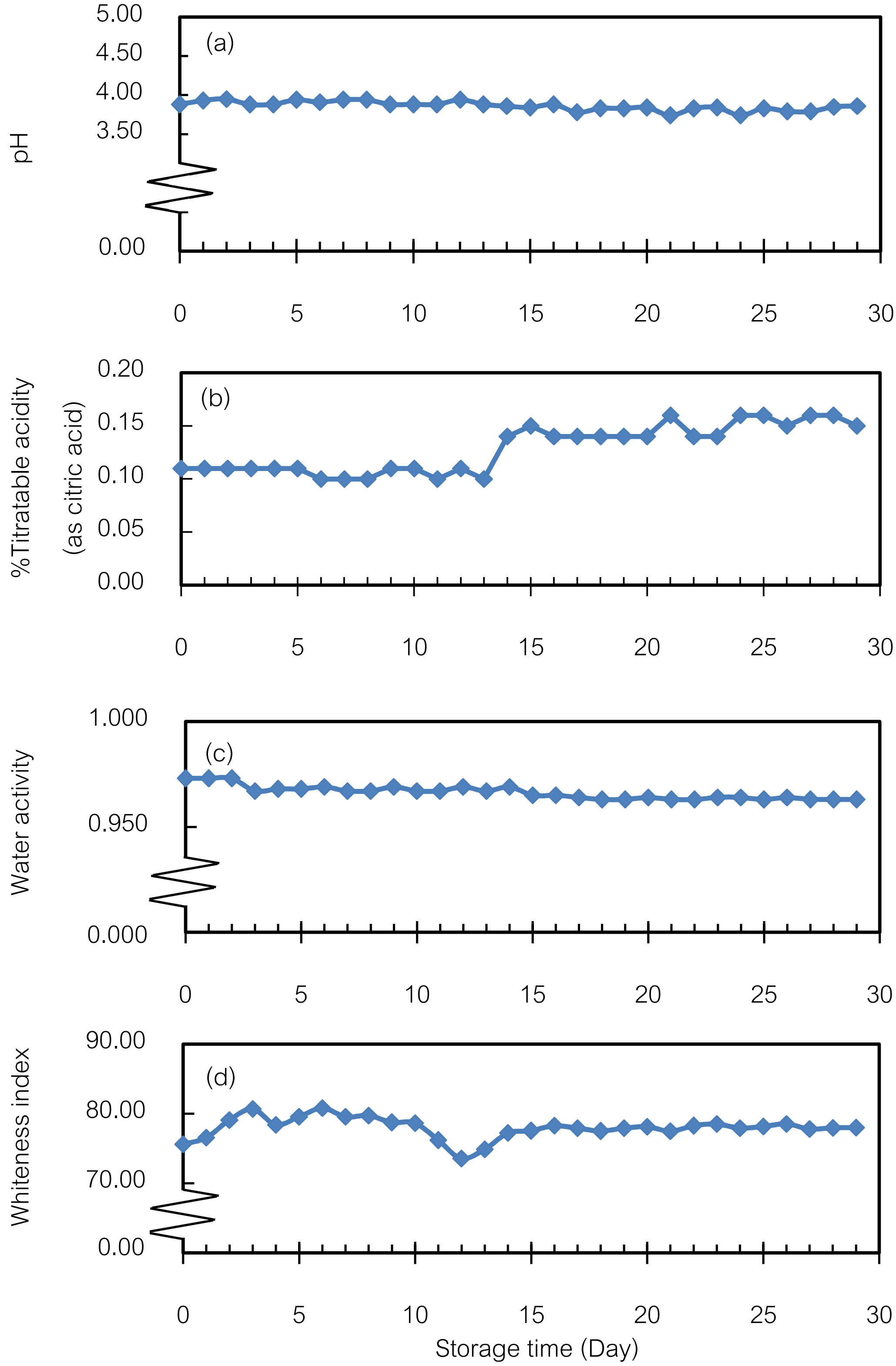


Figure 4.3 Change of pH (a), % titratable acidity (b), water activity (c) and whiteness index (d) of Kanom Jeen during storage

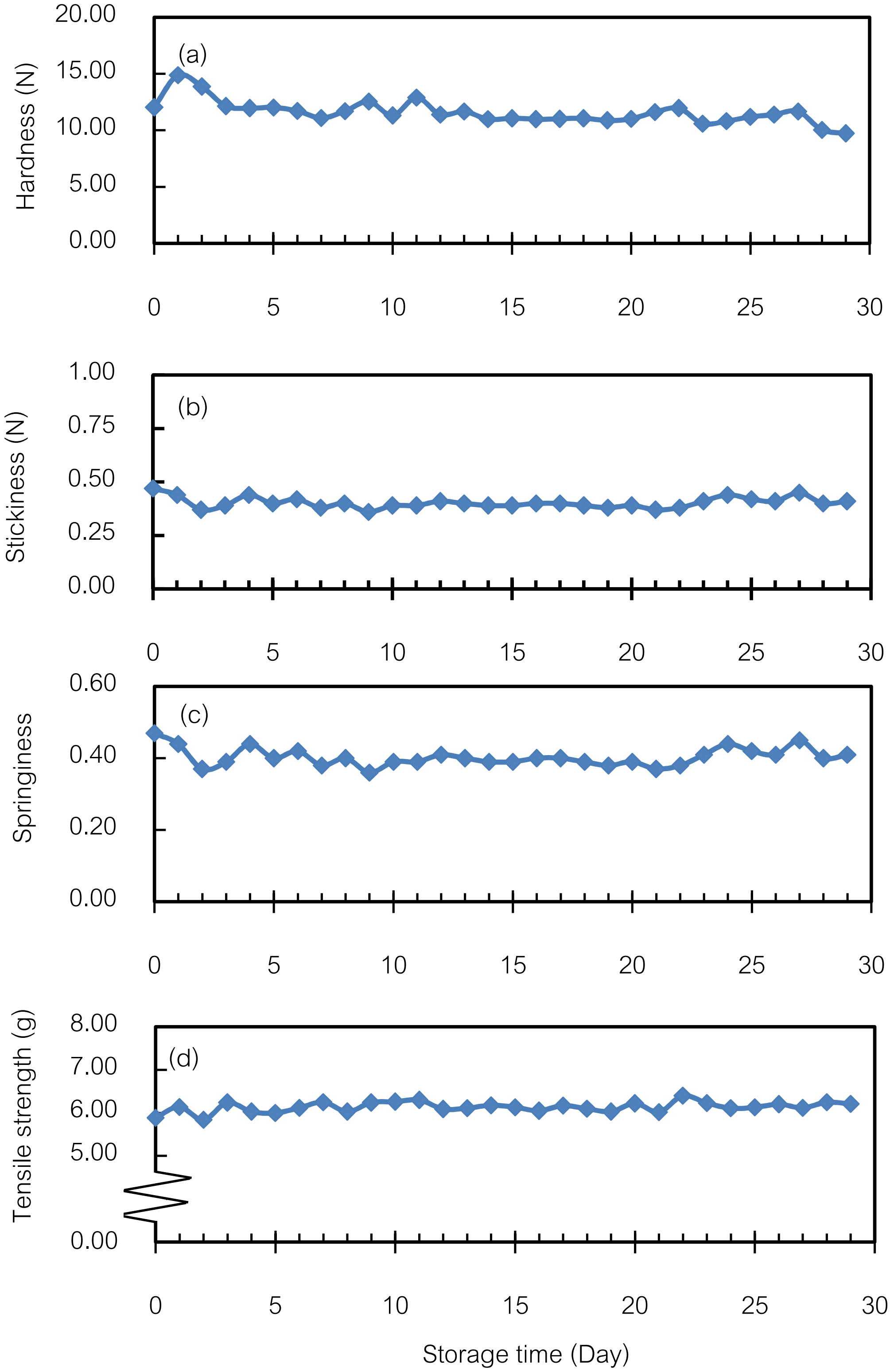


Figure 4.4 Change of hardness (a), stickiness (b), springiness (c) and tensile strength (d) of Kanom Jeen during storage

