Journal of Food Science and Agricultural Technology

International peer-reviewed scientific online journal

Published online: http://rs.mfu.ac.th/ojs/index.php/jfat

Original Research Article

Influence of long-term aging of rice paddy on qualities of fresh and dried rice noodle

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ARTICLE INFO

Article history:

Received 31 July 2018

Received in revised form 31 December 2018

Accepted 08 January 2019

Keywords:

Rice flour

Rice noodle

Aging

Dry milling

Cooking properties

ABSTRACT

Rice is a seasoning crop that can be grown 1 or 2 times a year so it must be stored throughout the year after harvest. Storage condition such as temperature, humidity, and time affects rice properties and qualities. This research investigated the effect of aged rice paddy (Chainat 1 cultivar) during various storage periods (1, 4, 12, 18, and 36 months) on physical and chemical properties of rice flour and influences on their corresponding fresh and dried noodle qualities. The results showed that whiteness index of rice flour decreased with increasing storage duration. However, storage duration did not affect on solubility and swelling power of rice flour until 18 months but decreased at 36 months. Aged rice flour possessed higher gelatinized temperature than fresh rice flour. Peak viscosity, final viscosity, trough viscosity, breakdown and setback decreased with storage. Whiteness index of fresh and dried rice noodles decreased significantly ($p \leq 0.05$) in fresh noodles and dried noodles. All dried noodles required 4 minutes to fully cooked. With the extended storage period, water uptake of corresponding dried rice noodle tended to decrease and cooking loss increased significantly ($p \leq 0.05$). Low water uptake ratio was related to texture of noodles which were hard and rough. Stickiness of dried noodle was significantly increased from 0.0074±0.0050 N/mm^2 (4 months) to 0.0283±0.0255 N/mm^2 (36 months). However, tensile strength decreased. The result showed that noodles produced from aged rice flour had less resistance to break than that of fresh rice noodles. Aged rice paddy resulted in inferior qualities of rice noodles such as color, cooking properties, and textural properties. More than 18 months storage of rice paddy was not recommended for making noodle. Milled rice flour from long-term aged rice had certain changes in properties and influenced the consequent rice noodle qualities.

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Published by School of Agro-Industry, Mae Fah Luang University

ISSN: 2408-1736

INTRODUCTION

Rice is staple food in Thailand and more than half of the world. Rice can be stored for long time due to low moisture content, but deterioration of rice can occur. Storage condition such as temperature, humidity, moisture content of paddy rice and time affects the qualities of rice (Perdon et al., 1997). Physical and chemical properties of rice can be changed during storage, which is also known as aging of rice (Perdon et al., 1997). Aging of rice is elaborated that involves physical, chemical and biological changes (Zhou et al., 2002). Bhattacharya (2011) reported that characteristics of rice change during storage such as color and appearance. Aged rice has darker color (brownish) while fresh rice is shining and translucent. Temperature and humidity are main factors that cause musty smell because of volatile compounds changing such as lipid, amino acid, and vitamin. In term of cooking and eating properties, fresh rice does not expand but it is rather sticky and soft inside a rice cooker. When stored for a long time, the expansion volume of aged rice is better than fresh rice. Moreover, it is not stick together when cooked. Gel of freshly harvest rice has limitation in gel qualities because starch granules are partially swell. Therefore, aged rice is typically used in rice noodle production because starch granules have an ability to swell better (Bemiller, 1997). Thai manufacturers normally store rice for 6 months before making it into flour. (Hormdok and Noomhorm, 2007) Quality improvement of rice flour is important to rice noodle qualities (Bemiller, 1997). Aged rice flour has higher gel hardness than fresh rice flour (Hormdok and Noomhorm, 2007). Cooking and eating properties of aged rice are affected by starch, protein and lipid which are the main component of rice grain. Amount of starch, protein and lipid was not significantly differed, while structure of rice grain changes during aging of rice. As a consequence, pasting properties, gel properties, flavor and texture of cooked rice change. Swelling, gelatinization and retrogradation of rice flour could indicate cooking qualities and rheological properties of rice (Zhou et al., 2002). Many researches have been conducted to find alternative methodologies to obtain aged rice. Jaisut et al. (2009) studied accelerate aging of jasmine brown rice by using high-temperature fluidization technique. According to Hormdok and Noomhorm (2007), both annealing and heat moisture treatments resulted in increased gel hardness with increasing temperature and time. Treated rice starch could produce aged rice with time-saving and it is possible to manufacture at economical level.

