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นางสาวปาริตา ปัทมรังสรรค์

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ปีการศึกษา 2550

PARTIAL SUBSTITUTION OF WHEAT FLOUR WITH SOYMEAL IN INSTANT EGG NOODLES

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for the Degree of Master of Science Program in Food Science and Technology

Department of Food Technology

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ปาริตา ปัทมรังสรรค์ : การทดแทนแป้งสาลีบางส่วนด้วยกากถั่วเหลืองในผลิตภัณฑ์บะหมี่กึ่งสำเร็จรูป (PARTIAL SUBSTITUTION OF WHEAT FLOUR WITH SOYMEAL IN INSTANT EGG NOODLES) อ. ที่ปรึกษาวิทยานิพนธ์หลัก : รศ. ดร. สายวรุฬ ชัยวานิชศิริ , อ. ที่ปรึกษาวิทยานิพนธ์ร่วม : รศ. ดร. กัลยา เลาหสงคราม, 64 หน้า.

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาผลของกากถั่วเหลือง และกระบวนการทำแห้งที่มีต่อคุณภาพของบะหมี่กึ่งสำเร็จรูป โดยการทดแทนแป้งสาลีด้วยกากถั่วเหลืองในปริมาณร้อยละ 20-30 จากการวัดค่าสี (L*, a* และ b*) ของโด ค่าแรงต้านการดึงขาด ปริมาณโปรตีน ปริมาณเยื่อใย และสมบัติทางประสาทสัมผัสของบะหมี่สุก พบว่าการเพิ่มปริมาณกากถั่วเหลืองทำให้บะหมี่มีค่าสี a*, ปริมาณโปรตีนและเยื่อใยเพิ่มขึ้น แต่มีค่าสี L* และ b*, ค่าแรงต้านการดึงขาด และสมบัติทางประสาทสัมผัสลดลง ทั้งนี้บะหมี่ที่ทดแทนด้วยกากถั่วเหลืองร้อยละ 25 ได้รับคะแนนความชอบโดยรวมจากผู้ทดสอบสูงที่สุด ($p \leq 0.05$) โดยบะหมี่สูตรนี้มีปริมาณโปรตีน และเยื่อใยเพิ่มขึ้นร้อยละ 49 และ 447 ตามลำดับ จากการปรับปรุงคุณภาพของบะหมี่ด้วยการใช้สารไฮโดรคอลลอยด์ทางการค้า (Isagum®) ในปริมาณร้อยละ 0-0.3% พบว่าค่าแรงต้านการดึงขาด คะแนนทางประสาทสัมผัสด้านความยืดหยุ่น และความชอบโดยรวมของบะหมี่เพิ่มขึ้นเมื่อปริมาณ Isagum® เพิ่มขึ้น โดยบะหมี่ที่ทดแทนด้วยกากถั่วเหลืองร้อยละ 25 และเติม Isagum® ร้อยละ 0.2 ได้รับคะแนนความชอบโดยรวมมากที่สุด ($p \leq 0.05$) จากการศึกษากระบวนการทำแห้งด้วยวิธีอบแห้งที่อุณหภูมิ 60°, 70° และ 80 °C จนบะหมี่มีความชื้นประมาณร้อยละ 8 โดยน้ำหนักแห้ง และวิธีทอดในน้ำมันท่วมที่อุณหภูมิ 130°, 140° และ 150 °C เป็นเวลา 30, 60 และ 90 วินาที พบว่า เมื่ออุณหภูมิอบแห้งเพิ่มขึ้น บะหมี่มีค่า cooking loss เพิ่มขึ้น แต่ a_w และ rehydration rate ลดลง นอกจากนี้การเพิ่มขึ้นของอุณหภูมิ และเวลาการทอด มีผลทำให้ค่าแรงต้านการดึงขาดลดลง ขณะที่ปริมาณการดูดซับน้ำมัน และ rehydration rate ลดลง อย่างไรก็ตามยังพบว่ามีกลิ่นถั่วในบะหมี่ที่ได้จากการทอด จึงใช้น้ำสกัดชาเขียวและใบมะกรูดในอัตราส่วน 1:3 และ 1:1 (w/v) แทนที่น้ำในสูตรเพื่อการกลบกลิ่นถั่วดังกล่าว ผลการศึกษาพบว่าคะแนนทางด้านกลิ่นและความชอบโดยรวมของบะหมี่ที่มีน้ำสกัดใบมะกรูดมากกว่าน้ำสกัดชาเขียว ดังนั้นสภาวะที่เหมาะสมต่อการทำแห้งของบะหมี่กึ่งสำเร็จรูปคือ อบแห้งที่ 80 °C เป็นเวลา 195 นาที และ ทอดบะหมี่ที่มีน้ำสกัดใบมะกรูดในอัตราส่วน 1:1 (w/v) ที่อุณหภูมิ 150°C เป็นเวลา 60 วินาที และจากการศึกษาอายุการเก็บของบะหมี่ทั้ง 2 ชนิด ที่อุณหภูมิ 35°, 45° และ 55 °C ในถุงอะลูมิเนียมลามิเนต โดยติดตามการเปลี่ยนแปลงของ a_w, ความชื้น, ค่า TBA, จำนวนจุลินทรีย์ทั้งหมด (TPC) และ ยีสต์รา พบว่า ค่า TBA และ a_w เป็นตัวแปรสำคัญในการกำหนดอายุการเก็บของบะหมี่กึ่งสำเร็จรูป และจากการใช้จลนพลศาสตร์ของการเปลี่ยนแปลงสมบัติต่างๆในการทำนายอายุการเก็บของผลิตภัณฑ์พบว่า บะหมี่กึ่งสำเร็จรูปที่ได้จากการอบแห้ง และการทอดมีอายุการเก็บเท่ากับ 2398 และ 1625 วัน ตามลำดับ

ภาควิชา.... เทคโนโลยีทางอาหาร......................... ลายมือชื่อนิสิต...

สาขาวิชา..วิทยาศาสตร์และเทคโนโลยีทางอาหาร.... ลายมือชื่ออาจารย์ที่ปรึกษาวิทยานิพนธ์หลัก.............................

ปีการศึกษา...2550... ลายมือชื่ออาจารย์ที่ปรึกษาวิทยานิพนธ์ร่วม....................................

4973601123 : MAJOR FOOD SCIENCE AND TECHNOLOGY

KEY WORD: INSTANT NOODLES / SOYMEAL / DRYING METHODS / ESTIMATE SHELF-LIFE

PARITA PATTAMARUNGSON: PARTIAL SUBSTITUTION OF WHEAT FLOUR WITH SOYMEAL IN INSTANT EGG NOODLES. THESIS ADVISOR: ASSOC. PROF SAIWARUN CHAIWANICHSIRI, Ph. D., THESIS COADVISOR: ASSOC. PROF. KALAYA LAOHASONGKRAM, Ph. D., 64 pp.

The objectives of this research were to investigate the effects of soymeal and drying methods on the qualities of instant egg noodles. Wheat flour was replaced by soymeal at 20-30% of flour in the formula. The color (L*, a*, b*) of dough and tensile strength, protein and fiber contents and sensory attributes of cooked noodle were determined. The result showed that a* value (redness), protein and fiber contents increased but L* value (lightness), b* value (yellowness), tensile strength and sensory attributes decreased as the soymeal level increased. Based on sensory attributes and tensile strength, egg noodle substituted with 25% soymeal was the most acceptable ($p \leq 0.05$) and its protein and fiber contents increased about 49% and 447%, respectively. The qualities of the noodles were improved by the addition of commercial hydrocolloid, Isagum®, at the level of 0-0.3% (w/w). The results showed that increasing the amount of Isagum® would increase the tensile strength, elasticity and overall preference scores of the noodle. The appropriated level of Isagum® addition was 0.2%. The noodle was then either dried at 60°, 70° and 80°C until its moisture content reached 8% (db) or fried at 130°, 140° and 150°C for 30, 60 and 90 seconds. The results showed that increasing the drying temperature would increase cooking loss but decrease water activity and rehydration rate of the noodle. Increasing the frying temperature and time would decrease tensile strength but increase oil absorption and rehydration rate. However the fried noodle still had beany odor. In order to overcome the problem, water in the formula was replaced by the extract of green tea (1:3 and 1:1 w/v) or Kaffir lime leave with water (1:3 and 1:1 w/v). It was found that the sensory scores on odor and overall preference increased with the Kaffir lime leave extract giving the higher scores. Thus the optimum conditions for dried noodle was drying at 80°C for 195 minutes and fried noodle with Kaffir lime leave extract (1:1, w/v) was deep-fat frying at 150°C for 60 seconds. The samples were stored (35°, 45° and 55°C) in aluminum-laminate bags and the changes of the quality properties (a_w, moisture, TBA value, TPC, and yeast-mold) were evaluated. It was found that TBA and a_w were the important factors in shelf-life determination. From the kinetic parameters of these quality properties the predicted shelf-life of instant dried and fried noodles were 2398 and 1625 days, respectively.

Department: ……….Food Technology………….. Student's Signature: ..……………………. ……………..

Field of study: ..Food Science and Technology... Principal Advisor's Signature: …….……………………

Academic year: ……..2007….... Co-advisor's Signature: ……………………………........

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CHAPTER 1
INTRODUCTION

Nowadays, noodles are popular foods in many Asian countries and there are many types of noodles such as Chinese noodles, Japanese noodles and Korean noodles. Most noodles are prepared from flour, water, salt and other additives with preferences varying on a regional basis. In addition instant noodles are widely preferred by consumers due to their flavor, convenience and ease of preparation. Soybean (*Glycine max*) is an important global crop, grown for oil and protein. They usually are extracted for oil. Very small proportion of the crop is consumed directly for food by humans. Although soymeal contains high amounts of components with health benefits, such as proteins and dietary fiber (Kuo *et al.,* 2006), it is mostly used for animal feed. Hence using soymeal in human food might be a good preference for value added to itself, meals and increasing nutritional content in food products.

Instant noodles and dried noodles are becoming popular due to some factors such as convenience, acceptable taste and texture. On the contrary a major nutrient of noodles is carbohydrate, and they are low in protein and fiber contents. Therefore dried noodle substituted with soymeal could be a good way to increase noodle nutrition as soymeal is a source of complete protein which contains significant amounts of essential amino acids as well as fiber. Addition of soymeal into noodles could enhance yellowness of noodles. The noodle with soymeal is rarely found and not many research published. With sufficient nutritional contents especially protein and fiber, soymeal is an interesting material for instant noodle production.

The objectives of this research are to investigate the effects of soymeal and the drying methods on the qualities of instant egg noodles.

CHAPTER 2
LITERATURE REVIEW

2.1 General characteristics of noodle

Many varieties of noodles exist as a result of differences in composition, method of preparation and presentation depending on regional preference (Edwards *et al.* 1996). Noodles can be generally classified into Chinese type wheat noodles, Japanese type wheat noodles, buckwheat noodles (Soba), Naengmyon noodles (Korean type noodles), rice noodles, starch noodles, and pasta according to their main raw materials and other ingredients used. They are generally made from flour, water, salt and/or other additives depending on noodle types.

Within wheat flour, starch is the most abundant component and plays an important role in the end-product quality. The protein component of wheat flour is represented by albumin, globulin, gliadin and glutenin. In the preparation of the dough, albumin and globulin, although necessary, have relatively marginal functions, while gliadin and glutenin are the two protein fractions insoluble in water, which form gluten and affect to noodle texture especially hardness (Huang and Morrison, 1988; Toyokawa *et al*., 1989; Park *et al*., 2003).

During mixing, water is added to flour and the gluten network is formed, which contributes to the structure of noodles. Addition of water contributes to the viscoelastic properties of the dough and increases the smoothness of the noodle surface (Hou, 2001). The optimum water absorption for noodles should hydrate the surface of flour particles to form cohesive noodle granule during mixing and to develop the gluten during sheeting. The amount of added water depends principally on flour protein content, particle size of starch granule, starch damage, and pentosans (Oh *et al*., 1985a).

Salt is another main ingredient used, in the form of NaCl or alkaline salts or a combination of these. The alkaline salts are often referred to as lye water or kansui and are typically mixtures of sodium and potassium carbonates (Moss *et al*., 1986). Salt has a variety of important functions in the noodle processing. They not only enhance flavor and strengthen the gluten network but also help in moisture diffusion, inactivate enzymes and inhibit dough fermentation (Nagao, 1996).

Eggs are used as an ingredient for some noodle preparation to improve preferences in color and taste. Besides, adding eggs can increase health benefit in term of nutrients such as proteins and vitamins (Janto *et al*., 1998; Hou, 2001).

Gum additives are added in high quality noodles. They provide viscosity and texture, and can be used by themselves or in combination with starch to create certain effects and used in noodle making to provide viscosity, improve firmness and mouth feel to the final noodles (Hou, 2001).

2.2 Noodle qualities

Generally, there are four principal quality factors which determine food quality. These are appearance (color, shape, and size), flavor (taste and odor), texture and nutrition.

2.2.1 Appearance

All noodle types require brightness. Color can be either white or yellow depending on the alkaline salts, protein level and textural changes during cooking. The brightness of noodle decreases with increasing protein level. The color varies with textural changes during cooking and the intensity of yellowness is developed in the alkaline medium of kansui. Asenstorfer and coworkers (2006) investigated the chemical structure of flavonoid compounds in wheat flour that contribute to the yellow color of noodles. They found that flavone-*C*-diglycosides were the major components responsible for the alkali-induced change in noodle color. These flavonoids were relatively stable at ambient temperature.

Pluempavarn and coworkers (2005) reported that color values of dried udon in term of brightness decreased and yellowness increased as soymeal substituted level increased. Replacing wheat flour with peanut flour resulted in a reduction of xanthophylls and, consequently, a loss of yellow color (Chompreeda *et al*., 1987). Miskelly and Moss (1985) found that the yellowness of noodle was directly related to wheat flour carotenoids, principally xanthophyll, together with flavone compounds.