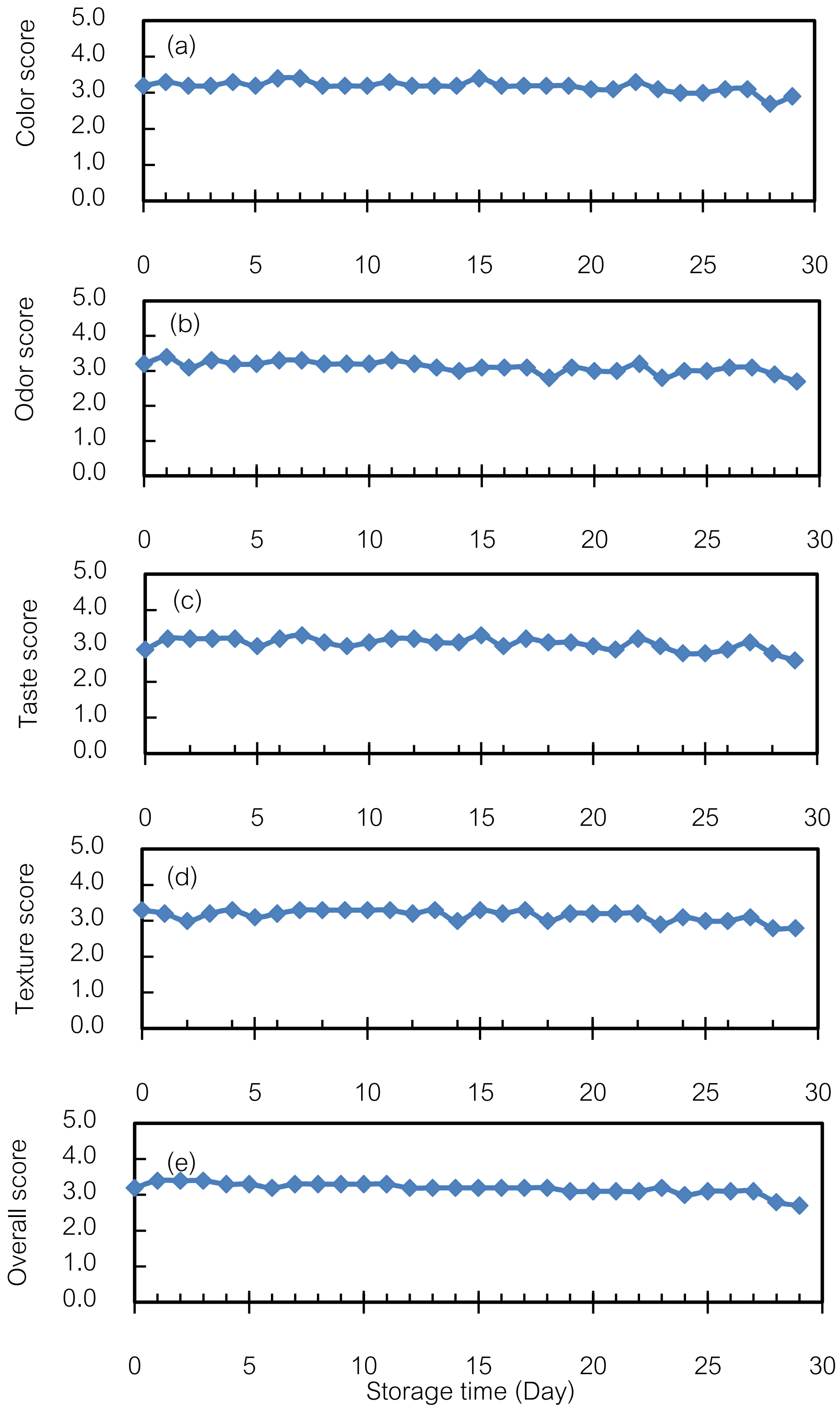


Figure 4. 5 Change of sensory scores of Kanom Jeen during storage : color (a), odor (b), taste (c), texture (d) and overall (e) score

Table 4.15 Microbiological properties of Kanom Jeen during storage at 30^{O}C

Date	Aerobic plate counts (CFU/g)		Yeast and moulds (CFU/g)	
	Control sample	Treated sample	Control sample	Treated sample
0	11 ± 2	<250	<100	<100
1	312 ± 17	<250	<100	<100
2	672 ± 30	<250	<100	<100
3	2460 ± 140	<250	<100	<100
4	8750 ± 200	<250	120 ± 34	<100
5		<250		<100
6		<250		<100
7		<250		<100
8		<250		<100
9		<250		<100
10		<250		<100
11		<250		<100
12		<250		<100
13		<250		<100
14		295 ± 7		<100
15		410 ± 14		<100
16		517 ± 11		<100
17		900 ± 14		<100
18		905 ± 7		<100
19		930 ± 14		<100
20		1000 ± 141		<100
21		1700 ± 141		<100
22		1400 ± 283		<100
23		1850 ± 71		<100
24		2000 ± 141		<100
25		2100 ± 141		<100
26		3250 ± 354		<100
27		3100 ± 141		<100
28		3250 ± 212		<100
29		3350 ± 212		<100
30		6000 ± 566		120 ± 14

CHAPTER V

CONCLUSIONS

5.1 CONCLUSIONS

The chemical components (protein, fat and amylose) and RVA viscosity of rice flour decreased while onset temperature (DSC), swelling power, and solubility at 75^{O}C increased after acid treatment.

The preparation process for Kanom Jeen can be summarized as Figure 5.1.

Broken rice

↓

Wet - mill and centrifuge at 950 rpm for 15 min

↓

Soak in 2% (w/w) citric acid solution
(ratio of sediment : acid solution of 1 : 2, w/w) for 2 h

↓

Centrifuge

↓

15% of rice sediment → Steam at 100 ^{O}C for 10 minutes | 85% rice sediment

↓

Knead and adjust moisture content to 50%.

↓

Extrude through a die into boiling water containing 7% salt (w/w) and 0.25% citric acid (90-95^{o}C) and cook for 20 s

↓

Pick up the cooked noodle and cool in 7% salt (w/w) solution (~4 ^{O}C) for 20 s

↓

Pack 30 g. of Kanom Jeen in 18 cm. x 21 cm. PE / Al / PE bag

↓

Seal with nitrogen flushed (rate 80 bar/min) for 1 min.

↓

Heat in 95^{O}C water bath till the center temperature reaches 90^{O}C then hold for 3 min

↓

Cool under tap water to reduce center temperature to 25 - 30 ^{O}C.

↓

Pasteurized Kanom Jeen

Figure 5.1 Preparation process for pasteurized Kanom – Jeen

The Kanom Jeen can be stored up to 29 days at 30 $\pm$ 5 ^{O}C.

5.2 SUGGESTIONS

To extend the shelf - life of Kanom Jeen more than 29 days, the texture must be improved. It could be observed that Kanom Jeen cannot withstand sterilization heating, therefore application of other starch or hydrocolloid may be used to increase the tensile strength of rice noodle. Moreover, application of radiation, which is cold sterilization, may be used to extend the shelf - life of fresh Kanom Jeen.

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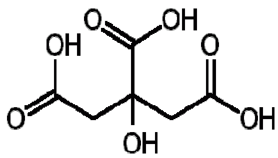
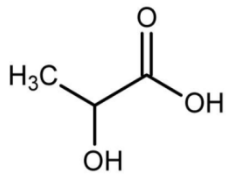
APPENDICES

APPENDIX A
CHEMICAL

Acid	Citric acid (powder)	Lactic acid (solution)
Formula	$C_6H_8O_7$	$C_3H_6O_3$
Name	2 – hydroxy – 1,2,3 – propane tricaboxylic acid	2 – hydroxy propanoic acid
Structure		
Molecular weight	192.13	90.08
CAS – No.	77 – 92 - 9	50 - 21 - 5
Purity	86.67%	80%
Cost*	200 Baht / kg.	350 Baht / kg.