Cooked grains and products from flour and starch are mostly consumed as part of a daily life. Asian people regularly eat rice, noodle, and steam bread. Noodle is the staple food in Asian countries for a long time. There are many types of noodle in various raw materials, formulas, and shapes. Rice, wheat, buckwheat, potato, and sweet potato can be prepared for noodle (Fu, 2008). Noodle made of rice and buckwheat is gluten-free, therefore gelatinization of starch during cooking helps binding structure together. Traditional rice noodle is made from long-grain rice (more than 22% amylose content). Noodle made by high amylose content rice has bright color and low bulk density because of limited swelling capacity. Preparation of rice noodle particularly follows these two fashions, which are extrusion for vermicelli and sheeting batter for sheet and flat noodle. Sheeted fresh rice noodle is popular in Southeast Asia, China, and Japan. Gelatinization of starch granule happens during steaming. The noodle can be cut into strips (1 cm wide), dried for dried noodle, or sold as sheets (Fu, 2008).

Thailand's Rice Pledging policy was conducted for rice price guarantee. The main objective of this policy was to delay rice sales until rice price in the market rises to reasonable price. At the beginning of harvest season rice price drops and in the end of season the price is usually higher than at the beginning (Sukkumnoed, 2017). However, deterioration of paddy rice occurs during long-term storage at warehouses without controlled temperature and humidity. Quality of rice was decreased when time passed (Namchaidee, 2017). Aging of rice leads to the changes on cooking and eating qualities of rice (Gujral and Kumar, 2003; Bhattacharya, 2011). Change in properties of rice flour affected texture of rice noodles that was considered as the most important attribute for consumer acceptance (Wang et al., 2018). The objectives of this research were to determine physical and chemical properties of rice flour made from rice paddy stored at different periods (1, 4, 12, 18, and 36 months) and to investigate the long-term aging effect on qualities of fresh and dried noodle.

MATERIALS AND METHODS

Storage of paddy rice and preparation of flour

Paddy rice Chainat 1 cultivar (obtained from Rice Department, Ministry of Agriculture and Cooperatives, Thailand) was harvested and stored in a warehouse for natural aging without temperature and humidity control. Storage duration was 1, 4, 12, 18, and 36 months. Paddy rice was taken out of the warehouse at different storage periods and delivered to Kasetsart University. Rice paddy was stored at -18°C before further processed. Prior to milling, the paddy was thaw at 10°C for 24 h and then kept at room temperature overnight. Rice paddy was dehusked and polished. Dry milling was used in this study by hammer mill. Rice flour was then passed through a 100-mesh sieve. It was kept in plastic bag and stored at 4°C until analyses. When analyzed, the flour was tempered to room temperature.

Influence of storage duration on selected properties of rice flour

Moisture content of rice flour was analyzed by the method of AOAC (2000). Color of rice flour was measured on L*, a* and b* by Hunter Lab Model Miniscan XE. Whiteness index (WI) was calculated by equation 1. Pasting properties of rice flour were studied by Rapid Visco Analyzer (RVA 4500, Perten Instruments, Sweden). Rice starch (3 g) was mixed with 25 ml distilled water in RVA can. Slurry was stirred at 50°C for 2 min. After that, it was heated to 95°C (7.5°C/ min) and held for 2 min. Lastly, the slurry was cooled to 50°C (7.5°C/ min) and held for 4 min (Lumdubwong and Seib, 2000). Pasting temperature (PT), peak viscosity (PV), trough viscosity, final viscosity (FV), breakdown (BD), and setback (SB) were observed. Solubility and swelling power were determined according to method described by Phimolsiripol (2002). Briefly, rice flour (0.5 g) was mixed with distilled water in centrifuge tubes, heated in a shaking water bath at 85°C for 30 min, and cooled to room temperature. Then, it was centrifuged at 2,200 x *g* for 20 min and supernatant was removed. Sediment was weighed to determine solubility of rice flour (equation 2) and supernatant was dried at 105°C to analyze for swelling power (equation 3).

$$\text{Whiteness index} = 100-[(100-L^*)^2-(a^*)^2-(b^*)^2]^{1/2} \quad (1)$$

$$\text{Solubility (\%)}=(\text{weight of dried solid/weight of dried sample})\times 100 \quad (2)$$

$$\text{Swelling power}=[\text{weight of sediment/weight of dried sample} -(100-\text{solubility})]\times 100 \quad (3)$$

Preparation of fresh and dried rice noodle

Fresh noodles were prepared by mixing rice flour with distilled water in a ratio of 40 to 60. The slurry was stirred by magnetic stirrer for 3 hours. Rice batter was poured on the tray for sheeting and steamed in a temperature-controlled water bath (Memmert, Germany) for 3 minutes. Sheets were cut into strands of 1.5 cm width. For dried noodles, fresh sheeted noodle was dried at 60°C for 20 minutes in a tray dryer then rested the sheets in a plastic box at 25°C and 85% relative humidity for 24 hours. After that, sheets were cut into strands and further dried at 45°C for 2 hours. Quality determination of fresh and dried noodle was investigated and compared from all aged rice flour samples.