2.2.2 Flavor

Different types of noodles possess characteristic flavor depending on the noodle ingredients (Hou, 2001). Sawatari and coworkers (2005) developed the fermented instant Chinese noodle using *Lactobacillus plantarum* and found that pH decreased and lactic acid increased with fermentation time. The sensory test of rehydrated noodle revealed that the fermented Chinese instant noodle at pH 5.7 had increased hardness, elasticity and sour taste.

2.2.3 Texture

A study of rheological characteristics of dough as influenced by added ingredients should have great relevance in predicting the machinability of dough as well as the quality of the noodle product. Shiau and Yeh (1999) studied effects of alkali and acid on dough rheological properties and characteristics of extruded noodles. The noodle ingredients were unblanched wheat flour, 0.25 and 0.50% lactic acid and kansui at the levels of 0.25, 0.50 and 1.00%. The results showed that the addition of kansui reduced protein extractability but slightly increased the apparent viscosity, storage modulus and total content of sulfhydryl groups (SH) and disulphide bonds (S-S). This indicated that high protein extractability was not associated with high total content of SH and S-S. Alkaline addition affects gelatinization properties of starch. For example, sodium hydroxide causes starch to gelatinize at room temperature. The results agreed with Maher (1983).

Indrani and Rao (2006) studied the effects of addition of salt, sugar, egg and refined groundnut oil on rheological characteristics of wheat dough and found that addition of salt and egg increased the hardness and dough strength. However, addition of sugar and oil to the dough resulted in soft dough as indicated by the lower values of hardness. The decrease in hardness was greater for the dough containing oil than that containing sugar. Doughs containing varying amounts of salt and egg were more cohesive than those containing sugar and oil. Cohesiveness of the dough decreased with increasing sugar and oil contents. However, the decrease was greater for the dough containing oil. This was due to the dough offering lesser resistance to the compression force. The addition of sugar or egg or oil decreased adhesiveness and the dough was less sticky.

Starch and protein mainly govern the noodle texture. Starch characteristics, including amylose-amylopectin ratio, starch pasting properties and swelling power are highly related to eating quality of white salted noodles (Crosbie *et al*., 1999). Oh *et al.* (1985b) reported that the maximum cutting stress and the resistance to compression of cooked dry noodles were highly correlated with noodle firmness and chewiness. Hou and Kruk (1998) reported that cohesiveness, hardness and chewiness were significantly correlated with the eating quality of cooked noodles. They concluded that cohesiveness was the most useful parameter for the evaluation of the eating quality of fried instant noodle.

Kaur and coworkers (2005) studied the effects of glycerol monostearate (GMS) on the physico-chemical, thermal, rheological, textural and noodle making properties of corn starch and potato starch noodles. The results showed that the noodles prepared with the addition of GMS had higher cooking time and lower cooked weight and cooking loss. Texture profile analysis (TPA) of the cooked noodles revealed that the addition of GMS decreased the hardness, cohesiveness, gumminess, springiness and chewiness slightly.

Hatcher and coworkers (2008) studied the effects of wheat flour and buckwheat flours (whole, white and dark) on the texture of soba noodles. It was found that the milling process affected the starch and fiber contents in buckwheat flours. The results also showed that the dietary fiber (DF) constituents were concentrated in the dark flour, but most of the DF in the dark flour was insoluble. The starch content of dark flour was lower compared to white and whole flour. Moreover, whole flour and white flour exhibited relatively high peak viscosity, final viscosity and setback values compared to wheat flour. These results indicated that the swelling and gelling tendency for buckwheat flour were greater than for wheat flour. The differences in the pasting properties between buckwheat whole flour and white flour fractions were ascribed to the differences in their starch contents. The dark flour fractions exhibited the low pasting parameters compared to whole and white flours because of the lower starch content. Soba noodle prepared with white flour gave the highest chewiness, springiness and recovery parameters.

2.2.4 Nutrition

According to the noodle ingredients, the major nutrient of noodles is carbohydrate while the protein and fiber contents are low. However, noodles could be made from wheat flour mixed with other type of flour such as durum wheat flour, peanut flour, mungbean flour and/or other additives such as oat bran to increase nutritional values (Reungmaneepaitoon *et al*., 2006).

2.3 Improvement of noodle qualities

2.3.1 Nutritional improvement

Chompreeda and coworkers (1987) studied the quality of peanut-supplemented Chinese type noodles which were prepared from blends of durum wheat flour and partially defatted peanut flour (10-30%) to increase protein content and found that increasing peanut flour decreased the lightness, gluten content, cutting force, firmness and sensory attributes of noodles. As the yellowness was directly related to wheat flour carotenoids, principally xanthophyll, together with flavone compounds therefore, replacing wheat flour with peanut flour resulted in a reduction of xanthophyll and a loss of yellowness. The softness of supplemented noodles was due to a decreased amount of gluten. Replacement of up to 15% of wheat flour with peanut flour resulted in an acceptable noodle.

Chayapancha (2000) studied the effect of mungbean or peanut flour substitution (10-30%) on qualities of dried noodle and found that legume flour substitution affected the protein and fiber contents of noodles as they increased up to 12.31-14.70% and 14.25-21.75% in mungbean flour and peanut flour-containing samples. Substitution wheat flour with mungbean or peanut flour affected protein content, gluten content, water absorption and stability of dough. Protein content increased while gluten, water absorption and stability decreased. Because most protein in wheat flour was able to form the gluten network, therefore, increasing mungbean or peanut flour resulted in lower gluten content in dough. Noodle substituted with 30% mungbean flour or 20% peanut flour was the most acceptable.

Brennan and coworkers (2004) studied the effects of inulin on the cooking properties, texture and nutritional characteristics of durum wheat pasta. It was found that addition of inulin decreased the swelling index and firmness, but had no effect on the adhesiveness and elasticity of pasta products. The levels of reducing sugar released during in vitro starch digestion suggested that the rate of digestion of pasta declined with increasing inulin addition.

Improvement of the nutrition in instant fried noodles by oat bran which is rich in β-glucan, a soluble fiber was studied (Reungmaneepaitoon *et al*., 2006). Oat bran extruded flour (OBCXF), oat bran extruded fine flour (OBCXEF) and oat bran native flour (OBC native) were used to replace wheat flour at the levels of 5, 10, and 15% (w/w). The results showed that increasing the amount of various OBC in the mixes caused an increase in protein and β-glucan contents in the products. Addition of OBC flours also decreased the lightness (L*), firmness and sensory attributes but increased redness (a*), yellowness (b*) and stickiness. The noodle substituted with 10% OBC-XEF was the most acceptable.

Limroongreungrat and Huang (2007) studied the effects of sweet potato fortified with soy protein on pasta products. Sweet potato flour was treated with sodium hydroxide solution and then fortified with defatted soy flour or soy protein concentrate at the levels of 0, 15, 30, and 45 g/100 g. The results showed that alkaline-treated sweet potato flour had the highest carbohydrate content followed by defatted soy flour and soy protein concentrate. However, soy protein concentrate had the highest protein content followed by defatted soy flour and alkaline-treated sweet potato flour. Addition of defatted soy flour and soy protein concentrate increased the lightness and cooking loss, and decreased the redness, β-carotene, firmness, cohesiveness and springiness. Pasta made from 100% alkaline-treated sweet potato flour had the highest firmness and β-carotene content and the lowest cooking loss.

2.3.2 Textural improvement

Gums are polysaccharides causing a large viscosity increase in solution, even at low concentrations. They are used as thickening agents, gelling agents, emulsifiers and stabilizers. Hua and coworkers (2003) studied gelling property of soy protein-gum mixtures. It was found that the combination of propylene glycol alginate (PGA) with soy protein gave a strong mixed gel because PGA had been found to form gel with starch by cross-links at alkaline pH. It was suggested that glutamic acid residues of soy proteins and mannuronate residues of PGA were involved in the interaction. Sittikijyothin and coworkers (2004) studied the rheological behavior of galactomannan aqueous solution. They found that the ratios of mannose to galactose in Tara gum (TG) and locust bean gum (LBG) were 3:1 and 4:1 while instrinsic viscosity and molecular mass of TG was higher than LBG. The behavior of all solutions was shear-thinning with a Newtonian region in the low shear rate range. For similar concentration, LBG solutions were less viscous than TG solutions. The concentrated domain was characterized by a power law dependence of viscosity on concentration. For typical polymer, the exponent is usually found in the range 3-4 while a significantly higher value (4.7) was found in this study. This was related to a relatively high rigidity of LBG and TG backbones as compared to typical polymers. They concluded that both galactomannan exhibited quite similar rheological properties in the similarly concentrations and shear rates. Garcia and Totosaus (2008) studied the effect of the interaction between locust bean gum (LBG), potato starch (STR) and k-carrageenan (KCG) in low-fat sodium-reduced sausages. It was found that KCG and LBG were more effective in retaining added water. This was probably because their chemical structures and synergistic interaction, which were enhanced by the presence of other ions.

From the studies of nutritional improvement, substitution of wheat flour with other type of flour and/or other additives resulted in worse noodle texture such as the tensile strength (Chompreeda *et al*., 1987; Chayapancha, 2000; Brennan *et al*., 2004; Reungmaneepaitoon *et al*., 2006 and Limroongreungrat and Huang, 2007). Yu and Ngadi (2004) studied the effects of guar gum (0-0.3%) and potato starch (0-9.2%) on textural and other quality properties of instant fried noodles. The results showed that the addition of gum played a significant role in maximum load, strain at point, fat absorption and moisture content of instant noodles. It was also observed that both starch and gum performed complimentary roles in enhancing the elasticity and extensibility of instant fried noodles.

Charles *et al*. (2006) investigated the effect of cassava starch and cassava mucilage in Chinese noodles and found that the addition of cassava starch increased the yellowness, tensile strength, cutting force and biting force higher than those with cassava mucilage. The addition of cassava mucilage reduced the intramolecular interaction between amylopectin and amylose molecules and resulted in softer gel structures in the noodle.

2.4 Drying method for instant noodles

There are many types of instant noodles according to the drying process. In this study, it focused on the instant noodles prepared from tray drying and deep fat frying.

2.4.1 Instant dried noodle

There were several researchers reported that the drying kinetics and drying conditions were usually used to describe the physical properties of food such as appearance, texture, rehydration rate and cooking loss. Inazu and coworkers (2003) studied the effect of air velocity (0.50, 0.75, 1.00, 1.25, 1.88 and 3.00 m/s) at 60°C on fresh Japanese noodle (Udon) drying. The results showed that the air velocities had no influence on the moisture diffusivity. The drying curve of cooked udon was in the falling rate period and the rate of drying increased with air velocity. The increase in the drying rate might be caused by decreasing the external mass transfer resistance. In addition, drying at high air velocity showed no constant rate period and the drying rate thus reduced sharply whereas a constant rate period was found under lower drying velocity.

Baiano and coworkers (2006) studied the influence of drying temperature on the spaghetti cooking quality. Spaghetti was dried at 60°, 75° and 90 °C (LTS, MTS and HTS). The results showed that the drying curve of spaghetti was mostly in the falling rate period and the drying rate increased with drying temperature. The drying temperatures did not affect starch crystallinity level as drying did not induce starch gelatinization. HTS samples were found to be less sticky than the others. It could be explained that the gluten network was better formed at the highest temperature and allowed starch to absorb water in a minor amount as also demonstrated by the low change in weight, length and diameter. Moreover, HTS samples released lower amylose amount than the other samples. The elastic modulus increased with the increase in drying temperature showing comparable values for MTS and HTS samples and confirming the firmness evaluation expressed by the panel. As expected the quality characteristics of pasta during cooking improved as drying temperature increased. Therefore, spaghetti dried at high temperature has the highest firmness and panel test scores, but the lowest stickiness. This agreed with the results reported by Pluempavarn *et al*. (2005) on dried udon.

Villeneuve and Gelinas (2007) studied the drying kinetics of whole durum wheat pasta at 40°, 60° and 80 °C. The results showed that drying rate of pasta increased but drying time and rehydration ratio decreased with increasing drying temperature. Decreased rehydration ratio might be due to detrimental effect of temperature that caused the pores on the surface to collapse which led to lower diffusion of water through the surface during rehydration. Moreover, it was found that the cooking loss was correlated with drying temperature as higher temperature resulted in higher cooking loss and main component of residue from cooking loss was amylose.

2.4.2 Instant fried noodles

The determination of physio-chemical properties such as texture, rehydration rate, cooking loss and oil absorption is necessary for evaluation of fried products. Some researches reported that these parameters depended on frying temperature, frying time, food ingredients and moisture content. Moss and coworkers (1987) investigated the influence of ingredients and processing on the quality and microstructure of instant noodles. The results showed that increasing frying temperature decreased the tensile strength and oil absorption but increased rehydration rate. It was because during frying the moisture loss from the noodle and simultaneous entrance of hot oil to the noodle in a short time. The expansion in volume associated with the creation of a porous structure usually took place. At higher frying temperature, the rate of moisture loss increased and then the water was replaced by oil more rapidly. The temperature gradient between noodle and oil increased the pressure and resulted in the rate of moisture loss was higher than the oil uptake rate. The creation of porous had effect on the microstructure of noodle was less in elastic and resulted in the tensile strength decreased. On the other hand, the noodle could absorb more water and increased the rehydration rate.