* Reference cost from CT Chemical Co., Ltd. (Thailand) (in 21 May 2010)

Acid solution preparation

For citric acid :

A 1% w/w solution of citric acid was prepared by adding 1.15 grams of citric acid (powder purity 86.67%) to a 100 ml flask half filled with water and then adjusted water to 100 ml.

For lactic acid :

A 1% w/w solution of citric acid was prepared by adding 1.25 ml of lactic acid (solution concentration 80%) to a 100 ml flask half filled with water and then adjusted water to 100 ml.

APPENDIX B

ANALYTICAL METHODS

B.1 Acidity

Acidity was determined following the method of AACC method 02-31 (2000). The sample (10 g) was dissolved and dispersed in 100 ml distilled water, mixed thoroughly and allowed to stand for approximately 1 hr. After stirring gently a 17.6 mL aliquot was pipetted into a porcelain casserole. The same pipette was rinsed out with 17.6 ml water that was added to the sample in the casserole. 0.5 mL phenolphthalein indicator was added and titrated with standardized 0.1N NaOH until a faint pink color persists for 30 seconds. The total acidity was calculated according to following expression.

$$\text{Percent acid} = \frac{N \times V \times \text{Eq. wt.} \times 100}{W \times 1000}$$

N = normality of NaOH (mEq/ml)

V = volume of titration (ml)

Eq. wt. = equivalent weight (mg/mEq) for citric acid = 64, lactic acid = 90

W = mass of sample (g)

1000 = factor relating mg to g (mg/g)

B.2 Swelling power and solubility at 75°C

Swelling power and solubility were determined following the modified method of Li and Yeh (2001). Rice flour was weighed 0.1 g (dry basis) into a centrifuge tube with coated screw cap and 10 ml distilled water was added. The coated screw cap tube was heated at 75°C in a shaking water bath for an hour and then cooled to room temperature in an ice water bath. The tube was centrifuged at 2,300 rpm for 15 min (ECMultiRF, Thermo IEC, U.S.A.).

The supernatant was removed from the tube and then dried to constant weight in an air oven at 100^{O}C. The swollen flour sediment in tube was weighed. The swelling power and solubility were calculated as:

$$\text{solubility (\%)} = \frac{\text{Weight of soluble matter in supernatant (g)} \times 100}{\text{Weight of sample (dry basis)}}$$

$$\text{swelling power (g/g)} = \frac{\text{Weight of swollen matter (g)} \times 100}{\text{Weight of sample (dry basis)} \times (100 - \text{solubility})}$$

B.3 Thermal properties

The thermal properties of rice flour samples were determined following the modified method of Ndife, Sumnu, and Bayindirli (1998) by using the Differential Scanning Calorimetry (Perkin Elmer, Model Diamond DSC, U.S.A.) equipped with intracooler unit (Perkin Elmer, Model 2P, U.S.A.) and nitrogen gas purge. Suspension of 10 ± 0.1 mg (rice flour – water ratio 1:2 (w/w)) was weighed in aluminum DSC pans that were hermetically sealed and allowed to stand overnight prior to thermal analysis. The sample pan was then heated from 30 to 100 °C at a rate of 10 °C/min. An empty pan was used as a reference. Onset temperature, peak temperature, conclusion temperature and enthalpy of gelatinization (ΔH gel) were calculated using the Pyris™ software equipped with the quipment.

B.4 Granule morphology

Rice flour sample was mounted on scanning electron microscope (SEM) stub using double sided adhesive tape and was coated with gold. Scanning electron micrographs were taken using a JEOL JSM-5800V microscope (JEOL, Tokyo, Japan). The accelerating voltage and the magnification were 15kV and 3,000x, respectively.

B.5 Texture properties

Instrumental texture evaluation of Kanom Jeen was performed using a Texture Analyzer (Stable Micro System, model TA-XT2i, England) equipped with a 1 kg load cell and a Texture Expert for Windows software (version 1.20) for data analysis.

The textural characteristics were measured using a 100 mm diameter aluminium cylinder probe (Code P/100) at testing condition mode: texture profile analysis (TPA), pre - test speed 1.0 mm/s, test speed 1.00 mm/s and post - test speed 10.00 mm/s and strain : 75%. Kanom Jeen samples cut into 4 – cm long strands. Four strands were placed side by side on the stand and compressed by the probe. Measurements were carried out in 20 replicates.

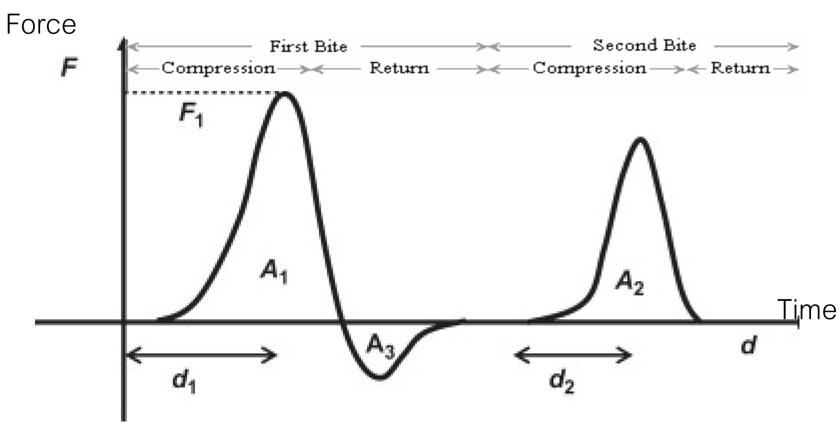


Figure B.1 Texture profile curve (TPA)

The textural parameters was obtained from Figure B.1. (Bourne, 1978)

Hardness : peak force of the first compression cycle in N, F_1

Springiness : ratio of the time duration of force input during the second compression to that during the first compression, d_1 / d_2

Stickiness : peak force of negative force of the first compression cycle in N, A_3

Tensile strength of the noodles was measured following the method of Stable Micro Systems using Spaghetti Tensile Rig probe (Code A/SPR) at testing condition mode : tensile test, pre - test speed 3.0 mm/s, test speed 3.00 mm/s and post

- test speed 5.00 mm/s and distance : 10 mm. Kamon Jeen samples cut into 15 – cm strands. The noodle were placed one into the lower rig arm slot and winding the loosened arm sufficiently, in order to anchor the noodle end (away from the slot) by at least two revolutions of the arm. The arm was tightened and the same procedure was performed to anchor the other noodle end to the upper arm. The maximum force (g) referred to the resistance to breakdown of the noodle (tensile strength) (Figure B.2) (Bourne, 1978). Measurements were carried out in 20 replicates.

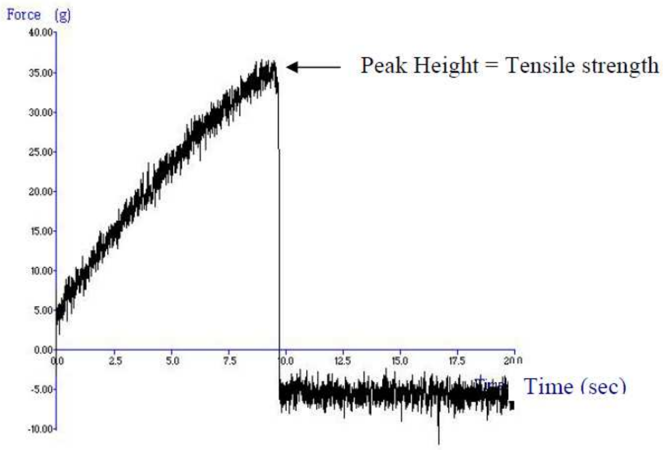


Figure B.2 Texture profile curve (Tensile strength)

B.6 Microbiology

B.6.1 Aerobic plate count

Aerobic plate count was evaluated using 3M Petrifilm™ aerobic count (AC) plates. The 10 grams of sample was crushed using 90 ml of normal saline (0.7% salt) as a diluent in sterile bag by stomacher (AES Laboratoire, Combourg, France) for 30 seconds and then diluted to 2 levels working concentration. The top film was lifted and 1 ml of sample suspension was placed onto the center of the bottom film. The plastic Petrifilm spreader was placed and pressd on the center of the plate to distribute the sample (at least 1 min to set gel). The incubation condition was at 32^{O}C ± 5 ^{O}C for 48 hours (AOAC, 1995). Bacterial colonies on Petrifilm AC plates were red because of the indicator dye in the medium and they can be counted on a standard colony counter or other light source.