Changes on qualities of rice noodle

Moisture content of rice noodle was analyzed by the AOAC (2000) method. Color of rice noodle was measured for L*, a* and b* and WI was calculated by equation 1. For determination of cooking qualities, dried noodle was cut into short pieces (5 cm length). The dried noodle (10 g) was cooked in boiling water. The sample was taken out every 2 minutes, then placed in cold water and drained for determination of cooking time. Cooking time of dried noodle was determined by moisture content of cooked noodle that was equal to fresh noodle (about 60%). Water uptake was observed by an increased weight of cooked noodle, compared to uncooked noodle. Cooking loss was analyzed by drying off the cooking water at 105°C until constant weight. Since texture is one of the main attributes affecting consumer acceptance, the fresh and dried noodle samples after cooking at specific cooking times were immediately kept in a plastics box until texture analyses. Texture analyzer (TA. XT. Plus, Stable Micro Systems Ltd., United Kingdom) was used to determine the texture of rice noodle in terms of firmness, stickiness and tensile strength. Cutting test was used to analyze firmness. Noodle was cut into 1.5x4.5 cm. and arranged into a row with 3 consecutive pieces. A/LKB probe was used at test speed of 0.2 mm/s. For stickiness, rice sheets were cut into 7x7 cm. and compressed by HDP/PFS probe. Adhesion test was used at test speed of 0.5 mm/s. For testing tensile strength, noodle strand was wrapped around A/SPR probe. Maximum force that break noodle indicated the sample resistance at test speed of 5 mm/s.

Statistical analysis

The data were presented by mean values ± standard deviation. Analysis of Variance (ANOVA) was performed. If statistically significant at the 95% confidence level ($p \le 0.05$) was found, the mean difference would be analyzed with Duncan's new multiple range test (DMRT) using SPSS 12.0 (version 12.0; SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Change on physical and chemical properties of rice flour during storage

Moisture content of rice flour ranged from 10.68±0.74 to 11.86±0.18%. The color analysis showed that lightness (L*) value decreased significantly ($p \le 0.05$) with increasing storage duration. Similar trend was found with whiteness index. The maximum value was 91.00±0.15 for 1 month and the lowest values were 90.26±0.28 for 12 months as well as 90.38±0.34 for 36 months rice flour (Table 1). When rice flour was heated to gelatinization temperature and had adequate water, starch granules adsorb water and swell. Some part leaches into solution that indicates solubility of rice flour (Hormdok and Noomhorm, 2007). Solubility and swelling power significantly increased up until 18 months, then reduced at 36 months ($p \le 0.05$). Rice flour that stored for 18 months had the highest solubility at 3.43±0.18 and the highest swelling power at 9.66±0.04, respectively (Table 1). Hormdok and Noomhorm (2007) reported that solubility and swelling power were slightly reduced ($p > 0.05$) following aging of rice. Solubility and swelling power of the rice starch had positive relation with cooking quality of rice noodle ($p < 0.01$) (Wang et al., 2018). Noodle prepared from high swelling power has softer texture than low swelling power. Properties of rice flour are important to noodle quality. Dry-milled rice flour had higher protein and ash content but lower carbohydrate than wet-milled rice flour. Wet-milled rice flour had lower impurities due to the presence of soaking and washing steps (Leewatchararongjaroen and Anuntagool, 2016). Protein content had positive relationship with firmness and was sometimes negative with elasticity (Fu, 2008).