Pedreschi and coworkers (2008) studied the kinetics of oil absorption and distribution in the structure of potato slices during frying. Either raw or blanched potato slices were fried at 120°, 150° and 180 °C. It was found that the total oil in potato chips was absorbed almost in the initial stage of frying once the potato slices were placed the hot oil. This agreed with the results reported by Moreira *et al*. (1997) on tortilla chips, Bouchon *et al*. (2003) on structure oil-absorption relationships during deep-fat frying and Duran *et al*. (2007) on potato slices. When the slices were removed from the fryer, a higher temperature difference develops between the surface and the interior, which, in turn, generates a higher negative pressure in the pore space leading to more oil penetration into their microstructure during cooling.

2.5 Instant noodle shelf-life

Instant noodles could deteriorate in many ways such as physical (moisture uptake), chemical (rancidity), and biological (microbial growth) deteriorations. Most researchers focused on the chemical deterioration. Rho and coworkers (1986) investigated the rancidity in deep-fried instant noodles (ramyon). The storage stability of noodles was determined by accelerated aging at 63 °C with organoleptic evaluation of the onset of rancidity. Three methods of extending the shelf-life of ramyon were examined: (a) addition of antioxidant, butylated hydroxyanisole (BHA), t-butylhydroquinone (TBHQ), or a polymeric antioxidant (Poly-A) to the frying (palm) oil; (b) coating the inner surface of the polyethylene package with TBHQ; and (c) addition of a mixture of TBHQ disodium ethylene-diaminetetraacetate (EDTA) to the frying oil. The results showed that 2-thiobarbituric acid (TBA) values increased with storage time. The addition of antioxidants to the oil could extend the shelf-life. The rancid off-flavors developed slowest in noodles with a_w of 0.3.

Gotoh and coworkers (2007) studied the oxidation of fat and oils in instant noodles stored under various conditions (bag-type, made from oriented polypropylene and polyethylene terephthalate, and stored at 23-60 °C). The results showed that the peroxide value and a_w in instant noodles stored at 40° to 60 °C gradually increased with storage time. During storage, the moisture from the surrounding might disperse through the package then a_w became higher and the moisture would transfer more rapidly with increasing storage temperature and time.

An accelerated shelf life test is widely used to estimate the shelf life of food as a function of parameters such as study of shelf-life of ripe olives (Garcia *et al*., 2008).

Changes of quality parameters followed the apparent first-order kinetics as showing the relationship between parameter [*C*] after time (*t*) as:

$$r = -d[C]/dt = k[C] \tag{2.1}$$

$$\ln [C] = -kt + \ln [C]_0 \tag{2.2}$$

where r is the reaction rate, t is time and [*C*] is the parameter value at each temperature–time which $[C]_0$ is the initial value (Garcia *et al.*, 2008). The rate constant (*k*) was related to the temperature *T* (in Kelvin) following the Arrhenius equation. The activation energy (E_a) could be determined from equation (2.3).

$$k = Ae^{-E_a/RT} \tag{2.3}$$

where *A* is the frequency factor, E_a was activation energy and *R* is gas constant. The Q_{10}, which also relates reaction rate with temperature and was defined as the relation of the reaction rates at (*T* + 10) and *T* as:

$$\ln Q_{10} = (E_a/R)\frac{10}{T(T+10)} \tag{2.4}$$

Shelf life (t_s), for a certain relative level of a quality attribute (critical value at that time, C_e, relative to the initial one, C_0) was defined as:

$$t_s = \frac{\ln (C_0/C_e)}{k} \tag{2.5}$$

It was found that there was a similar trend in the rate of changes of firmness, color and pH with temperature. Base on these parameters, it could estimate the appropriate shelf-life could be estimated for each storage condition and quality level.

2.6 Soybean

Soybeans are usually extracted for oil and the defatted soymeal is commonly used for animal feed. The chemical compositions of soymeal as reported by the National Oil Processors Association (2006) in the U.S. indicated that 100 g of dehulled soymeal approximately contains a minimum of 12.0% moisture, 47.5-49.0% protein, 0.5% fat, 3.3-3.5% fiber and less than 7.5% ash on a wet basis.

Soybean products, such as whole soybean, soybean flakes, soy flour and soybean dairy-like products, are an important low-cost source of proteins, fiber, mineral and vitamins (Garcia *et al.,* 1997). Many researchers were interested in their values and used to provide the nutrition in food products. Dongan and coworkers (2005) studied the effects of soy and rice flour addition on batter rheology and quality of deep-fat fried chicken nuggets. The results showed that soy flour provided the highest apparent viscosity and was found to be an effective ingredient in improving quality parameters in terms of crispness and color.

Pluempavarn and coworkers (2005) substituted wheat flour with soymeal (10-40%) from local soymilk production process in dried udon. They found that increasing soymeal substitution caused the addition of nutrients in udon and reduction of gluten content and sensory attributes. Lipid in soymeal was able to hold wheat flour during mixing and the gluten network could not be formed and resulted in the tension force of udon decreased. However the most acceptable level of substitution was found to be 20%.

Amatakulchai and Lilavanichakul (2007) partially replaced wheat flour with soymeal (0-25%) in fresh egg noodles. They found that increasing soymeal substitution resulted in decrease of lightness, yellowness and tensile strength of noodles while chemical compositions and redness increased. The substitution level of 20% gave the most acceptable product.

Singh and Mohamed (2007) investigated the incorporation of protein blends (10-30%) on the acceptability and quality characteristics of cookies. It was found that as total carbohydrates decreased, the protein content and the odor of soy protein increased with increasing soy substitution. The color of the soy-substituted cookies was darker as the protein blend increased beyond 20%. These resulted in an increase in protein content of cookies from 6 to 17.5%.

CHAPTER 3
METHODOLOGY

3.1 Raw materials

Wheat flour (Kite brand) was purchased from local supermarket in Bangkok. Soymeal was obtained from Wiwat Industry, Co. Ltd. Soymeal was ground (Moulinex Type 719, France) and sieved through a 100-mesh screen, prior to storage in plastic bag (Nylon/DL/LLDPE) at room temperature for further use.

A commercial gum (Isagum®) was provided by FMC Food ingredient, Inc., Bangkok, Thailand. It is a combination gum of Tara gum and propylene glycol alginate (PGA).

3.2 Chemical compositions of raw materials

Wheat flour and soymeal were analyzed for proximate composition:

- Moisture content (AOAC, 1995)
- Protein content (AOAC, 1995)
- Fat content (AOAC, 1995)
- Fiber content (AOAC, 1995)
- Ash content (AOAC, 1995)
- Available carbohydrate content (By 100 subtraction with the sum of moisture, protein, fat, fiber and ash contents).

The analyses were done in triplicates.

3.3 Effect of soymeal on physico-chemical and sensory properties of egg noodles

Noodles were prepared according to the formula modified from Amatakulchai and Lilavanichakul (2007) as shown in Table 3.1.

Table 3.1 Noodle formula

Ingredients	Content (g)
Wheat flour	100.0
Egg	10.0
Salt	3.0
Water	43.0

Wheat flour in the formula was replaced by soymeal at the level of 0, 20, 25 and 30% of total flour used. Firstly, all ingredients were mixed in mixer (Kenwood, model KM800, United Kingdom) for 15 minutes at room temperature then the dough was rested for 15 minutes and sheeted to the 2 mm thickness and slitting into 1 mm width noodle strand. Raw noodles were cooked in boiling water for 1 minute and then rinsed in cold water and kept in the plastic box for 5 minutes (Charles *et al*., 2006). The physico-chemical and sensory properties of noodle were evaluated as follows:

- Color of dough by colorimeter (Minolta CR300, Japan) (CIE L*, a* and b*). The measurement was randomly done at 5 points.
- Tensile strength by texture analyzer (TA.XT/2i, England) equipped with A/SPR measuring head and tension grips (Appendix A.1). Ten strands of cooked noodles were randomly selected for the measurement.
- Moisture, protein and fiber contents of cooked noodles (AOAC, 1995). The analyses were done in triplicate.
- Sensory evaluation on color, odor, elasticity and overall preference using a 9-point hedonic scale (1=dislike extremely and 9=like extremely) by 30 untrained panelists.

All experiments were conducted in 3 replicates. The appropriated substitution level was selected based on the protein and fiber contents, tensile strength and overall preference score.

3.4 Improvement of noodle qualities

Noodle was prepared according to the formula and level of soymeal substitution chosen in section 3.3. Isagum® 0-0.3% (w/w) was added to the total weight of noodle formula. Color, tensile strength, and sensory properties of the prepared noodles were determined as in section 3.3. The most suitable level of Isagum® was selected based on the tensile strength and overall preference score.

3.5 Optimum conditions of drying process

The raw noodle was prepared according to the formula obtained from section 3.4, cooked under steam for 5 minutes and left at room temperature for 15 minutes as the moisture content reduced to 27% (wet basis). The samples were dried under 2 drying methods:

3.5.1 Tray drying

The cooked noodles were dried at 60°, 70° and 80°C in tray dryer (Yeo Heng, HA-100s, Thailand) until its moisture content was constant. Air velocity in the dryer was maintained at 2 m/s. The noodles were determined for cooking loss (Appendix A.2), water activity (Aqua Ib 3 TE, USA), rehydration rate (Appendix A.3), color, tensile strength, and sensory quality in color, odor, elasticity and overall preference using a 9-point hedonic scale with 30 untrained panelists.

3.5.2 Deep-fat frying

The cooked noodles were fried in deep fryer at 130°, 140° and 150 °C for 90, 60 and 30 seconds using palm oil (Tip brand). Then fried noodles were left on oil blotting paper at room temperature for 10 minutes and dried in tray dryer at 60°C for 30 minutes. The 3x3 factorials in completely randomized design (CRD) was used in this experiment. The fried noodles were analyzed for oil absorption (AOAC, 1995) and the rehydrated samples were analyzed for the same properties as in 3.5.1.

All experiments were done in 3 replicates. The optimum conditions for each drying process were selected for the next study based on texture, rehydration rate, cooking loss and sensory test.

From the sensory test of fried noodle, the odor of the sample was not accepted (less than 5) by the panelists. Green tea and Kaffir lime leaves were used to improve the odor of fried noodles. They were extracted with water at the ratio of 1:3 and 1:1 (w/v).

The extracts replaced the water in the noodle formula. The raw noodle was cooked under steam, fried according to the previous conditions and then analyzed as in 3.5.1. The experiment was done in 3 replicates. The appropriate type and ratio of extract was chosen for further study based on the odor scores.

3.6 Shelf-life Evaluation for Dried Noodle

Both types of dried noodles prepared by the conditions chosen from section 3.5 were stored at 35, 45 and 55 °C in aluminum-laminate bags (its moisture vapor transmission rate or MVTR is about 0.1 grams per 100 square inches-days). Samples were taken every 5 days to be determined for:

- a_w (Aqua Ib 3 TE, USA)
- Moisture content (Mettler Toledo, HB43-S, Switzerland)
- Rancidity by TBA test (AOCS, 1997)
- Total bacterial count, yeast and mold using 3M Petrifilm (TIS, 2005)
- Sensory quality on color and overall preference of cooked noodles as in section 3.3

The a_w and moisture contents were measured in 5 replicates and others were done in triplicates. The experiments were conducted in 3 replicates. Finally, the shelf-life of the samples was estimated using the kinetic parameters of these quality changes (Garcia *et al*., 2008).

3.7 Statistical Analysis

The data were statistically analyzed by a one-way analysis of variance (ANOVA) using the statistical analysis program SPSS version 14.0 at the significant level of 95%.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Chemical composition of wheat flour and soymeal

Chemical composition of the wheat flour and soymeal was shown in Table 4.1. The major component in wheat was carbohydrate (86.57% dry basis) while that of soymeal was protein (53.91% dry basis). The protein and fiber contents of soymeal in this study were similar to those reported by the National Oil Processors Association (2006) (47.5-49.0% and 3.3-3.5%) and Amatakulchai and Lilavanichakul (2007) (50.53 and 3.42%). Moreover, protein and fiber contents in soymeal were very high compared with those in wheat flour (about 500% and 2000%). The high amounts of protein and fiber contents in soymeal were valuable in term of nutritional improvement to noodle products.

Table 4.1 Chemical composition of raw materials

Composition	Amount (%)	
	Wheat flour	Soymeal
Moisture	12.46 ± 0.26 (%wb)	6.33 ± 0.19 (%wb)
Protein	11.75 ± 0.29 (%db)	53.91 ± 0.23 (%db)
Lipid	0.96 ± 0.44 (%db)	0.17 ± 0.46 (%db)
Ash	0.52 ± 0.35 (%db)	6.24 ± 0.38 (%db)
Fiber	0.19 ± 0.61 (%db)	3.93 ± 0.52 (%db)
Carbohydrate	86.57 ± 0.59 (%db)	36.00 ± 0.64 (%db)

4.2. Effect of soymeal on noodle properties

Table 4.2 shows that the protein content of noodles increased up to about 45% (from 12.94 to 18.82%), 49% (from 12.94 to 19.15%) and 62% (from 12.94 to 20.91%) while the fiber content increased 313% (from 0.15 to 0.62%), 447% (from 0.15 to 0.82%) and 493% (from 0.15 to 0.89%) as the soymeal was substituted at 20, 25 and 30%, respectively. This was because soymeal had a much higher protein and fiber contents than wheat flour.

Table 4.2 Protein, fiber and moisture contents in noodles substituted with soymeal

Soymeal (%)	Amount (%)		
	Moisture (% wb)	Protein (% db)	Fiber (% db)
0	34.65±0.07a	12.94±0.02d	0.15±0.02d
20	32.47±0.03b	18.82±0.01c	0.62±0.01c
25	32.11±0.05c	19.15±0.02b	0.82±0.01b
30	31.84±0.03d	20.91±0.01a	0.89±0.01a

a, b, c, d means with different letters on each column are significantly different ($p \leq 0.05$).