B.6.2 Yeast and moulds plate count

Yeast and moulds were evaluated using 3M Petrifilm™ yeast and mould count (YM) plates. The samples were prepared similarly to an aerobic plate count but the incubation condition was at 25^{O}C ± 1 ^{O}C for 5 days (AOAC, 1995). Yeast colonies were small with defined edges and were pink-tan to blue-green in color. Mould colonies would be large and variable in color.

B.6.3 *E. coli*/Coliform plate count

E. coli/Coliform plate count was evaluated using 3M Petrifilm™ *E. coli*/Coliform count plates. The samples were prepared similarly to aerobic plate count but the incubation condition was at 32^{O}C ± 5 ^{O}C for 1 day (coliforms) and 2 days (*E.coli*) (AOAC, 1995). A red indicator dye in the plate color all colonies red, and a top film traps gas (seen as bubbles) were produced by the coliforms. In addition, a glucuronidase indicator formed a blue precipitate around any *E. coli* colonies that were present.

APPENDIX C

DATA

Table C.1 Color of rice flour after acid treatment

Sample		L*	a*	b*
Native		98.08 $\pm$ 0.18^{b}	- 0.13 $\pm$ 0.02^{bc}	2.45 $\pm$ 0.04^{b}
Citric acid	1%	96.58 $\pm$ 1.41^{a}	- 0.22 $\pm$ 0.06^{a}	3.00 $\pm$ 0.31^{c}
	2%	96.25 $\pm$ 1.46^{a}	- 0.20 $\pm$ 0. 10^{ab}	3.36 $\pm$ 0.30^{d}
	3%	96.56 $\pm$ 0.22^{a}	- 0.18 $\pm$ 0.04^{abc}	3.66 $\pm$ 0.1 3^{d}
Lactic acid	1%	95.69 $\pm$ 0.1 1^{a}	- 0.07 $\pm$ 0.06^{d}	3.43 $\pm$ 0.2 0^{d}
	2%	96.09 $\pm$ 1.5 3^{a}	- 0.17 $\pm$ 0.03^{abc}	1.53 $\pm$ 0.38^{a}
	3%	96.26 $\pm$ 1.70^{a}	- 0.12 $\pm$ 0.05^{cd}	2.35 $\pm$ 0.04^{b}

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$)

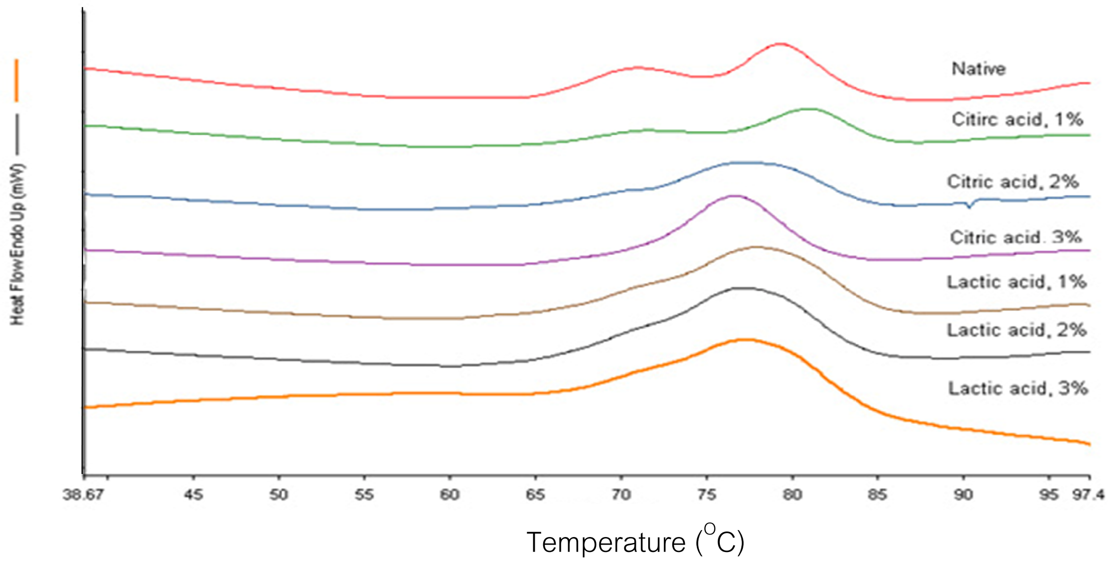


Figure C.1 DSC thermograms of native and acid - treated rice flour samples

Table C.2 Change of pH, acidity, water activity and whiteness index in Kanom Jeen during storage at 30 $\pm$ 5^{O}C