When a mixture of flour and water is heated, starch granules are swollen leading to increasing viscosity that is called gelatinization. Continuous stirring at high temperature causes a decrease in viscosity of paste. Since swollen starch granules are broken, structure of starch granules is destroyed. While paste is cooled, amylose will rearrange causing an increase in viscosity that is called retrogradation (Naiwikun, 2007). Aging of rice caused some changes on pasting properties of rice flour. The result showed that pasting temperature increased after 36 months storage while peak viscosity, trough viscosity, final viscosity, breakdown and setback tended to decrease (Table 2). Characteristic of RVA graph could indicate the quality of noodles (Fu, 2008; Hormdok and Noomhorm, 2007). High viscosity paste and swelling starch granules could be produced soft, smooth and elastic noodle (Fu, 2008). Qualities of rice noodle were related to properties of rice starch. Lower solubility, swelling power and RVA viscosity of rice starch was more suitable to produce rice starch noodle. Setback value was positively correlated with cooking quality of rice starch noodle ($p < 0.01$) (Wang et al., 2018).

Effect of aged rice on qualities of rice noodles

Table 3 shows moisture content of fresh noodle ranging from 56.22±0.20 to 58.76±2.02%. Normally, fresh noodle has 32-40% of moisture content, therefore; the noodle has short shelf life (one day or more) depending on storage condition and packaging. Firm, elastic and chewy are preferable characteristics of noodle. Color and appearance are key factors that used to judge production and quality of raw materials (Fu, 2008). The color analysis showed that L* value decreased and b* value increased significantly. Furthermore, whiteness index of noodle significantly decreased ($p \le 0.05$) when the storage time of rice paddy increased. The 1 and 4 months fresh rice noodle had the highest whiteness index of 74.74±0.55 and 75.59±1.35, respectively. Fresh noodle from 36 months rice flour had the lowest whiteness index of 69.33±0.42.

Final moisture content of dried noodle is commonly less than 14%, therefore; the noodle has long shelf life for 1-2 years. Dried noodle needs longer time for cooking than that of fresh noodle. Cooking for a long time in boiling water made the noodle soft and sticky (Fu, 2008). Results showed that moisture content of dried noodles was between 9.18±0.69 and 11.37±0.69%. The color analysis of dried noodles presented similar trends as fresh noodles. When the rice flour milled from long storage time paddy, L* value and whiteness index of rice noodle significantly decreased ($p \le 0.05$). Dried noodle prepared from 1, 4 and 12 months rice flour had the highest whiteness index values as the following 63.42±3.72, 63.07±1.30 and 63.82±2.41, while 36 months dried rice noodle had the lowest whiteness index of 56.54±2.33 (Table 3). Good quality noodle should be in bright shade and color changes slowly when storage (Fu, 2008).

Table 1. Moisture content, color parameters, solubility and swelling power of rice flour milled from rice paddy at different storage duration

Storage duration	Moisture content (%)	Color parameters			Whiteness Index	Solubility (%)	Swelling power
		L*	a*	b*			
1 month	10.70±0.69^{d}	93.17±0.15^{a}	-0.50±0.05^{b}	5.84±0.12^{b}	91.00±0.15^{a}	2.62±0.22^{b}	8.83±0.27^{b}
4 months	11.21±0.30^{c}	93.01±0.58^{ab}	-0.52±0.06^{bc}	6.37±0.10^{a}	90.52±0.43^{bc}	2.60±0.17^{b}	8.62±0.09^{bc}
12 months	11.55±0.30^{b}	92.66±0.31^{bc}	-0.57±0.08^{c}	6.37±0.16^{a}	90.26±0.28^{c}	2.61±0.13^{b}	8.67±0.23^{bc}
18 months	10.68±0.74^{d}	92.39±0.69^{c}	-0.46±0.09^{ab}	5.11±0.17^{d}	90.81±0.50^{ab}	3.43±0.18^{a}	9.66±0.04^{a}
36 months	11.86±0.18^{a}	92.26±0.40^{c}	-0.43±0.07^{a}	5.70±0.16^{c}	90.38±0.34^{c}	2.20±0.24^{c}	8.37±0.20^{bc}

Lightness (L*); redness (a*); yellowness (b*)

$^{a-d}$ Means in the same column with different letters expressed significant differences ($p \leq 0.05$) among samples

Dried noodle was cooked in boiling water to determine cooking time. The noodle was taken out every 2 minutes to observe moisture content. The result showed that moisture content of noodles increased during cooking. At 4 minutes, moisture content of cooked rice noodle was nearly 60%, which was moisture content of fresh noodles, in all samples (Figure 1). While water uptake significantly decreased, the amount of cooking loss increased significantly ($p \leq 0.05$) with increasing storage time (Table 4). Cooking loss and water uptake are two important parameters that can predict quality of noodle. Short cooking time and low solid loss are desired attributes of noodles. (Hormdok and Noomhorm, 2007)