From the measurement of tensile strength of the noodles (Table 4.3), it was found that the tensile strength of cooked noodles decreased significantly as the soymeal substitution increased ($p \leq 0.05$). This may be because less gluten network was formed as the wheat flour being replaced by soymeal (Fu *et al*., 1997). This result agreed with that reported by Chompreeda *et al*. (1987) on peanut-supplemented Chinese noodles, Chayapancha (2000) on legume flour substituted dried noodle, Brennan *et al*. (2004) on inulin-enriched pasta, Pluempavarn *et al*. (2005) on dried soymeal substituted udon, Reungmaneepaitoon *et al*. (2006) on instant fried oat bran added noodles, Limroongreungrat and Huang (2007) on sweet potato fortified with soy protein pasta, and Amatakulchai and Lilavanichakul (2007) on fresh soymeal substituted egg noodle.

The color of soymeal is light brown. Replacing wheat flour with soymeal resulted in a reduction of xanthophylls and a loss of yellow. Therefore, increasing soymeal substitution affected the color of dough as the redness (a*) of dough increased while the lightness (L*) and yellowness (b*) decreased ($p \leq 0.05$). This agreed with that reported by Amatakulchai and Lilavanichkul (2007) on fresh soymeal substituted egg noodles.

Table 4.3 Color of dough and tensile strength of noodles substituted with soymeal

Soymeal (%)	Color			Tensile strength (g)
	L*	a*	b*	
0	72.20±0.41a	0.34±0.12d	26.19±0.36a	12.75±0.13a
20	57.91±0.35b	5.58±0.18c	24.11±0.13b	9.16±0.22b
25	54.98±0.27c	5.86±0.15b	22.59±0.54c	7.32±0.11c
30	50.82±0.38d	6.12±0.21a	21.86±0.44d	6.04±0.21d

a, b, c, d means with different letters on each column are significantly different ($p \leq 0.05$)

From the sensory test (Table 4.4), it was found that all attributes decreased as soymeal substitution increased. Decreasing in color and elasticity agreed with the objective results (Table 4.3) as L* (lightness) and b* (yellowness), and tensile strength. Moreover, the soymeal substituted noodles had distinct beany odor as commented by the panelists. Therefore, the overall preference score decreased as the substitution level increased. This agreed with the results reported by Pluempavarn *et al*. (2005) on dried soymeal substituted udon; Amatakulchai and Lilavanichkul (2007) on fresh soymeal substituted egg noodles and Singh and Mohamed (2007) on gluten-soy protein blend cookies.

Table 4.4 Sensory scores of noodles substituted with soymeal

Soymeal (%)	Sensory scores			
	Color	Odor	Elasticity	Overall preference
0	8.5±0.8a	8.4±0.6a	8.6±0.1a	8.9±0.2a
20	6.3±0.7b	6.1±1.1b	5.6±0.4b	6.2±0.6b
25	6.2±0.9c	5.4±0.8c	5.3±0.4c	6.0±0.6b
30	5.6±0.9c	5.1±0.8c	5.0±0.4c	5.4±0.3c

Sensory evaluation using a 9-point hedonic scale (1=dislike extremely, 9=like extremely)

a, b, c, d means with different letters on each column are significantly different ($p \leq 0.05$)

Table 4.4 shows that there was no significant difference in overall preference scores of noodles with 20% and 25% soymeal. Since the protein and fiber contents of

25% substitution noodle were higher so the maximum soymeal substitution accepted was 25%. However the odor and elasticity scores were 5.38 and 5.28. The low tensile strength value and elasticity score indicated that the texture of noodle had to be improved.

4.3 Improvement of noodle qualities with Isagum®

The addition of Isagum® did not affect the color of dough obtained ($p>0.05$) while the tensile strengths of cooked noodle strands increased as Isagum® content increased ($p\leq0.05$) (Table 4.5). This is because Isagum® has an ability to improve tensile strength of the final noodles (Hou, 2001; Yu and Ngadi, 2004; Charles *et al*., 2006). The regions of mannuronate in PGA can interact with starch and glutamic acid resulting in the strong network structure (Hua *et al*., 2003). Tara gum is similar to locust bean gum which has a rigidity structure as super helices. It could reduce the syneresis and resulted in retaining water inside. (Sittikijyothin *et al*., 2004; Garcia and Totosaus, 2008).

Table 4.5 Color of dough and tensile strength of 25% soymeal substituted noodles with different Isagum®

Isagum® (%w/w)	Color^{ns}			Tensile strength (g)
	L*	a*	b*	
0	54.98±0.12	5.85±0.23	22.57±0.24	7.17±0.20d
0.1	55.04±0.14	5.90±0.15	22.60±0.16	7.85±0.12c
0.2	54.98±0.17	5.86±0.22	22.59±0.22	8.57±0.18b
0.3	55.02±0.11	5.88±0.27	22.66±0.19	9.14±0.18a

a, b, c, d means with different letters on each column are significantly different ($p \leq 0.05$)

ns means on each column are not significantly different ($p>0.05$)

Table 4.6 shows that increasing Isagum® could increase elasticity and overall preference scores of noodles which corresponded to the increase in tensile strength (Table 4.5). The elasticity and overall preference of noodle samples containing 0.2% and 0.3% Isagum® were significantly higher than those containing 0% and 0.1%

($p \leq 0.05$) while their color and odor were not significantly different ($p>0.05$). According to the results, 0.2% Isagum® addition was chosen for further study.

Table 4.6 Sensory scores of 25% soymeal substituted noodle with different Isagum®

Isagum® (%w/w)	Sensory scores			
	Color[ns]	Odor[ns]	Elasticity	Overall preference
0	6.3±0.4	5.4±0.5	5.3±0.2c	6.0±0.3c
0.1	6.2±0.4	5.5±0.4	6.3±0.5b	6.9±0.3b
0.2	6.3±0.5	5.4±0.5	6.7±0.4ab	7.0±0.4a
0.3	6.2±0.6	5.4±0.5	6.9±0.5a	7.1±0.4a

Sensory evaluation using a 9-point hedonic scale (1=dislike extremely, 9=like extremely)

a, b, c, d means with different letters on each column are significantly different ($p \leq 0.05$)

ns means on each column are not significantly different ($p>0.05$)

4.4 Determination of the optimum drying conditions

4.4.1 Tray drying

The 25% soymeal substitution with 0.2% Isagum® raw noodles were prepared and cooked with steam for 5 minutes, then dried in a tray dryer at 60°, 70° and 80 °C until their moisture contents were constant. The relationship between moisture of noodles dried at 60°, 70° and 80 °C and drying time showed that the time required to dry the cooked noodles to constant moisture content (8%, db) were 360, 255 and 195 minutes, respectively (Figure 4.1). It was found that a reduction of moisture content was higher with drying temperature and time. Drying at high temperature resulted in the lower rate of water movement from the interior to the surface than the rate at which water evaporated to the surrounding with a shorter drying time (Baiano *et al*., 2006). This agreed with those reported by Pluempavarn *et al.* (2005) on dried udon and Villeneuva and Gelinas (2007) on whole durum wheat pasta.

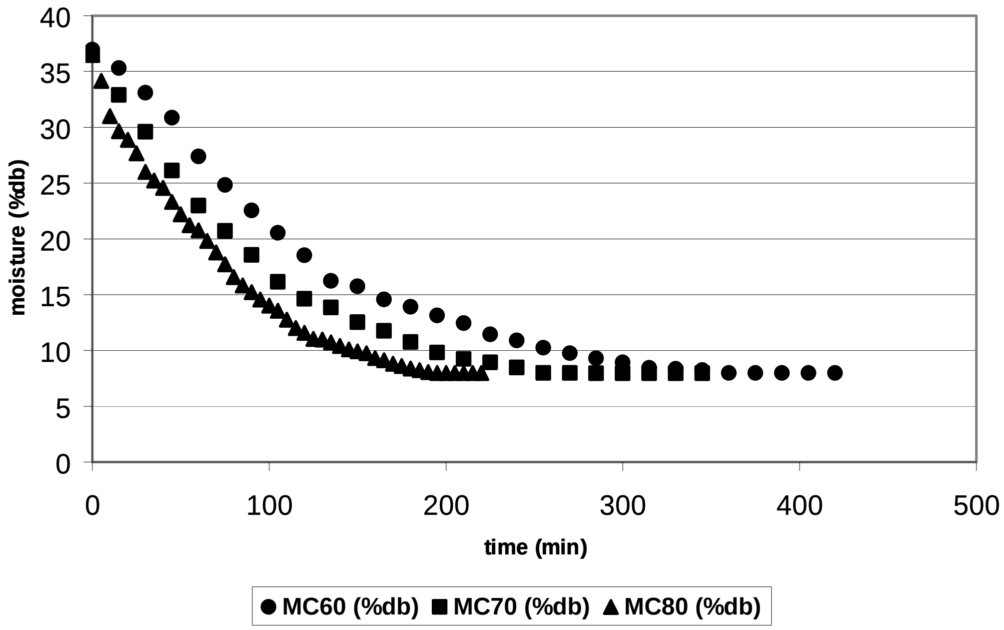

Figure 4.1 Drying curve of noodle dried at different temperatures

From the drying rate curve (Figure 4.2), it was found that the drying rate at 60°C had constant rate period and 2 falling rate periods while those at 70°C and 80°C had 2 falling rate periods. In the constant rate period, the moisture content reduced from the initial moisture content (about 37% dry basis) to approximately 30% (db). During the first falling rate period, the drying rate decreased linearly with the moisture content until the moisture content reached approximately 10% (db), then the second falling rate period started. The second falling rate period decreased slower than the first falling rate period. It might be because the remaining bound water attached with the biomolecules such as starch, protein, lipid or fiber and resulted in the water evaporated harder (Baiano *et al*., 2006). This agreed with those reported by Inazu *et al*. (2003) on fresh Japanese noodle and Baiano *et al*. (2006) on spaghetti which found the falling rate period with drying at a high temperature while the constant rate period was found at low temperature.

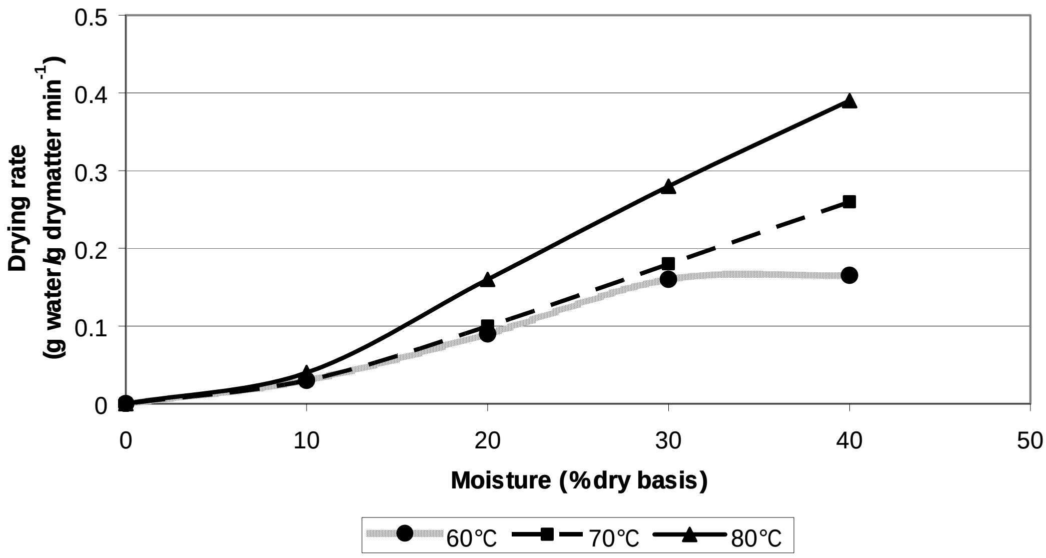

Figure 4.2 Drying rate of noodles at different temperatures

From Figure 4.2, it was also found that the drying rate (y) depends on the temperature as the drying temperature increased the y value increased which agreed with Baiano *et al*. (2006) and Villeneuve and Gelinas (2007). From Table 4.7 the slope of the equation reflected how fast the moisture content decreased in first falling rate period. It indicated that drying at higher temperature resulted in a reduction of moisture content to occur faster.

Table 4.7 Drying rate equation of first falling rate period at different temperatures

Drying temperature (°C)	Drying rate equation	R^2
60	y = 0.0073x-0.0521	0.993
70	y = 0.0077x-0.0512	0.986
80	y = 0.0117x-0.0746	0.990

x = moisture (%dry basis)

y = drying rate (g water/g dry matter min^{-1})

From Table 4.8, it was found that a_w and rehydration rate decreased ($p \leq 0.05$) and cooking loss increased ($p \leq 0.05$) with drying temperature. Higher drying temperature caused a higher water evaporation and lower a_w. It was because of the porous creation on the surface and expanding noodle structure therefore, the noodle structure became puffy and crisp and the noodles could absorb less water during rehydration (Baiano *et al*., 2006; Villeneuve and Gelinas, 2007). Higher drying temperature resulted in higher release of starch and main component of residue from cooking loss was amylose. (Villeneuve and Gelinas, 2007). This agreed with the results reported by Villeneuve and Gelinas (2007) on whole durum wheat pasta. However, it was found that the color and tensile strength of the rehydrated noodles were not significantly different (p>0.05).