Date	pH^{ns}	Acidity	Water activity	Whiteness Index
0	3.88 $\pm$ 0.11	0.11 $\pm$ 0.01^{a}	0.973 $\pm$ 0.002^{e}	75.60 $\pm$ 2.12^{ab}
1	3.93 $\pm$ 0.08	0.11 $\pm$ 0.01^{a}	0.973 $\pm$ 0.002^{e}	76.56 $\pm$ 1.93^{abcd}
2	3.95 $\pm$ 0.13	0.11 $\pm$ 0.01^{a}	0.973 $\pm$ 0.006^{de}	79.08 $\pm$ 2.58^{e}
3	3.88 $\pm$ 0.10	0.11 $\pm$ 0.01^{a}	0.967 $\pm$ 0.003^{cd}	80.70 $\pm$ 1.99^{e}
4	3.88 $\pm$ 0.11	0.11 $\pm$ 0.00^{a}	0.968 $\pm$ 0.001^{cd}	78.40 $\pm$ 1.73^{de}
5	3.94 $\pm$ 0.11	0.11 $\pm$ 0.02^{a}	0.968 $\pm$ 0.001^{cd}	79.57 $\pm$ 1.25^{de}
6	3.91 $\pm$ 0.17	0.10 $\pm$ 0.02^{a}	0.969 $\pm$ 0.001^{d}	80.82 $\pm$ 3.91^{e}
7	3.94 $\pm$ 0.11	0.10 $\pm$ 0.01^{a}	0.967 $\pm$ 0.001^{cd}	79.56 $\pm$ 1.25^{de}
8	3.94 $\pm$ 0.11	0.10 $\pm$ 0.02^{a}	0.967 $\pm$ 0.002^{cd}	79.74 $\pm$ 1.09^{de}
9	3.88 $\pm$ 0.11	0.11 $\pm$ 0.02^{a}	0.969 $\pm$ 0.001^{d}	78.75 $\pm$ 0.99^{cde}
10	3.88 $\pm$ 0.10	0.11 $\pm$ 0.02^{a}	0.967 $\pm$ 0.001^{cd}	78.66 $\pm$ 1.34^{cde}
11	3.88 $\pm$ 0.10	0.10 $\pm$ 0.01^{a}	0.967 $\pm$ 0.003^{cd}	76.19 $\pm$ 2.95^{bcde}
12	3.94 $\pm$ 0.11	0.11 $\pm$ 0.02^{a}	0.969 $\pm$ 0.002^{d}	73.57 $\pm$ 0.68^{a}
13	3.88 $\pm$ 0.10	0.10 $\pm$ 0.01^{a}	0.967 $\pm$ 0.001^{cd}	74.89 $\pm$ 1.76^{a}
14	3.86 $\pm$ 0.02	0.14 $\pm$ 0.01^{b}	0.969 $\pm$ 0.001^{d}	77.24 $\pm$ 1.11^{cde}
15	3.84 $\pm$ 0.04	0.15 $\pm$ 0.02^{bc}	0.965 $\pm$ 0.004^{abc}	77.55 $\pm$ 0.66^{bcde}
16	3.88 $\pm$ 0.01	0.14 $\pm$ 0.00^{b}	0.965 $\pm$ 0.004^{abc}	78.28 $\pm$ 0.39^{cde}
17	3.78 $\pm$ 0.04	0.14 $\pm$ 0.01^{b}	0.964 $\pm$ 0.003^{ab}	77.93 $\pm$ 0.57^{cde}
18	3.83 $\pm$ 0.03	0.14 $\pm$ 0.02^{bc}	0.963 $\pm$ 0.001^{a}	77.51 $\pm$ 0.74^{cde}
19	3.83 $\pm$ 0.03	0.14 $\pm$ 0.01^{b}	0.963 $\pm$ 0.000^{a}	77.92 $\pm$ 0.55^{cde}
20	3.84 $\pm$ 0.02	0.14 $\pm$ 0.01^{b}	0.964 $\pm$ 0.003^{ab}	78.13 $\pm$ 0.69^{cde}
21	3.74 $\pm$ 0.06	0.16 $\pm$ 0.02^{c}	0.963 $\pm$ 0.001^{a}	77.49 $\pm$ 1.18^{cde}
22	3.83 $\pm$ 0.08	0.14 $\pm$ 0.01^{b}	0.963 $\pm$ 0.000^{a}	78.27 $\pm$ 0.53^{cde}
23	3.84 $\pm$ 0.03	0.14 $\pm$ 0.00^{b}	0.964 $\pm$ 0.002^{ab}	78.52 $\pm$ 0.38^{cde}
24	3.74 $\pm$ 0.06	0.16 $\pm$ 0.02^{c}	0.964 $\pm$ 0.003^{ab}	77.93 $\pm$ 0.55^{cde}
25	3.83 $\pm$ 0.08	0.16 $\pm$ 0.03^{c}	0.963 $\pm$ 0.001^{a}	78.17 $\pm$ 0.41^{cde}
26	3.79 $\pm$ 0.13	0.15 $\pm$ 0.01^{c}	0.964 $\pm$ 0.002^{ab}	78.53 $\pm$ 0.59^{cde}
27	3.79 $\pm$ 0.07	0.16 $\pm$ 0.00^{c}	0.963 $\pm$ 0.001^{a}	77.80 $\pm$ 0.62^{cde}
28	3.85 $\pm$ 0.04	0.16 $\pm$ 0.02^{c}	0.963 $\pm$ 0.001^{a}	77.97 $\pm$ 0.59^{cde}
29	3.86 $\pm$ 0.03	0.15 $\pm$ 0.01^{c}	0.963 $\pm$ 0.000^{a}	78.01 $\pm$ 0.65^{cde}

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$) and ns is not significantly different ($p>0.05$)

Table C.3 Change of hardness (N), stickiness (N), springiness and tensile strength (g) in Kanom Jeen during storage at 30 $\pm$ 5^{O}C

Date	Hardness (N)	Stickiness (N)	Springiness	Tensile strength^{ns} (g)
0	12.05 $\pm$ 2.96^{ab}	0.30 $\pm$ 0.03^{a}	0.47 $\pm$ 0.04^{b}	5.89 $\pm$ 0.31
1	14.89 $\pm$ 3.02^{b}	0.35 $\pm$ 0.07^{ab}	0.44 $\pm$ 0.03^{b}	6.14 $\pm$ 0.62
2	13.88 $\pm$ 1.54^{b}	0.30 $\pm$ 0.03^{a}	0.37 $\pm$ 0.10^{ab}	5.84 $\pm$ 0.40
3	12.15 $\pm$ 1.13^{ab}	0.32 $\pm$ 0.08^{a}	0.39 $\pm$ 0.11^{ab}	6.24 $\pm$ 0.62
4	11.97 $\pm$ 2.35^{ab}	0.29 $\pm$ 0.06^{a}	0.44 $\pm$ 0.10^{ab}	6.03 $\pm$ 0.22
5	12.04 $\pm$ 1.45^{ab}	0.31 $\pm$ 0.06^{a}	0.40 $\pm$ 0.07^{ab}	6.00 $\pm$ 0.53
6	11.74 $\pm$ 2.22^{ab}	0.35 $\pm$ 0.06^{ab}	0.42 $\pm$ 0.01^{b}	6.12 $\pm$ 0.73
7	11.10 $\pm$ 1.64^{ab}	0.35 $\pm$ 0.06^{ab}	0.38 $\pm$ 0.01^{ab}	6.25 $\pm$ 0.49
8	11.71 $\pm$ 1.95^{ab}	0.33 $\pm$ 0.06^{ab}	0.40 $\pm$ 0.02^{ab}	6.03 $\pm$ 0.33
9	12.56 $\pm$ 0.74^{ab}	0.39 $\pm$ 0.05^{b}	0.36 $\pm$ 0.05^{a}	6.24 $\pm$ 0.54
10	11.32 $\pm$ 0.89^{ab}	0.37 $\pm$ 0.06^{b}	0.39 $\pm$ 0.11^{ab}	6.26 $\pm$ 0.42
11	12.91 $\pm$ 0.85^{ab}	0.34 $\pm$ 0.05^{ab}	0.39 $\pm$ 0.06^{ab}	6.30 $\pm$ 0.38
12	11.40 $\pm$ 1.37^{ab}	0.30 $\pm$ 0.06^{a}	0.41 $\pm$ 0.09^{ab}	6.09 $\pm$ 0.35
13	11.69 $\pm$ 1.90^{ab}	0.32 $\pm$ 0.04^{a}	0.40 $\pm$ 0.05^{ab}	6.11 $\pm$ 0.24
14	11.01 $\pm$ 0.89^{ab}	0.36 $\pm$ 0.04^{b}	0.39 $\pm$ 0.03^{ab}	6.18 $\pm$ 0.37
15	11.07 $\pm$ 1.28^{ab}	0.34 $\pm$ 0.03^{ab}	0.39 $\pm$ 0.03^{ab}	6.13 $\pm$ 0.11
16	10.99 $\pm$ 0.87^{ab}	0.36 $\pm$ 0.02^{b}	0.40 $\pm$ 0.02^{ab}	6.05 $\pm$ 0.14
17	11.02 $\pm$ 0.7^{ab}	0.34 $\pm$ 0.03^{ab}	0.40 $\pm$ 0.02^{ab}	6.17 $\pm$ 0.16
18	11.07 $\pm$ 0.78^{ab}	0.34 $\pm$ 0.04^{ab}	0.39 $\pm$ 0.02^{ab}	6.10 $\pm$ 0.07
19	10.89 $\pm$ 1.43^{ab}	0.38 $\pm$ 0.04^{b}	0.38 $\pm$ 0.02^{ab}	6.03 $\pm$ 0.09
20	11.03 $\pm$ 0.72^{ab}	0.34 $\pm$ 0.03^{ab}	0.39 $\pm$ 0.01^{ab}	6.22 $\pm$ 0.38
21	11.64 $\pm$ 1.43^{ab}	0.40 $\pm$ 0.02^{b}	0.37 $\pm$ 0.06^{ab}	6.02 $\pm$ 0.21
22	11.97 $\pm$ 1.05^{ab}	0.37 $\pm$ 0.05^{b}	0.38 $\pm$ 0.04^{ab}	6.40 $\pm$ 0.44
23	10.61 $\pm$ 0.84^{ab}	0.31 $\pm$ 0.02^{a}	0.41 $\pm$ 0.04^{ab}	6.23 $\pm$ 0.40
24	10.83 $\pm$ 1.33^{ab}	0.30 $\pm$ 0.04^{a}	0.44 $\pm$ 0.04^{b}	6.11 $\pm$ 0.18
25	11.21 $\pm$ 0.68^{ab}	0.32 $\pm$ 0.04^{a}	0.42 $\pm$ 0.04^{b}	6.13 $\pm$ 0.44
26	11.40 $\pm$ 1.92^{ab}	0.31 $\pm$ 0.05^{a}	0.41 $\pm$ 0.03^{ab}	6.20 $\pm$ 0.08
27	11.69 $\pm$ 1.44^{ab}	0.33 $\pm$ 0.05^{a}	0.45 $\pm$ 0.04^{b}	6.12 $\pm$ 0.34
28	10.06 $\pm$ 0.62^{ab}	0.33 $\pm$ 0.05^{a}	0.40 $\pm$ 0.01^{ab}	6.25 $\pm$ 0.41
29	9.74 $\pm$ 1.60^{a}	0.34 $\pm$ 0.06^{ab}	0.41 $\pm$ 0.03^{ab}	6.21 $\pm$ 0.30

