Kasetsart J. (Nat. Sci.) 40 (Suppl.) : 144 - 153 (2006)

Characterization of Pregelatinized and Heat Moisture Treated Rice Flours

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ABSTRACT

Three rice varieties; Chai Nat 1, Khao Dawk Mali 105 and RD 6 (28.72, 16.46 and 5.54% amylose content, respectively) were modified by pregelatinization (pregel) and heat moisture treatment (HMT) method. Pregelatinized flour was prepared by passing 40% rice flour solution through drum dryer, which conditions were set at 20 lb/inch^2 of steam pressure, 0.25 rpm of drum dryer speed and 0.01 inches of drum dryer gap. The modification of rice flour by HMT method was prepared by adjusting rice flour initial moisture to 30% and then incubating at 100∂C for 16 hr. When compared the pasting properties between native and pregel flours, the results were significantly different (p£0.05). For all three pregel rice flours, they show that the pasting temperature (49.90-51.47 ∂C), peak viscosity (198.41-281.42 RVU), breakdown (48.20-175.67 RVU) and final viscosity (156.75-306.83 RVU) decreased significantly. In addition, the degrees of syneresis or freeze thaw stability of three pregel flours (1.06-47.65 %) increased (p£0.05) as compared with the native flours (0.12-39.93 %). The pasting properties of native and three HMT rice flours were observed and the results were significantly different (p£0.05). For all three HMT rice flours, they show that the pasting temperature (80.18-88.64 ∂C) increased significantly; while peak viscosity (95.59-167.17 RVU), breakdown (12.50-22 RVU) and final viscosity (101.82-259.17 RVU) decreased siginificantly (p£0.05). In addition, swelling power and solubility of HMT flours decreased (p£0.05); whereas the freeze-thaw stability (1.06-37.36 %) increased (p£0.05).

Key words: pregelatinization, heat moisture treatment, pregel flour, heat moisture treated flour, rice noodles

INTRODUCTION

Wheat flour noodles, such as alkaline noodles and white salted noodles, are important diets for many Asian countries (Ross *et al.*, 1997; Hatcher *et al.*, 1999; Inglett *et al.*, 2005). One of the key factors to achieve the desired texture of cooked noodles is protein (gluten) in wheat flour (Ross *et al.*, 1997). Gluten in wheat gives firm and elastic texture; however, it could harm consumers with Celiac disease (Naivikul, 2004). Therefore, it is important to find other sources to replace wheat flour to make and yet maintain good quality noodles.

Rice flour is one of the most appropriate cereal flours for consumers with Celiac disease since there is no gluten in it (Yoenyongbuddhagal and Noomhorm, 2002). Due to lack of gluten, the

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Received date : 18/04/05 Accepted date : 30/06/05

quality of rice noodles depends mostly on starch properties (Yoenyongbuddhagal and Noomhorm, 2002), which serve as the structural network of the noodle products. Li and Luh (1980) found that rice varieties with high amylose, low gelatinization temperature and hard gel consistency were suited to make noodles. However, it is still crucial to use modified rice flour to replace wheat in alkaline noodles in order to get similar texture quality.

Pregelatinization is one of the physical methods used to modify starch by using drum dryer, spray dryer or extruder (Colonna *et al.*, 1984). This modification method affects physicochemical and functional properties of flour significantly (Lai, 2001). Due to starch granule disruption, pregelatinized flour can absorb water and increase viscosity immediately even with cold water (Glicksman, 1969; Doublier *et al.*, 1986). Therefore, it can create binder properties to obtain uniform matrix instantly when added into water (Bhattacharya *et al*., 1999). In addition, the degree of pregelatinization of flour is a key to get desirable noodle texture (Bhattacharya *et al*., 1999). Another physical modification method is heat moisture treatment (HMT), which could change physicochemical property of flour without disruption of starch granule (Stute, 1992; Jacobs and Delcour, 1998). HMT flour can be prepared by adjusting initial flour moisture content (18-27 %) and then incubating at high temperature (higher than its gelatinization temperature) for a certain period of times (Kulp and Lorenz, 1981; Lim *et al.*, 2002). It was shown in several researches that the combination of heat and moisture could yield a more compact, crystalline structure in starch granules (Osman, 1967). HMT flour has shown a decrease in swelling power, an increase of gelatinization temperature and a lower of the peak viscosity (Osman, 1967; Eerlingen *et al.*, 1997; Jacobs and Delcour, 1998). After heat moisture treatment, flour becomes more stable to freezing and thawing cycles resulting from inter- and intra-molecular hydrogen bonding within starch granules (Hoover and Manuel, 1996). In this research, our aims were to investigate rice flour properties after modification by pregelatinization and heat moisture treatment. In addition, modified rice flours were studied for their freeze-thaw stability. The information from this research can be applied to frozen rice noodle products and could be used to improve product quality.