Table 4.8 Color, a_w, tensile strength, cooking loss and rehydration rate of noodles dried at different temperatures

Drying temperature (°C)	Color^{ns}			a_w	Tensile strength^{ns} (g)	Cooking loss (%)	Rehydration rate (%)
	L*	a*	b*				
60	58.20±0.04	5.87±0.02	22.63±0.03	0.57±0.03a	8.69±0.82	3.26±0.38c	787.52±8.8a
70	58.14±0.03	5.85±0.03	22.64±0.04	0.50±0.10b	8.54±0.59	4.00±0.29b	782.74±2.9b
80	58.22±0.03	5.86±0.05	22.64±0.01	0.46±0.02c	8.57±0.70	5.66±0.58a	778.31±0.4c

a, b, c, d means with different letters on each column are significantly different ($p \leq 0.05$)

ns means on each column are not significantly different (p>0.05)

From the 9-point hedonic scale test on color, odor, elasticity and overall preference of cooked noodles (Table 4.9) it was found that there was no significant difference in all attributes (p>0.05). However, the sensory scores of noodles dried at 80°C were slightly higher than others. This was similar to the results reported by Baiano *et al*. (2006) on spaghetti that the elastic modulus increased with the drying temperature and the spaghetti dried at high temperature had the highest firmness and panel test scores.

Table 4.9 Sensory scores of rehydrated dried noodles

Drying temperature (°C)	Sensory scores^{ns}			
	Color	Odor	Elasticity	Overall preference
60	5.0±0.6	5.1±0.6	5.1±0.7	4.9±0.8
70	5.1±0.7	5.2±0.7	5.1±0.7	5.0±0.8
80	5.1±0.8	5.3±0.9	5.2±0.9	5.1±0.7

Sensory evaluation using a 9-point hedonic scale (1=dislike extremely, 9=like extremely)
ns means on each column are not significantly different ($p>0.05$)

Power is defined as the rate at which electrical energy is supplied to a circuit or consumed by a load. Its mathematical formula is expressed on a per time basis (Power = energy/time). Energy is expressed by (power of tray drier) x (time) so the amount of energy was depended on the drying time. Therefore, drying at high temperature might be a good way to save energy and time. Drying at 80°C was chosen because its sensory scores were the highest even though the rehydration rate was slightly lower and cooking loss was higher than other samples. This result was similar to that reported by Guler *et al*. (2002) on pasta and lower than that reported by Limroongruengrat and Huang (2007) on sweet potato pasta. So the condition for tray drying was drying the noodles at 80°C for 195 minutes.

4.4.2 Deep-fat frying

From section 4.3, 0.2% Isagum® was used to improve the qualities of noodle substituted with 25% soymeal. Then noodles were cooked with steam for 5 minutes and fried at 130°, 140° and 150 °C for 30, 60 and 90 seconds.

When noodles were placed in hot oil, temperature of the noodles increased rapidly causing the water to vaporize and creating porous structure with the internal temperature increased at the slower rate. The pores were filled by hot oil rapidly (Moss *et al*., 1987; Pedreschi *et al*., 2008). The results showed that frying temperature and frying time had no effect on color and cooking loss but had the effects on oil absorption, rehydration rate, while the tensile strength was affected by both factors and their interaction (Table 4.10 and Table B.1-B.5). Increasing frying temperature and time resulted in amount of pores to increase and gave the puffy noodle structure. They affected tensile strength of rehydrated noodles to decrease. This agreed with the results reported by Moss *et al*. (1987) on instant noodles. Higher amount of pores gave the noodle structure more puffy and resulted in lower elasticity of rehydrated noodles. The rehydration rate was related to the number of pores present in the noodle as higher water could be rehydrated with higher amount of pores (Moss *et al*., 1987). Higher amount of pores might affect the oil absorption to increase. However, the temperature gradients between oil and noodle increased the pressure inside the noodles and it caused the higher motive force of pressure difference. These resulted in higher moisture loss than oil uptake (Moss *et al*., 1987). The noodles absorbed more oil when they were fried longer. Frying at higher temperature would reduce the oil absorption of the noodles

Table 4.10 Physical properties of soymeal substituted fried noodle

Frying temperature (°C)	Frying time (s)	Color^{ns}			Cooking loss^{ns} (%)	Tensile strength (g)	Oil absorption (%)	Rehydration rate (%)
		L*	a*	b*				
130	30	58.7±0.1	5.8±0.1	22.6±0.3	2.09±0.02	6.97±0.05a	14.77±0.32e	765.44±2.21f
	60	58.6±0.1	5.8±0.3	22.6±0.4	2.18±0.04	6.87±0.03b	15.48±0.43b	769.57±1.94e
	90	58.6±0.1	5.8±0.3	22.6±0.2	2.20±0.03	6.78±0.01c	17.78±0.19a	771.22±1.00d
140	30	58.6±0.3	5.8±0.2	22.6±0.2	2.18±0.02	6.68±0.02d	12.31±0.27e	771.93±2.73d
	60	58.5±0.4	5.8±0.1	22.6±0.1	2.25±0.01	6.61±0.03d	13.59±0.14d	772.26±2.48c
	90	58.7±0.2	5.8±0.1	22.6±0.3	2.27±0.03	6.56±0.03e	14.62±0.22c	773.18±1.87c
150	30	58.7±0.1	5.8±0.2	22.6±0.3	2.13±0.01	6.47±0.04f	10.36±0.20g	775.46±1.22b
	60	58.5±0.1	5.8±0.1	22.6±0.1	2.19±0.02	6.22±0.02g	11.38±0.28f	778.87±0.83a
	90	58.6±0.3	5.8±0.3	22.6±0.3	2.06±0.02	5.99±0.02h	12.35±0.08e	779.43±2.36a

ns means on the column are not significantly different ($p>0.05$)

a, b, c, d means with different letters on each column are significantly different ($p\leq0.05$)

From Table 4.11, it was found that frying temperature affected odor, elasticity and overall preference scores. The elasticity scores corresponded to the decrease in tensile strength of rehydrated noodles (Table 4.10). High temperature during deep-fat frying could cause more medium- and short-chain aldehydes such as heptanal, hexanal, pentanal which are major compounds contributing to the beany flavor (Maheshwari *et al.*, 1995). However, the aldehydes are volatile compounds and can be removed at high temperature so the beany odor deceased and resulted in higher odor scores. These caused the low overall preference scores. Moreover, it was found that the sensory scores of the fried noodles were less than 5 from 9-point scale so the odor of all fried noodles should be improved.

Table 4.11 Sensory scores of rehydrated noodles

Frying temperature (°C)	Frying time (s)	Sensory scores			
		Color^{ns}	Odor	Elasticity	Overall preference
130	30	3.9±0.3	3.3±0.2f	4.5±0.3a	3.8±0.2e
	60	3.6±0.3	3.4±0.4f	4.2±0.2b	3.9±0.2d
	90	4.0±0.4	3.6±0.2d	4.0±0.1c	3.7±0.4f
140	30	3.9±0.2	3.5±0.1e	3.8±0.2d	4.1±0.3b
	60	3.9±0.2	3.6±0.3d	3.6±0.3e	3.6±0.1g
	90	4.0±0.1	3.8±0.4b	3.5±0.2e	4.0±0.2c
150	30	4.2±0.3	3.7±0.2c	3.3±0.4g	4.2±0.3b
	60	3.8±0.5	4.2±0.4a	3.4±0.1f	4.6±0.1a
	90	3.5±0.3	4.2±0.2a	3.2±0.2h	4.0±0.2c

Sensory evaluation using a 9-point hedonic scale (1=dislike extremely, 9=like extremely)

a, b, c, d means with different letters on each column are significantly different ($p \leq 0.05$)

ns means on each column are not significantly different ($p > 0.05$)

4.4.2.1 Improvement of the fried noodle odor

Green tea and Kaffir lime leave extracts were used in this study because green tea is a popular ingredient in food products, and contains high amount of antioxidant but rarely found in instant noodles while Kaffir lime leaves contain high amount of essential oil and had characteristic aroma which most Thais preferred. Therefore, using green tea and Kaffir lime leaves might improve the odor of fried noodles and make a new choice for the consumers.

It was found that replacing water with the extracts from green tea and Kaffir lime leaves did not affect the color and cooking loss of the soymeal substituted fried noodles (Tables 4.10, 4.12, 4.13). The results of physical properties of noodles with green tea extract were similar to those with Kaffir lime leave extract and were not different from only soymeal substituted fried noodles. Replacing the water with the green tea extracts did not affect the sensory scores of rehydrated noodles (Tables 4.11, 4.14). From Tables 4.14 and 4.15, it can be seen that Kaffir lime leave extract could improve the odor of the fried noodles more than green tea extract. The sensory score of noodles with Kaffir lime leave extract at the ratio of 1:1, w/v was the highest while the values of color, tensile strength, cooking loss, rehydration rate and oil absorption were not different from others. Therefore, the optimum condition for deep-fat frying was frying noodles with Kaffir lime leave extract (extraction ratio 1:1 w/v) at 150°C for 60 seconds.

Table 4.12 Physical properties of fried noodles with green tea extract

Frying temperature (°C)	Frying time (s)	Extract ratio (w/v)	Color^ns			Cooking loss^ns (%)	Tensile strength (g)	Oil absorption (%)	Rehydration rate (%)
			L*	a*	b*				
130	30	1:3	58.7±0.1	5.8±0.3	22.6±0.1	2.16±0.28	6.95±0.47a	14.71±0.27c	765.43±1.53g
		1:1	58.7±0.2	5.8±0.1	22.6±0.2	2.13±0.43	6.94±0.24a	14.75±0.06c	764.28±1.74h
	60	1:3	58.6±0.1	5.8±0.3	22.6±0.1	2.18±0.31	6.86±0.21b	15.48±0.28b	770.58±1.18f
		1:1	58.6±0.2	5.8±0.2	22.6±0.2	2.18±0.10	6.85±0.28b	15.50±0.31b	770.31±1.60f
	90	1:3	58.6±0.3	5.8±0.2	22.6±0.2	2.21±0.27	6.77±0.12c	17.78±0.23a	771.21±0.92e
		1:1	58.6±0.2	5.8±0.4	22.6±0.2	2.20±0.24	6.76±0.09c	17.78±0.14a	770.65±1.13f
140	30	1:3	58.6±0.2	5.8±0.1	22.6±0.4	2.18±0.18	6.68±0.17d	12.47±0.24e	771.44±2.28e
		1:1	58.6±0.3	5.8±0.3	22.6±0.2	2.19±0.28	6.68±0.36d	12.43±0.19e	771.93±2.03e
	60	1:3	58.5±0.1	5.8±0.1	22.6±0.1	2.25±0.39	6.61±0.32e	13.59±0.12d	772.75±1.67d
		1:1	58.6±0.4	5.8±0.3	22.6±0.1	2.26±0.12	6.61±0.14e	13.71±0.27d	772.83±1.42d
	90	1:3	58.7±0.1	5.8±0.3	22.6±0.2	2.19±0.31	6.55±0.11f	14.59±0.12c	772.74±1.80d
		1:1	58.7±0.2	5.8±0.3	22.6±0.3	2.24±0.48	6.52±0.18f	14.61±0.18c	773.24±2.41c
150	30	1:3	58.7±0.2	5.8±0.1	22.6±0.2	2.26±0.17	6.47±0.28g	10.47±0.21g	775.45±1.71b
		1:1	58.7±0.1	5.8±0.1	22.6±0.1	2.15±0.33	6.49±0.13g	10.50±0.44g	775.11±0.83b
	60	1:3	58.5±0.2	5.8±0.1	22.6±0.3	2.21±0.20	6.23±0.37h	11.39±0.27f	779.29±1.04a
		1:1	58.7±0.3	5.8±0.2	22.6±0.2	2.16±0.32	6.25±0.49h	11.71±0.26f	779.43±1.47a
	90	1:3	58.6±0.2	5.8±0.3	22.6±0.3	2.13±0.38	6.04±0.22i	12.75±0.13h	779.28±1.68a
		1:1	58.6±0.2	5.8±0.3	22.6±0.4	2.18±0.29	6.06±0.24i	12.48±0.32h	778.58±1.24a

ns means on the same column are not significantly different ($p>0.05$)

a, b, c, d means with different letters on each column are significantly different ($p\leq0.05$)

Table 4.13 Physical properties of fried noodles with Kaffir lime leave extract

Frying temperature (°C)	Frying time (s)	Extract ratio (w/v)	Color^{ns}			Cooking loss^{ns} (%)	Tensile strength (g)	Oil absorption (%)	Rehydration rate (%)
			L*	a*	b*				
130	30	1:3	58.6±0.2	5.8±0.3	22.6±0.2	2.13±0.17	6.97±0.14a	14.76±0.22d	765.39±2.07g
		1:1	58.6±0.2	5.8±0.2	22.6±0.1	2.07±0.13	6.91±0.36a	15.63±0.16d	764.95±1.67g
	60	1:3	58.6±0.1	5.8±0.4	22.6±0.3	2.18±0.08	6.86±0.38b	15.49±0.28d	771.75±1.43e
		1:1	58.6±0.3	5.8±0.1	22.6±0.5	2.18±0.26	6.85±0.23b	15.63±0.11d	770.53±2.22f
	90	1:3	58.6±0.4	5.8±0.5	22.6±0.1	2.21±0.47	6.79±0.27c	17.83±0.20b	773.01±2.31d
		1:1	58.7±0.2	5.8±0.3	22.6±0.2	2.17±0.23	6.76±0.12c	18.12±0.27a	772.62±0.93d
140	30	1:3	58.6±0.4	5.8±0.4	22.6±0.4	2.18±0.41	6.68±0.31d	12.55±0.12f	771.58±1.46e
		1:1	58.7±0.1	5.8±0.3	22.6±0.3	2.24±0.10	6.66±0.18d	12.44±0.07f	771.93±1.06e
	60	1:3	58.5±0.3	5.8±0.2	22.6±0.1	2.26±0.18	6.63±0.22e	13.59±0.09e	772.75±1.21d
		1:1	58.6±0.2	5.8±0.1	22.6±0.3	2.21±0.53	6.61±0.47e	13.56±0.32e	773.05±1.70d
	90	1:3	58.7±0.5	5.8±0.4	22.6±0.3	2.25±0.28	6.55±0.43f	14.59±0.18d	772.82±2.12d
		1:1	58.7±0.3	5.8±0.5	22.6±0.2	2.26±0.11	6.58±0.26f	14.66±0.26d	773.29±1.88d
150	30	1:3	58.6±0.1	5.8±0.3	22.6±0.2	2.17±0.06	6.50±0.18g	10.81±0.37h	774.12±0.08c
		1:1	58.7±0.2	5.8±0.3	22.6±0.3	2.15±0.32	6.49±0.11g	10.47±0.11h	775.45±1.42c
	60	1:3	58.6±0.4	5.8±0.2	22.6±0.4	2.22±0.24	6.26±0.27h	11.39±0.20g	779.25±2.41a
		1:1	58.7±0.4	5.8±0.1	22.6±0.1	2.21±0.17	6.27±0.17h	11.35±0.23g	779.76±1.58a
	90	1:3	58.7±0.2	5.8±0.3	22.6±0.2	2.04±0.28	6.04±0.22i	12.28±0.09f	778.83±1.21b
		1:1	58.6±0.2	5.8±0.3	22.6±0.2	2.11±0.13	6.02±0.43i	12.39±0.28f	778.98±1.69b

ns means on the same column are not significantly different ($p>0.05$)

a, b, c, d means with different letters on each column are not significantly different ($p>0.05$)