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$) and ns is not significantly different ($p>0.05$).

Table C.4 Sensory evaluation of Kanom Jeen during storage at 30^{O}C

Date	Color	Odor	Flavour	Texture^{ns}	Overall
0	3.2 ± 0.8^{bcd}	3.2 ± 0.8^{bcde}	2.9 ± 0.8^{abcd}	3.3 ± 0.6	3.2 ± 0.7^{cd}
1	3.3 ± 0.8^{bcd}	3.4 ± 0.7^{e}	3.2 ± 0.8^{cd}	3.2 ± 1.0	3.4 ± 0.7^{d}
2	3.2 ± 0.5^{bcd}	3.1 ± 0.6^{abcde}	3.2 ± 0.5^{bcd}	3.0 ± 0.4	3.4 ± 0.5^{d}
3	3.2 ± 0.7^{bcd}	3.3 ± 0.8^{de}	3.2 ± 0.7^{bcd}	3.2 ± 1.0	3.4 ± 0.7^{d}
4	3.3 ± 0.6^{cd}	3.2 ± 0.8^{bcde}	3.2 ± 0.5^{d}	3.3 ± 0.9	3.3 ± 0.7^{cd}
5	3.2 ± 0.7^{bcd}	3.2 ± 0.8^{bcde}	3.0 ± 0.7^{bcd}	3.1 ± 0.9	3.3 ± 0.6^{cd}
6	3.4 ± 0.8^{cd}	3.3 ± 0.8^{cde}	3.2 ± 0.5^{d}	3.2 ± 0.6	3.2 ± 0.6^{cd}
7	3.4 ± 0.7^{d}	3.3 ± 0.5^{de}	3.3 ± 0.6^{d}	3.3 ± 0.5	3.3 ± 0.5^{cd}
8	3.2 ± 0.7^{bcd}	3.2 ± 0.8^{bcde}	3.1 ± 0.7^{bcd}	3.3 ± 1.0	3.3 ± 0.7^{cd}
9	3.2 ± 0.7^{bcd}	3.2 ± 0.8^{bcde}	3.0 ± 0.8^{bcd}	3.3 ± 1.0	3.3 ± 0.7^{cd}
10	3.2 ± 0.8^{bcd}	3.2 ± 0.8^{bcde}	3.1 ± 0.9^{bcd}	3.3 ± 1.0	3.3 ± 0.8^{cd}
11	3.3 ± 0.7^{cd}	3.3 ± 0.4^{cde}	3.2 ± 0.7^{d}	3.3 ± 0.4	3.3 ± 0.4^{cd}
12	3.2 ± 0.8^{bcd}	3.2 ± 0.8^{bcde}	3.2 ± 0.5^{cd}	3.2 ± 0.5	3.2 ± 0.7^{cd}
13	3.2 ± 0.6^{bcd}	3.1 ± 0.8^{bcde}	3.1 ± 0.5^{bcd}	3.3 ± 0.9	3.2 ± 0.6^{cd}
14	3.2 ± 0.5^{bcd}	3.0 ± 0.6^{abcd}	3.1 ± 0.4^{bcd}	3.0 ± 0.4	3.2 ± 0.4^{cd}
15	3.4 ± 0.7^{d}	3.1 ± 0.6^{bcde}	3.3 ± 0.6^{d}	3.3 ± 0.5	3.2 ± 0.5^{cd}
16	3.2 ± 0.8^{bcd}	3.1 ± 0.9^{abcde}	3.0 ± 0.8^{bcd}	3.2 ± 1.0	3.2 ± 0.8^{cd}
17	3.2 ± 0.8^{bcd}	3.1 ± 0.9^{abcde}	3.2 ± 0.5^{bcd}	3.3 ± 0.6	3.2 ± 0.9^{cd}
18	3.2 ± 0.5^{bcd}	2.8 ± 0.6^{ab}	3.1 ± 0.4^{bcd}	3.0 ± 0.6	3.2 ± 0.6^{cd}
19	3.2 ± 0.6^{bcd}	3.1 ± 0.9^{abcde}	3.1 ± 0.5^{bcd}	3.2 ± 0.9	3.1 ± 0.7^{bcd}
20	3.1 ± 0.7^{bcd}	3.0 ± 0.9^{abcde}	3.0 ± 0.6^{bcd}	3.2 ± 1.0	3.1 ± 0.7^{cd}
21	3.1 ± 0.7^{bcd}	3.0 ± 0.9^{abcde}	2.9 ± 0.7^{abcd}	3.2 ± 1.0	3.1 ± 0.7^{cd}
22	3.3 ± 0.8^{bcd}	3.2 ± 0.5^{bcde}	3.2 ± 0.7^{bcd}	3.2 ± 0.6	3.1 ± 0.6^{bcd}
23	3.1 ± 0.6^{bcd}	2.8 ± 0.6^{ab}	3.0 ± 0.5^{bcd}	2.9 ± 0.5	3.2 ± 0.6^{cd}
24	3.0 ± 0.7	3.0 ± 0.9^{abcde}	2.8 ± 0.7^{abc}	3.1 ± 0.6	3.0 ± 0.7^{abc}
25	3.0 ± 0.7^{abc}	3.0 ± 0.9^{abcde}	2.8 ± 0.7^{abc}	3.0 ± 1.0	3.1 ± 0.7^{bcd}
26	3.1 ± 0.8^{bcd}	3.1 ± 0.9^{abcde}	2.9 ± 0.8^{abcd}	3.0 ± 0.9	3.1 ± 0.8^{cd}
27	3.1 ± 0.9^{bcd}	3.1 ± 0.9^{abcde}	3.1 ± 0.6^{bcd}	3.1 ± 0.6	3.1 ± 1.0^{bcd}
28	2.7 ± 0.7^{a}	2.9 ± 0.9^{abc}	2.8 ± 0.7^{ab}	2.8 ± 0.8	2.8 ± 0.4^{ab}
29	2.9 ± 0.8^{ab}	2.7 ± 0.6^{a}	2.6 ± 0.6^{a}	2.8 ± 0.8	2.7 ± 0.5^{a}

using five-point hedonic scales (5- most like; 4- like; 3- neither like nor dislike, 2- dislike; 1- dislike very much).

a, b, c,... Means having different superscripts in a column are significantly different ($p \leq 0.05$) and ns is not significantly different ($p>0.05$).

APPENDIX D

SENSORY EVALUATION FORMS

Acceptance test of Ready – To – Eat Kanom Jeen Date……………….