Texture of rice noodle is a main characteristic that affects consumer acceptance (Li and Vasanthan, 2003). Firmness of fresh rice noodle was the highest in noodles produced from 12 months rice flour, which was 0.3214±0.0615 N/mm^2. In term of dried noodle, the highest firmness was obtained from the 4 and 36 months noodle, which were 0.3230±0.0504 and 0.3000±0.0609 N/mm2, respectively. Stickiness of the noodle increased in fresh noodle, while decreased in dried noodle when storage time increased. Strength and elasticity of noodle while cooking were tested by tensile strength, which represent the quality of rice noodle that resistance to break. These characteristics are desirable for production and packing (Bhattacharya et al., 1999).

fresh rice noodle had softer texture and more adhesive than aged rice noodle. The authors also reported that fresh rice noodle (10.26±1.19 g) had lower tensile strength and required shorter time to break than aged rice noodles (12.53±1.13 g) but the results were not significantly different ($p>0.05$).

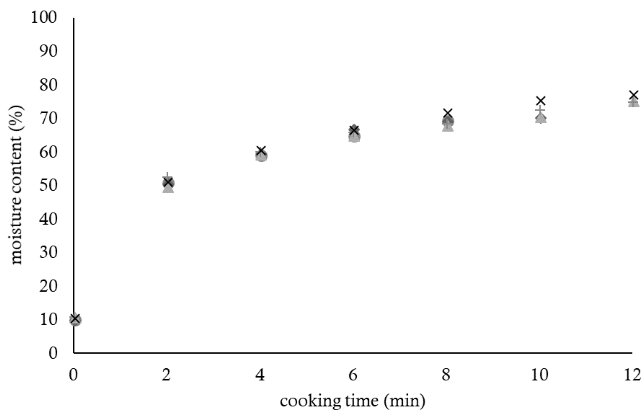

Figure 1. Changes in moisture content (%) of dried noodles during cooking. 1 month (●); 4 months (♦); 12 months (▲); 18 months (+); 36 months (×).

Table 2. Pasting properties of rice flour milled from rice paddy at different storage duration

Storage duration	Pasting temperature (°C)	Peak viscosity (RVU)	Trough viscosity (RVU)	Final viscosity (RVU)	Breakdown (RVU)	Setback (RVU)
1 month	80.73±0.62^{b}	433.8±5.7^{a}	287.9±7.5^{a}	592.7±6.8^{a}	145.97±13.15^{a}	304.8±5.2^{a}
4 months	80.05±1.28^{b}	417.4±5.0^{b}	274.6±4.7^{b}	589.3±7.6^{a}	142.83±1.62^{a}	314.7±5.9^{a}
12 months	80.60±0.30^{b}	313.6±7.6^{c}	220.7±4.7^{c}	503.4±7.0^{b}	92.94±10.08^{b}	282.8±9.7^{b}
18 months	80.30±0.26^{b}	306.6±10.5^{c}	206.4±5.7^{d}	491.9±18.9^{b}	100.17±6.09^{b}	285.5±16.5^{b}
36 months	88.22±0.55^{a}	284.2±5.4^{d}	209.4±2.8^{d}	471.4±6.0^{c}	74.83±8.18^{c}	262.0±8.1^{c}

$^{a-d}$ Means in the same column with different letters expressed significant differences ($p \leq 0.05$) among samples

Tensile strength of fresh and dried noodle from 4 months rice flour was the lowest as 0.0387±0.0063 and 0.0094±0.0027 N/mm^{2,} respectively. When compared texture of fresh noodle with dried noodle, firmness of fresh noodle was higher than dried noodle except for samples from 4 and 36 months. Stickiness and tensile strength of fresh noodle were higher than those of dried noodle (Table 5). Previous study by Hormdok and Noomhorm (2007) showed that

Table 3. Moisture content and color parameters of fresh and dried noodle made from different aged rice