Table 4.14 Sensory scores of fried noodles with green tea extract

Frying Temperature (°C)	Frying Time (s)	Extract Ratio (w/v)	Sensory scores			
			Color	Odor	Elasticity	Overall preference
130	30	1:3	3.8±0.3c	3.7±0.1f	4.4±0.1a	3.8±0.4e
		1:1	3.8±0.3c	3.9±0.2e	4.4±0.1a	3.8±0.2e
	60	1:3	3.6±0.5d	3.4±0.1g	4.2±0.2b	3.9±0.1d
		1:1	3.7±0.2c	3.5±0.3g	4.2±0.1b	3.9±0.2d
	90	1:3	3.9±0.3b	3.1±0.1h	4.0±0.4c	3.6±0.3f
		1:1	3.9±0.1b	3.6±0.1g	4.1±0.2b	3.7±0.3f
140	30	1:3	3.9±0.4b	4.4±0.3c	3.8±0.3d	4.1±0.1c
		1:1	3.8±0.3c	4.6±0.2b	3.6±0.3e	4.1±0.4c
	60	1:3	3.8±0.3c	4.1±0.2d	3.6±0.1e	3.5±0.1g
		1:1	3.8±0.2c	4.2±0.4d	3.6±0.1e	3.7±0.3f
	90	1:3	4.0±0.2a	3.8±0.1e	3.5±0.3f	4.0±0.2c
		1:1	3.9±0.2b	4.1±0.4d	3.4±0.3g	4.2±0.3b
150	30	1:3	4.2±0.3a	4.6±0.3b	3.4±0.3g	4.2±0.2b
		1:1	4.1±0.1a	4.9±0.2a	3.5±0.5f	4.3±0.3b
	60	1:3	4.0±0.4a	4.5±0.1b	3.3±0.1h	4.6±0.1a
		1:1	3.7±0.3c	4.4±0.2c	3.3±0.2h	4.6±0.4a
	90	1:3	3.5±0.1e	4.4±0.3c	3.1±0.4i	3.9±0.1d
		1:1	3.6±0.1d	4.6±0.3b	3.1±0.1i	4.1±0.3c

Sensory evaluation using a 9-point hedonic scale (1=dislike extremely, 9=like extremely)

a, b, c, d means with different letters on each column are significantly different ($p \leq 0.05$)

Table 4.15 Sensory scores of fried noodles with Kaffir lime leave extract

Frying Temperature (°C)	Frying time (s)	Extract ratio (w/v)	Sensory scores			
			Color	Odor	Elasticity	Overall preference
130	30	1:3	3.8±0.3b	4.4±0.4f	4.5±0.1a	4.4±0.3f
		1:1	3.8±0.2b	4.6±0.4e	4.5±0.1a	4.5±0.3e
	60	1:3	3.7±0.3c	4.1±0.1g	4.1±0.2b	4.2±0.3g
		1:1	3.6±0.1d	4.6±0.3e	4.4±0.2a	4.6±0.1e
	90	1:3	3.9±0.1b	4.2±0.3g	3.4±0.2e	4.2±0.3g
		1:1	3.9±0.4b	4.6±0.2e	4.1±0.3b	4.7±0.4d
140	30	1:3	3.9±0.2b	5.3±0.2c	3.8±0.1c	4.8±0.2d
		1:1	3.8±0.3b	5.3±0.2c	3.9±0.4c	5.3±0.2b
	60	1:3	3.9±0.2b	5.0±0.1d	3.6±0.4d	4.5±0.3e
		1:1	3.9±0.2b	5.1±0.1d	3.7±0.1d	4.6±0.1e
	90	1:3	3.8±0.3b	4.9±0.3d	3.5±0.2d	4.4±0.2f
		1:1	4.1±0.1a	5.1±0.4d	3.6±0.3d	5.1±0.3b
150	30	1:3	4.2±0.1a	5.6±0.4b	3.3±0.1e	5.0±0.1c
		1:1	4.2±0.3a	5.9±0.5a	3.5±0.3d	5.2±0.3b
	60	1:3	3.8±0.2b	5.3±0.1c	3.4±0.1e	4.8±0.2d
		1:1	3.8±0.2b	5.6±0.1b	3.4±0.3e	5.6±0.2a
	90	1:3	3.6±0.3d	5.4±0.2c	3.1±0.1g	4.8±0.2d
		1:1	3.6±0.1d	5.7±0.1b	3.2±0.2f	5.1±0.4b

Sensory evaluation using a 9-point hedonic scale (1=dislike extremely, 9=like extremely)

a, b, c, d means with different letters on each column are significantly different ($p \leq 0.05$)

4.5 Evaluation of the shelf-life of dried noodles

From the results of section 4.4, the instant dried noodles (drying at 80°C for 195 minutes) and instant fried noodles with 1:1 (w/v) of Kaffir lime leave extract (150°C for 60 seconds) were stored at 35°, 45° and 55°C in aluminum-laminate bags. The shelf-life of the instant noodles was determined from the a_w, moisture content, TBA values, total plate count (TPC), and yeast-mold in the samples and sensory scores.

It was found that a_w, moisture content, TBA values, TPC and yeast-mold slightly increased but color and overall preference scores did not change significantly with time (Tables 4.16-4.18). It was because the samples were not vacuum packed or nitrogen flushed. The air inside the package might have higher moisture content and thus the water could move into the samples causing the increase in a_w and moisture content of the noodles during storage. From the analysis of rancidity values, it was found that the TBA values of fried noodles were higher than dried noodles. The TBA values of fried noodles increased with time and temperature while the TBA values of dried noodles did not change. This may be because the oxygen inside the package could react with oil to form peroxide radicals that initiate the autoxidation of fat. Moreover, oil in fried noodles was also obtained from frying process which could result in higher TBA value.

From the results of TPC and yeast-mold values (Table 4.16-4.17), TPC values could be detected in instant fried noodles while yeast-mold values could be detected in both instant noodles within a_w range of 0.467-0.569. Since the minimum a_w that bacteria, yeast, and mold can grow are 0.75, 0.60, and 0.50, respectively (An *et al*., 2008), the a_w range of these samples should be able to inhibit the bacterial growth. The increasing of TPC values in instant fried noodles might be caused by the contamination in the product during packing or contamination from the packaging material. Nevertheless, the number of microbial growth is within the standard of noodles (TIS, 2005). From the sensory test, the panelists could not detect the changes in the samples as can be seen in the scores (Table 4.18). From the results of TPC and yeast-mold values of instant noodles and TBA values of instant dried noodles, they indicated that there is not enough to estimate the shelf-life of instant noodles from these qualities. Therefore, the shelf-life of instant noodles were estimated from the data of a_w and moisture content for instant noodles and TBA values for instant fried noodles.

Table 4.16 a_w, moisture content, TBA values, TPC and yeast-mold of instant dried noodles

Time (days)	Temperature (°C)	a_w	Moisture content (% dry basis)	TBA^{ns} (mg/kg)	TPC (CFU)	Yeast-mold (CFU)
0	35	0.462±0.002f	7.95±0.03i	0.027±0.005	ND	ND
	45	0.462±0.001f	7.95±0.03i	0.027±0.004	ND	ND
	55	0.462±0.001f	7.95±0.04i	0.027±0.004	ND	ND
5	35	0.461±0.001f	7.95±0.01i	0.027±0.004	ND	ND
	45	0.462±0.002f	7.95±0.04i	0.027±0.002	ND	ND
	55	0.462±0.005f	7.95±0.02i	0.027±0.002	ND	ND
10	35	0.462±0.003f	7.95±0.02i	0.027±0.003	ND	ND
	45	0.462±0.001f	7.95±0.03i	0.027±0.001	ND	ND
	55	0.463±0.001f	7.95±0.01i	0.027±0.003	ND	ND
15	35	0.462±0.001f	7.96±0.01hi	0.027±0.005	ND	ND
	45	0.463±0.002f	7.96±0.02hi	0.027±0.004	ND	ND
	55	0.464±0.004e	7.96±0.01hi	0.028±0.001	ND	ND
20	35	0.463±0.001f	7.96±0.01hi	0.027±0.002	ND	ND
	45	0.464±0.002e	7.96±0.04hi	0.028±0.002	ND	ND
	55	0.465±0.002e	7.97±0.03h	0.028±0.004	ND	ND
25	35	0.463±0.002f	7.96±0.05h	0.027±0.001	ND	ND
	45	0.465±0.001e	7.97±0.02h	0.028±0.004	ND	ND
	55	0.465±0.004e	7.98±0.01g	0.028±0.001	ND	ND
30	35	0.464±0.003e	7.97±0.03h	0.028±0.004	ND	ND
	45	0.466±0.004d	7.99±0.02g	0.029±0.002	ND	ND
	55	0.467±0.003d	8.01±0.05f	0.030±0.002	ND	1
35	35	0.464±0.002e	7.97±0.02h	0.028±0.002	ND	ND
	45	0.467±0.001d	7.99±0.03g	0.029±0.003	ND	1
	55	0.471±0.001c	8.03±0.03f	0.031±0.003	ND	1
40	35	0.466±0.003d	7.99±0.02g	0.029±0.002	ND	1
	45	0.469±0.003d	8.02±0.03f	0.032±0.001	ND	1
	55	0.474±0.001c	8.07±0.02d	0.031±0.001	ND	1
45	35	0.467±0.003d	8.00±0.02g	0.031±0.002	ND	1
	45	0.471±0.004c	8.03±0.03f	0.033±0.001	ND	1
	55	0.476±0.002b	8.09±0.04c	0.032±0.002	ND	1
50	35	0.470±0.004d	8.00±0.04g	0.032±0.001	ND	1
	45	0.474±0.003c	8.06±0.01e	0.033±0.002	ND	1
	55	0.477±0.002b	8.12±0.03b	0.032±0.003	ND	2
55	35	0.472±0.002c	8.03±0.03f	0.032±0.003	ND	1
	45	0.476±0.003b	8.08±0.02c	0.034±0.003	ND	2
	55	0.483±0.003a	8.15±0.02a	0.033±0.003	ND	2

ND = not detected

a, b, c, d means with different letters on each column are significantly different ($p \leq 0.05$)

Table 4.17 a_w, moisture content, TBA values, TPC and yeast-mold of instant fried noodles

Time (days)	Temperature (°C)	a_w	Moisture content (% in dry basis)	TBA (mg/kg)	TPC (CFU)	Yeast-mold (CFU)
0	35	0.541±0.001j	8.87±0.02i	0.235±0.004i	ND	ND
	45	0.541±0.001j	8.87±0.05i	0.235±0.007i	ND	ND
	55	0.541±0.004j	8.87±0.04i	0.235±0.002i	ND	ND
5	35	0.542±0.003i	8.87±0.01i	0.235±0.002i	ND	ND
	45	0.541±0.001j	8.87±0.06i	0.235±0.001i	ND	ND
	55	0.541±0.001j	8.87±0.02i	0.235±0.006i	ND	ND
10	35	0.542±0.002i	8.89±0.02h	0.235±0.005i	ND	ND
	45	0.542±0.002i	8.89±0.02h	0.235±0.003i	ND	ND
	55	0.543±0.002i	8.90±0.03g	0.236±0.002i	ND	ND
15	35	0.543±0.004i	8.89±0.05h	0.235±0.003i	ND	ND
	45	0.544±0.001i	8.90±0.05h	0.237±0.001h	ND	ND
	55	0.545±0.003h	8.92±0.01g	0.239±0.001g	ND	ND
20	35	0.543±0.002i	8.89±0.01h	0.236±0.004i	ND	ND
	45	0.545±0.002h	8.90±0.06h	0.238±0.004h	ND	ND
	55	0.546±0.003h	8.92±0.01g	0.240±0.003g	ND	1
25	35	0.543±0.003i	8.90±0.02h	0.237±0.002h	ND	ND
	45	0.545±0.001h	8.91±0.03g	0.238±0.003h	ND	ND
	55	0.546±0.001h	8.93±0.03gf	0.240±0.002g	ND	1
30	35	0.545±0.004h	8.91±0.02g	0.238±0.002h	ND	ND
	45	0.547±0.005h	8.92±0.02g	0.240±0.001g	ND	ND
	55	0.549±0.001g	8.95±0.01f	0.243±0.003f	325	1
35	35	0.546±0.001h	8.92±0.01f	0.238±0.005h	ND	ND
	45	0.549±0.001g	8.94±0.04f	0.241±0.004g	342	1
	55	0.552±0.003f	8.97±0.04e	0.244±0.006f	495	1
40	35	0.549±0.003g	8.93±0.01g	0.240±0.003g	ND	1
	45	0.553±0.004f	8.98±0.01e	0.243±0.001f	340	1
	55	0.557±0.003d	9.02±0.02d	0.246±0.003e	490	1
45	35	0.551±0.003f	8.95±0.02f	0.241±0.002g	ND	1
	45	0.555±0.003e	9.03±0.02d	0.246±0.001e	370	1
	55	0.560±0.002c	9.06±0.02c	0.250±0.002c	480	2
50	35	0.552±0.004f	8.98±0.02e	0.243±0.003f	ND	1
	45	0.559±0.002c	9.06±0.03c	0.248±0.003d	390	2
	55	0.564±0.003b	9.10±0.04b	0.253±0.003b	480	2
55	35	0.552±0.003f	9.01±0.02d	0.243±0.002f	320	1
	45	0.563±0.003b	9.09±0.03b	0.251±0.001c	390	2
	55	0.569±0.004a	9.15±0.03a	0.257±0.003a	510	2