Name…………………………..Gender ( ) Male ( ) Female

Age ( ) 15 – 20 years ( ) 21 – 25 years ( ) 26 – 30 years

( ) 31 – 40 years ( ) over 41 years

Please evaluate acceptance of the sample by scoring (/) on the scale

Code...............................

Scale / Qualities	Most like	Like	Neither like nor dislike	Dislike	Dislike very much
Color					
Odor					
Flavor					
Texture					
Overall acceptance					

Suggestion…………………………………………………………………………………….

……………..……………..

THANK YOU

Figure D.1 Sensory evaluation form for verification of Kanom Jeen.

APPENDIX E
STATISTICAL ANALYSIS DATA

Table E.1 ANOVA: overall effect of independent variables Citric acid (1, 2 and 3 %) and Lactic acid (1, 2 and 3 %) on response variables of rice flour

E.1.1 Dependent Variable: chemical compositions

E.1.1.1 Protein

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	13.599	6	2.266	8813.988	0.000
Within Groups	0.004	14	0.000		
Total	13.602	20			

E.1.1.2 Fat

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.078	6	0.013	105.513	0.000
Within Groups	0.002	14	0.000		
Total	0.080	20			

E.1.1.3 Ash

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.004	6	0.001	1.855	0.160
Within Groups	0.005	14	0.000		
Total	0.009	20			

E.1.1.4 Amylose

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	58.196	6	9.699	51.778	0.000
Within Groups	2.623	14	0.187		
Total	60.819	20			

E.1.2 Dependent Variable: pH, acidity, swelling power, solubility and whiteness index

E.1.2.1 pH

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	27.899	6	4.650	976473.000	0.000
Within Groups	0.000	14	0.000		
Total	27.899	20			

E.1.2.2 Acidity

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.098	6	0.516	27105.000	0.000
Within Groups	0.000	14	0.000		
Total	3.098	20			

E.1.2.3 Swelling

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.130	6	0.022	2.329	0.090
Within Groups	0.130	14	0.009		
Total	0.260	20			

E.1.2.4 Solubility

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.727	6	0.955	64.164	0.000
Within Groups	0.208	14	0.015		
Total	5.935	20			

E.1.2.5 Whiteness index

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	36.414	6	6.069	7.132	0.000
Within Groups	11.914	14	0.851		
Total	48.328	20			

E.1.3 Dependent Variable: peak viscosity, trough, breakdown, final viscosity and setback

E.1.3.1 Peak viscosity

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	32873.031	6	5478.839	444.877	0.000
Within Groups	172.416	14	12.315		
Total	33045.447	20			

E.1.3.2 Trough

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	19566.579	6	3261.097	509.962	0.000
Within Groups	89.527	14	6.395		
Total	19656.106	20			

E.1.3.3 Breakdown

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2622.366	6	437.061	36.488	0.000
Within Groups	167.694	14	11.978		
Total	2790.060	20			

E.1.3.4 Final viscosity

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	67332.295	6	11222.049	394.735	0.000
Within Groups	398.010	14	28.429		
Total	67730.305	20			

E.1.3.5 Setback

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15754.703	6	2625.784	127.866	0.000
Within Groups	287.496	14	20.535		
Total	16042.199	20			

E.1.4 Dependent Variable: pasting temperature, onset temperature, peak temperature and conclusion temperature

E.1.4.1 Pasting temperature

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	242.331	6	40.389	5.115	0.006
Within Groups	110.547	14	7.896		
Total	352.878	20			

E.1.4.2 Onset temperature

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	88.568	6	14.761	59.441	0.000
Within Groups	3.477	14	0.248		
Total	92.044	20			

E.1.4.3 Peak temperature (first peak)

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.318	2	3.659	14.101	0.005
Within Groups	1.557	6	0.259		
Total	8.875	8			

E.1.4.4 Peak temperature (second peak)

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	92.392	6	15.399	10.713	0.000
Within Groups	20.124	14	1.437		
Total	112.515	20			

E.1.4.5 Conclusion temperature

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	38.843	6	6.474	3.359	0.029
Within Groups	26.979	14	1.927		
Total	65.822	20			

E.1.5 Dependent Variable: range of gelatinization temperature and enthalphy

E.1.5.1 Range of gelatinization temperature

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	163.573	6	27.262	12.234	0.000
Within Groups	31.197	14	2.228		
Total	194.770	20			

E.1.5.2 Enthalphy

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.439	6	1.073	0.390	0.873
Within Groups	38.541	14	2.753		
Total	44.980	20			

Table E.2 ANOVA: overall effect of independent variables Citric acid (1, 2 and 3 %) and Lactic acid (1, 2 and 3 %) on response variables of Kanom Jeen

E.2.1 Dependent Variable: pH and acidity

E.2.1.1 pH

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	29.806	9	4.968	15119.237	0.000
Within Groups	0.005	17	0.000		
Total	29.811	26			

E.2.1.2 Acidity

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.036	9	0.006	95.923	0.000
Within Groups	0.001	17	0.000		
Total	0.036	26			

E.2.2 Dependent Variable: whiteness index, hardness, stickiness, springiness and tensile strength

E.2.2.1 Whiteness index

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	36.200	9	6.033	39.037	0.000
Within Groups	2.164	17	0.155		
Total	38.364	26			

E.2.2.2 Hardness

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	641.664	9	106.944	11.429	0.000
Within Groups	1244.492	190	9.357		
Total	1886.156	199			

E.2.2.3 Stickiness

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.148	9	0.025	9.419	0.000
Within Groups	0.349	190	0.003		
Total	0.498	199			

E.2.2.4 Springiness

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.386	9	0.064	22.983	0.000
Within Groups	0.373	190	0.003		
Total	0.759	199			

E.2.2.5 Tensile strength

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.265	9	1.044	4.742	0.000
Within Groups	29.283	190	0.220		
Total	35.548	199			

E.2.3 Dependent Variable: sensory liking score

E.2.3.1 Color

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Sample	10.562	6	1.760	2.188	0.046
Block	49.624	29	1.711	2.127	0.002
Error	140.010	174	0.805		
Total	2621	210			

E.2.3.2 Odor

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Sample	9.724	6	1.621	1.670	0.131
Block	50.686	29	1.748	1.801	0.011
Error	168.8478	174	0.970		
Total	2266	210			

E.2.3.3 Taste

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Sample	28.629	6	4.771	5.590	0.000
Block	51.052	29	1.760	2.063	0.002
Error	148.514	174	0.854		
Total	2197	210			

E.2.3.4 Texture

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Sample	20.029	6	3.338	3.138	0.006
Block	34.952	29	1.205	1.133	0.304
Error	185.114	174	1.064		
Total	2442	210			

E.2.3 (continue) Dependent Variable: sensory liking score

E.2.3.5 Overall

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Sample	20.029	6	3.338	3.138	0.006
Block	34.952	29	1.205	1.133	0.304
Error	185.114	174	1.064		
Total	2442.000	210			

Table E.3 ANOVA: overall effect of independent variables (15:85, 20:80 and 25:75 (w/w) gelatinized rice ratio) on response variables of Kanom Jeen

E.3.1 Dependent Variable: pH, acidity and water activity

E.3.1.1 pH

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.000	2	0.000	0.000	1.000
Within Groups	0.001	6	0.000		
Total	0.001	8			

E.3.1.2 Acidity

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.000	2	0.000	1.000	0.422
Within Groups	0.000	6	0.000		
Total	0.000	8			

E.3.1.3 Water activity

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.000	2	0.000	2.714	0.145
Within Groups	0.000	6	0.000		
Total	0.000	8			

E.3.2 Dependent Variable: whiteness index, hardness, stickiness, springiness and tensile strength

E.3.2.1 Whiteness index

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.139	2	0.069	0.017	0.983
Within Groups	24.540	6	4.090		
Total	24.679	8			

E.3.2.2 Hardness

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.238	2	3.619	3.217	0.047
Within Groups	64.120	57	1.125		
Total	71.358	59			