Storage duration	Moisture content (%) ^{ns}	Color parameters			Whiteness Index
		L*	a*	b*	
Fresh noodles					
1 month	58.76±2.02	76.36±0.41^{b}	-1.79±0.13^{b}	8.69±0.67^{c}	74.74±0.55^{ab}
4 months	58.73±3.03	77.94±1.41^{a}	-1.95±0.30^{c}	10.24±0.24^{b}	75.59±1.35^{a}
12 months	58.33±2.76	75.96±1.30^{b}	-1.80±0.27^{b}	10.82±0.42^{a}	73.56±1.16^{c}
18 months	58.20±3.58	75.57±3.66^{b}	-1.69±0.33^{ab}	8.44±0.41^{d}	74.08±3.59^{bc}
36 months	56.22±0.20	71.40±0.46^{c}	-1.58±0.09^{a}	10.96±0.20^{a}	69.33±0.42^{d}
Storage duration	Moisture content (%)	Color parameters			Whiteness Index
		L*	a*	b*	
Dried noodles					
1 month	10.50±0.83^{A}	65.51±4.05^{A}	-1.91±0.53^{C}	11.44±3.43^{C}	63.42±3.72^{A}
4 months	9.18±0.69^{B}	65.06±1.93^{A}	-1.79±0.39^{C}	11.35±2.99^{C}	63.07±1.30^{A}
12 months	11.37±0.69^{A}	66.54±2.75^{A}	-1.81±0.47^{C}	13.42±2.04^{B}	63.82±2.41^{A}
18 months	10.99±0.34^{A}	62.14±2.86^{B}	-1.54±0.26^{B}	9.64±2.51^{D}	60.82±2.86^{B}
36 months	10.82±1.58^{A}	59.57±3.62^{C}	-0.48±0.73^{A}	15.28±3.52^{A}	56.54±2.33^{D}

Lightness (L*); redness (a*); yellowness (b*)

$^{a-d}$ Means in the same column with different letters expressed significant differences ($p≤0.05$) among fresh noodle samples

$^{A-D}$ Means in the same column with different letters expressed significant differences ($p≤0.05$) among dried noodle samples

^{ns} Means in the same column were not significantly different ($p>0.05$)

Table 4. Water absorption and cooking loss of dried noodles

Storage duration	Water absorption (%)	Cooking loss (%)
1 month	149.40±2.02^{a}	3.87±0.44^{c}
4 months	148.37±3.15^{a}	4.08±0.33^{c}
12 months	148.14±3.46^{a}	4.87±0.40^{b}
18 months	150.62±5.80^{a}	4.91±0.48^{b}
36 months	135.67±2.28^{b}	5.34±0.38^{a}

$^{a-c}$ Means in the same column with different letters expressed significant differences ($p≤0.05$) among samples

CONCLUSIONS

Physical and chemical properties of rice changed during storage. This research found that whiteness index of rice flour was decreased. Solubility and swell power did not affect by aging until 18 months but decreased at 36 months. Aged rice flour had higher pasting temperature but lower overall paste viscosities. Dried noodle needed 4 minutes to re-cook. Water uptake decreased, while solid loss increased with storage. The flour properties influenced by paddy's storage duration affected textural properties of rice noodle. Rice paddy stored not more than 18 months was suitable for preparation of rice noodle.

Table 5. Textural properties of fresh and dried noodles

Storage duration	Fresh noodles		
	Firmness (N/mm^2)	Stickiness (N/mm^2)	Tensile strength (N/mm^2)
1 month	0.2850±0.0514^{b}	0.0416±0.0286^{a}	0.0732±0.0067^{a}
4 months	0.2451±0.0128^{c}	0.0232±0.0206^{b}	0.0387±0.0063^{e}
12 months	0.3214±0.0615^{a}	0.0315±0.0207^{ab}	0.0454±0.0037^{d}
18 months	0.2831±0.0224^{b}	0.0196±0.0174^{b}	0.0553±0.0040^{c}
36 months	0.2713±0.0073^{bc}	0.0277±0.0261^{ab}	0.0670±0.0039^{b}
Storage duration	Dried noodles		
	Firmness (N/mm^2)	Stickiness (N/mm^2)	Tensile strength (N/mm^2)
1 month	0.2422±0.0218^{C}	0.0154±0.0034^{B}	0.0119±0.0033^{C}
4 months	0.3230±0.0504^{A}	0.0074±0.0050^{B}	0.0094±0.0027^{C}
12 months	0.2737±0.0419^{B}	0.0087±0.0023^{B}	0.0214±0.0041^{B}
18 months	0.2146±0.0203^{D}	0.0074±0.0042^{B}	0.0230±0.0114^{B}
36 months	0.3000±0.0609^{AB}	0.0283±0.0255^{A}	0.0545±0.0105^{A}

$^{a-d}$ Means in the same column with different letters expressed significant differences ($p≤0.05$) among fresh noodle samples

$^{A-D}$ Means in the same column with different letters expressed significant differences ($p≤0.05$) among dried noodle samples

ACKNOWLEDGEMENTS

This research was financially supported by Kasetsart University Research and Development Institute (KURDI), Kasetsart University, Thailand.

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