ND = not detected

a, b, c, d means with different letters on each column are significantly different ($p \leq 0.05$)

Table 4.18 Sensory scores of instant noodles

Time (days)	Temperature (°C)	Instant dried noodle		Instant fried noodle	
		Color^{ns}	Overall preference^{ns}	Color^{ns}	Overall preference^{ns}
0	35	5.2±0.2	5.2±0.1	3.9±0.1	5.7±0.2
	45	5.2±0.2	5.2±0.1	3.9±0.2	5.7±0.3
	55	5.2±0.4	5.2±0.2	3.9±0.2	5.7±0.3
5	35	5.2±0.1	5.2±0.5	3.9±0.2	5.7±0.2
	45	5.1±0.1	5.2±0.3	3.9±0.2	5.6±0.2
	55	5.2±0.3	5.2±0.3	3.9±0.1	5.6±0.3
10	35	5.2±0.3	5.2±0.2	3.9±0.1	5.7±0.2
	45	5.2±0.6	5.2±0.6	3.8±0.1	5.7±0.2
	55	5.2±0.1	5.2±0.2	3.8±0.3	5.6±0.3
15	35	5.2±0.2	5.2±0.1	3.8±0.3	5.6±0.2
	45	5.2±0.4	5.2±0.5	3.8±0.2	5.6±0.3
	55	5.1±0.1	5.1±0.5	3.8±0.2	5.6±0.3
20	35	5.2±0.5	5.2±0.3	3.8±0.4	5.6±0.2
	45	5.2±0.3	5.2±0.4	3.8±0.1	5.6±0.2
	55	5.1±0.3	5.1±0.1	3.8±0.2	5.6±0.3
25	35	5.2±0.1	5.2±0.4	3.8±0.2	5.6±0.3
	45	5.2±0.2	5.2±0.3	3.7±0.5	5.6±0.2
	55	5.1±0.1	5.1±0.2	3.7±0.3	5.5±0.2
30	35	5.1±0.3	5.2±0.2	3.7±0.2	5.5±0.3
	45	5.1±0.2	5.1±0.1	3.7±0.1	5.5±0.1
	55	5.1±0.5	5.1±0.1	3.7±0.2	5.5±0.4
35	35	5.1±0.4	5.1±0.3	3.7±0.3	5.5±0.1
	45	5.1±0.2	5.1±0.2	3.7±0.3	5.5±0.5
	55	5.1±0.3	5.1±0.2	3.7±0.3	5.5±0.5

Sensory evaluation using a 9-point hedonic scale (1=dislike extremely, 9=like extremely)

ns means on the same column are not significantly different ($p>0.05$)

The kinetics of a_w, moisture content and TBA value changes were investigated. It was found that a_w and moisture content of instant noodles and TBA values of fried noodles followed the first-order kinetic. The activation energies (E_a) and rate constant (k) of these parameters were listed in Table 4.19. It can be seen that the k values of a_w and moisture in instant dried noodles were lower than instant fried noodles. Since E_a value denoted the minimum energy necessary for a specific chemical reaction to occur, lower E_a values of a_w value in dried noodles indicated that the minimum energy of reaction required to occur was less than that in fried noodles. The k values of these quality parameters also showed that the sequences of deterioration in dried noodles were from a_w and moisture while in fried noodles were rancidity, a_w and moisture.

Table 4.19 Kinetic parameters for a_w, moisture content and TBA values of instant noodles

Attributes	E_a (kJ/kg mol)		k at 30°C (days^{-1})		A (day^{-1})	
	Dried noodles	Fried noodles	Dried noodles	Fried noodles	Dried noodles	Fried noodles
a_w	28.99	34.18	3.18×10^{-4}	3.36×10^{-4}	31.63	262.28
moisture	38.42	21.47	1.53×10^{-4}	2.63×10^{-4}	642.46	1.33
TBA value	-	34.82	-	5.80×10^{-4}	-	583.01

The results shown in Table 4.20 indicated that all Q_{10} of instant noodles were low and different. The higher Q_{10} values mean that the reaction rates were higher when the temperature was raised by 10°C. It was found that Q_{10} of a_w in dried noodles was lower than in fried noodles while Q_{10} of moisture was higher. The low Q_{10} values indicated that the storage temperature did not affect the reaction rates when the temperature was increased.

Table 4.20 Q_{10} of instant noodles at 30°C

Attributes	Q_{10}	
	Dried noodles	Fried noodles
a_w	0.35	0.41
moisture	0.46	0.26
TBA value	-	0.42

To determine the shelf-life of instant noodles, the critical value of various properties must be set. The critical value of moisture content was 12.0% (wb) or 13.6% (db) as set in the standard of TIS (2005) for dried noodle. This was used to predict the critical value of a_w by sorption isotherm (Figure 4.3) and found that the critical value of a_w of dried and fried noodles was 0.99. From the reports of other works the critical value of TBA was set at 2.0 mg/kg (Yashoda *et al.*, 2008).

The shelf-life of instant noodles was calculated based on the critical values of 0.9, 13.6% (db) and 2.0 (mg/kg) for a_w, moisture content, and TBA values, respectively. It was found that the important parameter for shelf-life of dried noodles was a_w followed by moisture while in fried noodles was moisture, a_w, and TBA (Table 4.21). Therefore, the least time required to ensure the qualities of instant dried and fried noodles were 2398 and 1625 days, respectively. With the aluminum-laminate bags, they could protect the products from moisture and oxygen and prolong the shelf-life of instant noodles. On the contrary, the commercial instant noodles were generally packed in LDPE plastic bags and their shelf-life was about 6-12 months. These indicated that the aluminum-laminate bags could prolong the shelf-life of instant noodles more than commercial instant noodles.

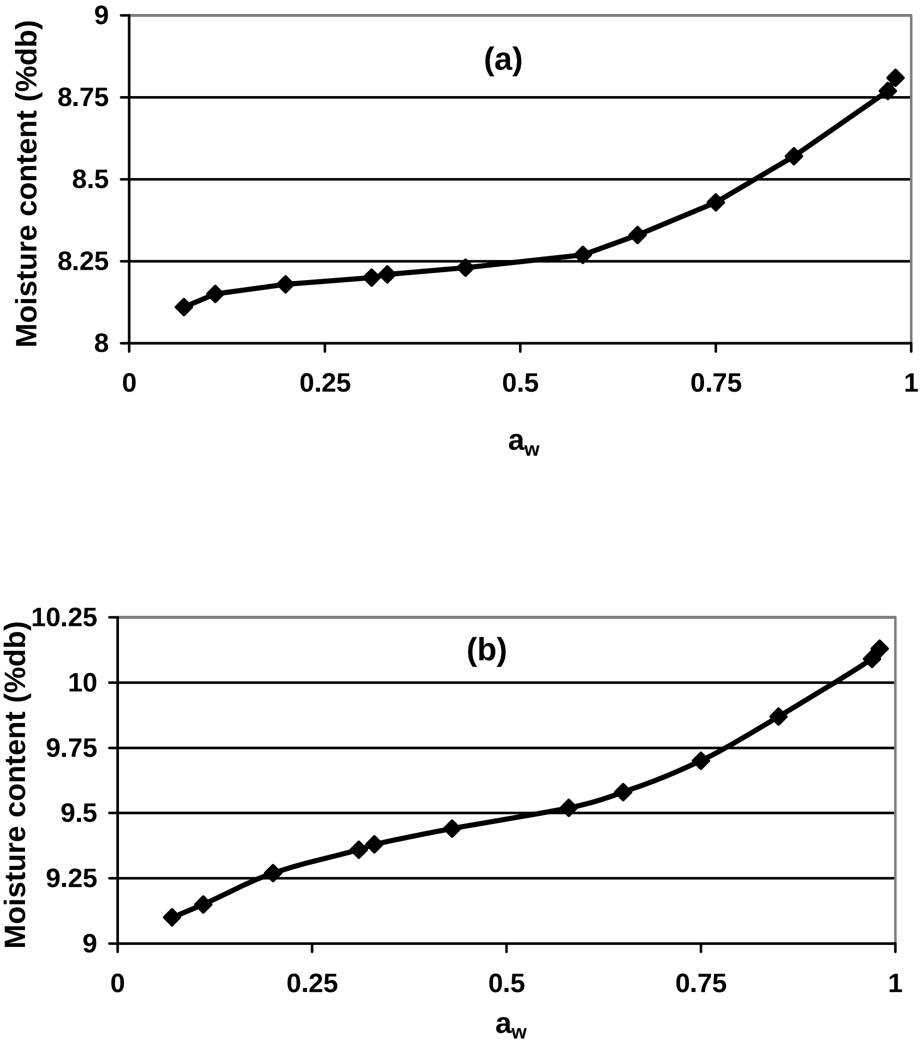

Figure 4.3 Water sorption isotherms of (a) dried and (b) fried noodles

Table 4.21 Calculated shelf-life of instant noodles at 30°C based on quality parameters

Parameters	Calculated shelf-life (days)	
	Dried noodles	Fried noodles
a_w	2398	1799
Moisture	3514	1625
TBA value	-	3692

CHAPTER 5
CONCLUSIONS AND SUGGESTIONS

5.1 Conclusions

The chemical compositions of soymeal and wheat flour were 53.91, 0.17, 6.24, 3.93 and 36.00 %, and 11.75, 0.96, 0.52, 0.19 and 86.57 % (db) for protein, lipid, ash, fiber and carbohydrate, respectively. Increasing soymeal substitution resulted in an increase in protein and fiber contents, and redness and decrease in lightness (L*), yellowness (b*), tensile strength and sensory attributes. The most acceptable level of soymeal substitution was 25%. Addition of 0.2% Isagum® to the formula improved the tensile strength, elasticity and overall preference scores. For tray drying, increasing drying temperature increased drying rate and cooking loss but decreased a_w and rehydration rate. Drying at 80 °C for 195 minutes was the optimum condition for tray drying. For deep-fat frying, frying temperature and frying time affected oil absorption, rehydration rate and tensile strength. The odor of the fried noodle was improved by replacing water with Kaffir lime leave extract (1:1, w/v). The optimum condition for deep-fat frying was frying at 150 °C for 60 seconds. The shelf-life of the dried noodle was 2398 days based on a_w while fried noodle was 1625 days based on moisture content.

5.2 Suggestions for further study

5.2.1 Vacuum frying may improve the qualities of instant fried noodles.

5.2.2 Oxygen absorber or nitrogen-flush may extend the shelf-life of the product.

5.2.3 Longer storage test should be done to determine the critical value of TBA for instant noodles.

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APPENDICES

APPENDIX A
PHYSICAL AND CHEMICAL MEASUREMENT TECHNIQUES

A.1 Tensile strength (Charles *et al.,* 2006).

1. Apparatus

Texture analyzer (TA.XT/2i, England) equipped with A/SPR measuring head and tension grips

2. Methodology

Set up the computer to the texture analyzer and calibrate force every times before used. The measuring head and tension grips are established with texture analyzer then probe is calibrated before measurement by adjusted the probe distance. Two ends of noodle stand were rolled with the measuring head and the pattern was set as Table A.1.

Table A.1 Conditions for tensile strength measurement

Mode	Measure Force in Tension
Option	Return to start
Pre-Test Speed	3.0 mm/s
Test Speed	3.0 mm/s
Post-Test Speed	5.0 mm/s
Distance	75 mm.
Trigger Type	Auto
Data Acquisition Rate	200 pps.

A.2 Cooking loss (Collins and Pangloli, 1997)

Twenty gram of samples were cooked in 600 ml boiling water for 11 min and drained in a colander 2 min, the cooking water was collected. Volume was brought to 450 ml with stirring. Aliquots (25 ml) were evaporated to apparent dryness in an air oven at 105°C until samples reached constant weight. Remaining solids were weighed to determine cooking loss which was expressed as percentage of initial dry matter.

Cooking loss (%) = (Bx100)/A

where

A = weight of sample before cooking (g)

B = weight of remaining solids after cooking (g)

A.3 Rehydration rate (Beta and Corke, 2001)

Twenty gram of samples were cooked in 450 ml boiling point for 4 min until the white inner core disappeared. The cooked noodle strands were then placed in cold water, drained, wiped with paper towels, and kept covered in plastic box. The gain in noodle weight after cooking was recorded as rehydration rate (%).

Rehydration rate (%) = (Bx100)/A

where

A = weight of sample before rehydration (g)

B = weight of sample after rehydration (g)

A.4 TBA values (AOCS, 1997)

1. **Reagents**
   1.1 1-butanol
   1.2 2-Thiobarbituric acid
   1.3 TBA reagent is prepared by dissolving 200 mg 2-thiobarbituric in 100 ml 1-butanol. Leave the weighed amount with butanol overnight or use an ultrasonic apparatus, filter, or centrifuge the suspension to remove the undissolved residue and make up the filtrate to 100 ml with 1-butanol.
2. **Procedure**
   2.1 Accurately weigh 50-200 mg of the sample into a 25-ml volumetric flask. Mix the sample in a small volume of 1-butanol for 30 minutes and make up to volume with 1-butanol.