E.3.2.3 Stickiness

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.003	2	0.002	1.015	0.369
Within Groups	.088	57	0.002		
Total	.091	59			

E.3.2.4 Springiness

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.002	2	0.001	2.179	0.122
Within Groups	.032	57	0.001		
Total	.034	59			

E.3.2.5 Tensile strength

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.373	2	0.187	0.930	0.401
Within Groups	11.442	57	0.201		
Total	11.815	59			

Table E.4 ANOVA: overall effect of independent variables (water containing 0.25% (w/w) citric acid and / or 7% (w/w) salt) on response variables of Kanom Jeen

E.4.1 Dependent Variable: pH, acidity, water activity and whiteness index

E.4.1.1 pH

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.247	2	0.623	2953.316	0.000
Within Groups	0.001	6	0.000		
Total	1.248	8			

E.4.1.2 Acidity

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.903	2	0.452	13548.000	0.000
Within Groups	0.000	6	0.000		
Total	0.903	8			

E.4.1.3 Water activity

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.000	2	0.000	31.000	0.001
Within Groups	0.000	6	0.000		
Total	0.000	8			

E.4.1.4 Whiteness index

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11.205	2	5.602	9.223	0.015
Within Groups	3.644	6	0.607		
Total	14.849	8			

E.4.2 Dependent Variable: hardness, stickiness, springiness and tensile strength

E.4.2.1 Hardness

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	28.409	2	14.205	7.460	0.001
Within Groups	108.530	57	1.904		
Total	136.939	59			

E.4.2.2 Stickiness

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.004	2	0.002	2.256	0.114
Within Groups	0.051	57	0.001		
Total	0.055	59			

E.4.2.3 Springiness

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.015	2	0.007	3.133	0.051
Within Groups	0.134	57	0.002		
Total	0.149	59			

E.4.2.4 Tensile strength

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.387	2	0.193	1.547	0.222
Within Groups	7.127	57	0.125		
Total	7.514	59			

Table E.5 ANOVA: overall effect of independent variables (temperature : 85^{O}C and 90^{O}C and time : 1, 3 and 5 min) on response variables of Kanom Jeen

E.5.1 Dependent Variable: hardness, stickiness and springiness

E.5.1.1 Hardness

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Temp	11.758	1	11.758	1.884	0.172
Time	16.763	2	8.382	1.343	0.264
temp * time	15.498	2	7.749	1.242	0.292
Error	873.630	133	6.240		
Total	23417.626	140			

E.5.1.2 Stickiness

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Temp	0.002	1	0.002	0.759	0.385
Time	0.016	2	0.008	2.671	0.073
temp * time	0.009	2	0.004	1.398	0.251
Error	0.427	133	0.003		
Total	12.657	140			

E.5.1.3 Springiness

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Temp	0.013	1	0.013	5.229	0.024
Time	0.055	2	0.027	11.394	0.000
temp * time	0.041	2	0.021	8.572	0.000
Error	0.337	133	0.002		
Total	30.076	140			

E.5.2 Dependent Variable: tensile strength and sensory liking score.

E.5.2.1 Tensile strength

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Temp	7.475	1	7.475	61.211	0.000
Time	9.663	2	4.832	39.564	0.000
temp * time	9.657	2	4.829	39.539	0.000
Error	17.097	133	0.122		
Total	5043.676	140			

E.5.2.2 Color

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Temp	0.050	1	0.050	0.063	0.802
Time	0.233	2	0.117	0.146	0.864
temp * time	3.633	2	1.817	2.281	0.105
Error	161.700	203	0.797		
Total	2519.000	210			

E.5.2.3 Odor

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Temp	0.089	1	0.089	0.101	0.751
Time	2.678	2	1.339	1.515	0.222
temp * time	0.678	2	0.339	0.384	0.682
Error	179.367	203	0.884		
Total	2305.000	210			

E.5.2 (continue) Dependent Variable: sensory liking score

E.5.2.4 Taste

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Temp	1.089	1	1.089	1.275	0.260
Time	2.544	2	1.272	1.489	0.228
temp * time	3.411	2	1.706	1.996	0.138
Error	173.433	203	0.854		
Total	2403.000	210			

E.5.2.5 Texture

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Temp	3.200	1	3.200	5.781	0.017
Time	7.500	2	3.750	6.775	0.001
temp * time	3.100	2	1.550	2.800	0.063
Error	112.367	203	0.554		
Total	2567.000	210			

E.5.2.6 Overall

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Temp	5.339	1	5.339	8.292	0.004
Time	2.433	2	1.217	1.890	0.154
temp * time	1.544	2	0.772	1.199	0.304
Error	130.700	203	0.644		
Total	2649.000	210			

Table E.6 ANOVA: response variables of Kanom Jeen during storage.

E.6.1 Dependent Variable: pH, acidity, water activity and whiteness index

E.6.1.1 pH

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.279	29	0.010	1.3269	0.175
Within Groups	0.434	60	0.007		
Total	0.712	89			

E.6.1.2 Acidity

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.092	29	0.003	16.951	0.000
Within Groups	0.011	60	0.000		
Total	0.103	89			

E.6.1.3 Water activity

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.001	29	0.000	6.787	0.000
Within Groups	0.000	60	0.000		
Total	0.001	89			

E.6.1.4 Whiteness index

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	339.852	29	11.719	5.514	0.000
Within Groups	255.019	120	2.125		
Total	594.872	149			

E.6.2 Dependent Variable: hardness, stickiness, springiness and tensile strength

E.6.2.1 Hardness

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	196.003	29	6.759	2.568	0.000
Within Groups	481.309	180	2.674		
Total	677.313	209			

E.6.2.2 Stickiness

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.160	29	0.006	2.260	0.001
Within Groups	0.438	180	0.002		
Total	0.598	209			

E.6.2.3 Springiness

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.135	29	0.005	1.557	0.037
Within Groups	0.527	180	0.003		
Total	0.662	209			

E.6.2.4 Tensile strength

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.828	29	0.098	0.671	0.898
Within Groups	26.146	180	0.145		
Total	28.974	209			

E.6.3 Dependent Variable: sensory liking score

E.6.3.1 Color

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Sample	21.966	29	0.757	1.669	0.011
Block	66.966	29	2.309	5.231	0.000
Error	371.454	841	0.441		
Total	9555.000	900			

E.6.3.2 Odor

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Sample	21.966	29	0.772	1.719	0.011
Block	141.512	29	4.880	10.872	0.000
Error	377.454	841	0.449		
Total	9147.00	900			

E.6.3.3 Taste

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Sample	21.072	29	0.727	2.035	0.001
Block	78.206	29	2.697	7.551	0.000
Error	300.361	841	0.357		
Total	8833.00	900			

E.6.3.4 Texture

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Sample	22.357	29	0.771	1.426	0.072
Block	153.957	29	5.309	11.735	0.000
Error	381.877	841	0.454		
Total	9413.000	900			

E.6.3 (continue) Dependent Variable: sensory liking score

E.6.3.5 Overall

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Sample	22.982	29	0.792	2.230	0.000
Block	86.028	29	2.960	8.332	0.000
Error	298.818	841	0.355		
Total	9458.000	900			

APPENDIX F

PRODUCT PICTURE

Broken rice

Milling stone

Weighting

(Traditional method)

Sediment by centrifuged

(Modified method)

Steaming

(Traditional method)

Steaming

(Modified method)

Kneading

Pressing

Cooked Kanom Jeen

Kanom Jeen

VITA

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Publication/ Presentation:

Chinkrua, P., Chaiwanichsiri, S., and Laohasongkram, K. 2011. Effects of acid on qualities of Kanom Jeen. Proceedings of the 37th congress on Science and Technology of Thailand. Section N. October 10-12, 2011. Centara Grand & Bangkok Convention Center at Central World, Bangkok, Thailand.