2.2 Transfer 5.0 ml of the sample solution to a dry test tube and close the test tube and mix thoroughly.

2.3 Place the prepared test tube into a water bath at 95°C.

2.4 After 120 min, remove the test tube from the water bath and cool it under running tap water for about 10 min until it reaches room temperature.

2.5 Measure the absorbance of the reaction solution in a 10-mm cuvette at 530 nm and using distilled water in the reference cuvette.

2.6 Use distilled water as reagent blank at the same time as the sample. The OD reading of the blank determination should not exceed 0.1 in a 10-mm cuvette.

3. Calculation

$$\text{TBA value} = [50\times(A-B)] / m$$

where

A = absorbance of the test solution

B = absorbance of the reagent blank

m = mass of the test portion (mg)

50 is a valid factor if the volume of the volumetric flask is 25 ml and the cuvette width is 10 mm.

A.4 Determination of the sorption isotherm

Methodology

1. Determine the initial moisture content of sample and prepare different saturated salt solutions (Table A.2).
2. Cut a hole at the center of the aluminium dish and place filter paper on it.
3. Weigh the dish with filter paper and place a piece of sample on the filter paper and weigh the dish again.
4. Expose the dish with sample to various constant relative humidity atmosphere established by using a number of saturated salt solutions (Table A.2).
5. After equilibrium is reached, determine the final moisture content of samples

6. Plot graph between equilibrium relative humidity and moisture content of sample

Table A.2 Relative humidities of saturated salt solutions

Salt	Relative humidity (%)
LiBr	7
$LiCl.H_2O$	11
CH_3COOK	20
$CaCl_2.6H_2O$	31
$MgCl.6H_2O$	33
K_2CO_3	43
$NaBr.2H_2O$	58
$NaNO_2$	65
NaCl	75
KCl	85
K_2SO_4	97
$KClO_2$	98

A.4 Evaluation of the shelf-life of dried noodle

The changes of a_w, moisture and TBA values followed the first-order kinetics and ln (C) was plotted versus time (t). For example in the result of a_w in dried noodles;

Table A.3 a_w and ln (a_w) values of instant dried noodles during storage

Time (day)	a_w			ln(a_w)		
	35°C	45°C	55°C	35°C	45°C	55°C
0	0.462	0.462	0.462	-0.772	-0.772	-0.772
5	0.461	0.462	0.462	-0.774	-0.772	-0.772
10	0.462	0.462	0.463	-0.772	-0.772	-0.770
15	0.462	0.463	0.464	-0.772	-0.770	-0.768
20	0.463	0.464	0.465	-0.770	-0.768	-0.766
25	0.463	0.465	0.465	-0.770	-0.766	-0.766
30	0.464	0.466	0.467	-0.768	-0.764	-0.761
35	0.464	0.467	0.471	-0.768	-0.761	-0.753
40	0.466	0.469	0.474	-0.764	-0.757	-0.747
45	0.467	0.471	0.476	-0.761	-0.753	-0.742
50	0.47	0.474	0.477	-0.755	-0.747	-0.740
55	0.472	0.476	0.483	-0.751	-0.742	-0.728

From the data in Table A.3, ln (a_w) was plotted versus time (Figure A.1) and the *k* values of each temperature were represented as slope (TableA.4). ln *k* values at each temperature were plotted versus 1/T (1/K) as shown in Figure A.3.

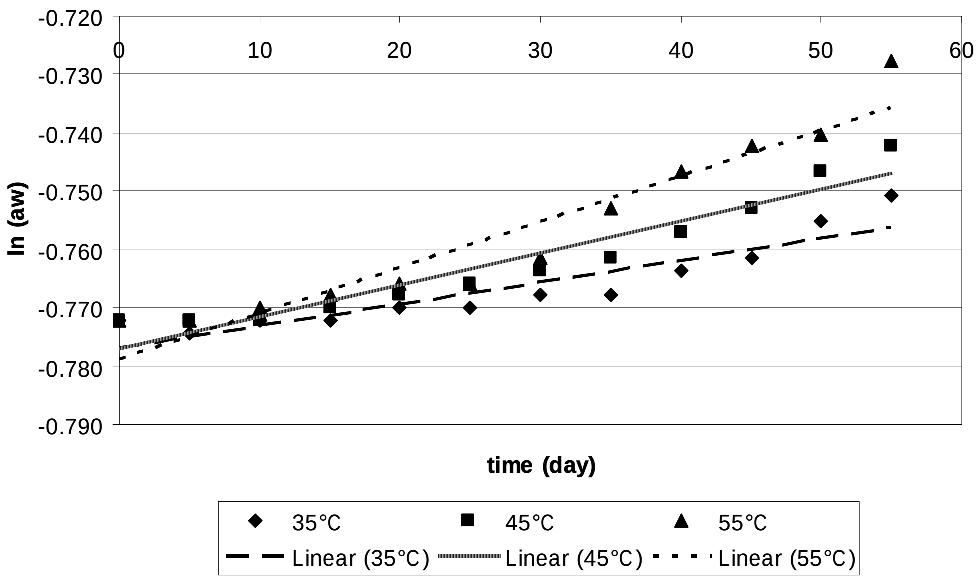

Figure A.1 Rate of a_w changes during storage of dried noodle

Table A.4 Equation of first-order kinetics of a_w of dried noodle during storage

Temperature (°C)	Equation	*k*	ln *k*	1/T (1/K)
35	y=0.0004x (R^2 = 0.8380)	0.0004	-7.824	0.003247
45	y=0.0005x (R^2 = 0.9181)	0.0005	-7.601	0.003145
55	y=0.0008x (R^2 = 0.9136)	0.0008	-7.131	0.003049

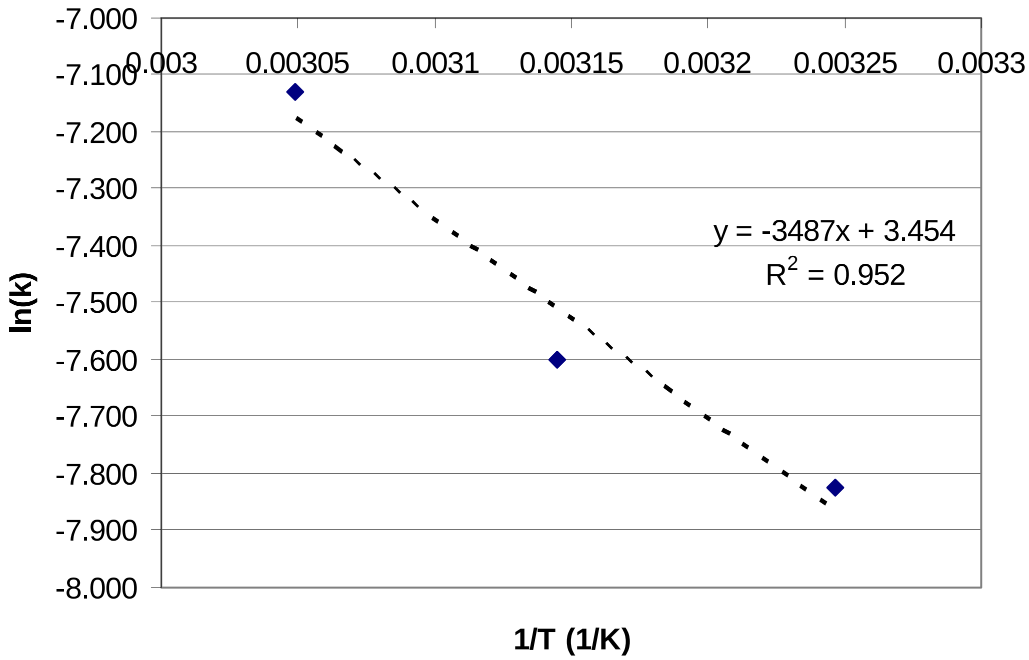

Figure A.2 Arrhenius plot for a_w changes during storage of dried noodle

From the equation shown in Figure A.2, the slope and y-axis intercept were calculated as the values of – (E_a/R) and A. From the slope, it was -3487 therefore, E_a was equal to 28990.92 J/mol and A was 31.6266. From the equation 2.3, *k* value at 30°C was 3.18×10^{-4} (day^{-1}) and Q_{10} value was calculated from equation 2.4.

According to the critical value of a_w from sorption isotherm, the shelf-life of dried noodle was estimated from equation 2.5 with *k* at 30°C. C_0 was 0.462 and C was 0.99.

$$\text{Shelf-life} = \frac{\ln (C_0/C)}{k}$$

$$= \frac{\ln (0.462/0.99)}{3.18\times10^{-4}}$$

$$= 2398 \quad \text{days}$$

APPENDIX B

Statistical Analysis

Table B.1 The ANOVA showing the interaction of frying temperature and frying time on the L*, a* and b* of rehydrated noodles at the 95% confidence interval

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	0.367[(a)]	8	0.041	3.756	0.038
Intercept	61827.689	1	61827.689	5691847	0.000
Temp	0.009	2	0.005	0.418	0.672
Time	0.059	2	0.030	2.727	0.125
Temp*Time	0.040	4	0.010	0.913	0.501
Error	0.087	8	0.011		
Total	61828.143	18			
Corrected Total	0.454	17			

[a] R Squared = 0.809 (Adjusted R Squared = 0.593)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	0.001[(a)]	8	8.89E-005	0.364	0.915
Intercept	607.145	1	607.145	2483775.3	0.000
Temp	1.11E-005	2	5.56E-006	0.023	0.978
Time	0.001	2	0.000	1.114	0.370
Temp*Time	0.000	4	3.89E-005	0.159	0.954
Error	0.002	9	0.000		
Total	607.148	18			
Corrected Total	0.003	17			

[a] R Squared = 0.823 (Adjusted R Squared = 0.752)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	0.001[(a)]	8	0.000	0.581	0.772
Intercept	9184.642	1	9184.642	48624576.471	0.000
Temp	0.000	2	0.000	0.581	0.772
Time	7.78E-oo5	2	3.89E-005	0.206	0.818
Temp*Time	0.000	4	0.000	0.647	0.643
Error	0.002	9	0.000		
Total	9184.645	18			
Corrected Total	0.003	17			

[a] R Squared = 0.875 (Adjusted R Squared = 0.813)

Table B.2 The ANOVA showing the interaction of frying temperature and frying time on the cooking loss of rehydrated noodles at the 95% confidence interval

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	0.082[(a)]	8	0.010	0.269	0.961
Intercept	84.760	1	84.760	2231.837	0.000
Temp	0.039	2	0.020	0.519	0.612
Time	0.014	2	0.007	0.185	0.834
Temp*Time	0.028	4	0.007	0.187	0.940
Error	0.342	9	0.038		
Total	85.184	18			
Corrected Total	0.424	17			

[a] R Squared = 0.944 (Adjusted R Squared = 0.890)

Table B.3 The ANOVA showing the interaction of frying temperature and frying time on the oil absorption of rehydrated noodles at the 95% confidence interval

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	84.241[(a)]	8	10.530	109.001	0.000
Intercept	3341.531	1	3341.531	34589.432	0.000
Temp	64.997	2	32.499	336.405	0.000
Time	18.017	2	9.009	98.251	0.000
Temp*Time	1.227	4	0.307	3.175	0.069
Error	0.869	9	0.097		
Total	3462.642	18			
Corrected Total	85.110	17			

[a] R Squared = 0.962 (Adjusted R Squared = 0.936)

Table B.4 The ANOVA showing the interaction of frying temperature and frying time on the rehydration rate of rehydrated noodles at the 95% confidence interval

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	311.545[(a)]	8	38.943	10.155	0.001
Intercept	10756604.227	1	10756604.227	2804891.8	0.000
Temp	255.868	2	127.934	33.360	0.000
Time	40.912	2	20.456	5.334	0.030
Temp*Time	14.765	4	3.691	0.963	0.473
Error	34.515	9	3.835		
Total	10756950.286	18			
Corrected Total	346.059	17			

[a] R Squared = 0.900 (Adjusted R Squared = 0.812)

Table B.5 The ANOVA showing the interaction of frying temperature and frying time on the tensile strength of rehydrated noodles at the 95% confidence interval

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.533[a]	8	0.192	50.710	0.000
Intercept	776.705	1	776.705	205598.494	0.000
Temp	1.259	2	0.630	166.687	0.000
Time	0.206	2	0.103	27.249	0.000
Temp*Time	0.067	4	0.017	4.453	0.029
Error	0.034	9	0.004		
Total	778.272	18			
Corrected Total	1.567	17			

[a] R Squared = 0.978 (Adjusted R Squared = 0.959)

APPENDIX C

Thai Industrial Standard 2005

Table C.1 Chemical and sanitation properties of instant noodles according to TIS (2005)

Properties	Level of regulation	
	Fried noodle	Dried noodle
Moisture content (%), must less than	8	12
Fat content (%), must less than	20	-
Total plate count (CFU), must less than	$1.0x10^3$	$1.0x10^3$
Yeast-Mold (CFU), must less than	10	10

APPENDIX D

Sensory test

This sensory test limited to select the appropriate formula and/or optimum condition in noodle preparation and rehydrated noodles.

Name ………………………………………………………..…… Gender ………..… Age ………

Date ……………………...

Please, test the samples with obtained code and make the preference scores

Where

1	=	dislike extremely
2	=	dislike strongly
3	=	dislike moderately
4	=	dislike slightly
5	=	average
6	=	like slightly
7	=	like moderately
8	=	like strongly
9	=	like extremely

Sample code / Attributes					
Color					
Odor					
Elasticity					
Overall preference					

Suggestion

____

____

VITA

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