MATERIALS AND METHODS

Materials

Three rice varieties: Chai Nat 1 (CN1), Khao Dawk Mali 105 (KDM105) and RD 6 (RD6) were obtained from Karasin Rungruang rice mill and wheat flour (all-purposed) was attained from local market.

Rice flour was prepared by using wet-milling method (Gullapanayutt, 2004). Polished rice grains were steeped in tap water for 4 hours, before milling. Rice flour cake was separated from slurry by centrifugation, and then it was dried in tray dryer at 45±5∂C. Flour was milled 2 times by electric miller and passed through 100-mesh sieve. Samples were kept in polyethylene bag, sealed and stored at room temperature until used. Three rice flours were then analyzed for moisture, protein and fat content by using AOAC method (1990); while their amylose contents were determined by using Juliano method (1971). In addition, three rice flours were modified by pregelatinization and heat moisture treatment.

Pregelatinized flour preparation

Pregelatinized flour (pregel flour) was prepared by passing flour solution containing 40% solid through drum dryer of which the conditions were set at 20 lb/inch^2 of steam pressure, 0.25 rpm of drum speed and 0.01 inch of drum dryer gap. Then rice flour flakes were dried by using tray dryer at 45±5∂C. Pregel flour was milled 2 times by electric miller and passed through 100-mesh sieve. Samples were kept in polyethylene bag, sealed and stored at room temperature.

Heat moisture treated flour preparation

Heat moisture treated rice flour (HMT flour) was prepared by adjusting initial moisture of rice flours to 30%. Consequently, rice flours were heated in a tray dryer at 100∂C for 16 hours. Samples were allowed to cool down and got uniform moisture content (within the range of 10% by wt) before milling by electric miller and passing through 100-mesh sieve. Samples were kept in polyethylene bag, sealed and stored at room temperature.

Swelling and solubility properties

Flour swelling power was determined by mixing flour (0.5 g) with water (15 ml), then heating at 55, 65, 75 and 85∂for 30 min. The samples were then cooled and centrifuged at 2,200 rpm for 15 min (Schoch, 1964). The supernatants were carefully removed from the sediments. The swelling power (SP) was the ratio of the weight of the wet sediment to the initial weight of dried flour. The supernatants were dried overnight at 130∂C and weighed. Solubility was the ratio of the weight of the dried supernatant to the initial weight of the dried flour. All measurements were duplicated.

Pasting Properties

The pasting properties of the rice flour samples were studied by using Rapid Visco Analyser (RVA) model 3D (Newport Scientific, Warriewood, Australia). Flour was weighed (3g) directly in the aluminum RVA sample canister, and distilled water was added to a total constant sample weight of 28g. A programmed heating and cooling cycle was used where the samples were held at 50∂C for 1 min, heated to 95∂C in 7.5 min, held at 95∂C for 5 min before cooling to 50∂C in 7.5 min, and holding at 50∂C for 1 min. Peak viscosity (PV), time from onset of pasting to peak viscosity (P_{time}), holding strength or hot paste viscosity, at the end of holding at 95∂C (HPV), breakdown (BD) (PV-HPV), final viscosity at 50∂C or cold paste viscosity (CPV), and setback (SB) (CPV-PV) were recorded. All measurements were replicated.

Freeze-thaw stability of flour

Aqueous suspensions of the flours (5% w/v) were rapidly heated to 95∂C under constant agitation to prevent granule sedimentation. These suspensions were maintained at 95∂C for 30 min and stored at (-)18∂C for 24 hours. Five freeze-thaw cycles were performed. To measure freeze-thaw stability, gels were thawed at 35∂C for 1.5 hours and then refrozen at -18∂C. The excluded water was determined after centrifuging the tubes at 8,000 rpm for 10 min (Yuan and Thomson, 1998).

RESULTS AND DISCUSSIONS

Chemical composition

Four different flour varieties; Chai Nat 1 (CN1), Khao Dawk Mali 105 (KDM105), RD 6 (RD6) and all-purposed wheat flour (WF) were analysed for their chemical compositions (Table 1).It has shown that the protein contents of all flours were significantly different. The protein content in WF (10.62%) was higher than rice flours (CN1, RD6 and KDM105, 7.62, 6.78 and 6.21% respectively). In cereal, this composition is a key to achieve desirable product quality as well as nutrition value (Yada, 2000). Another component is lipid, which is varied not only the amount but also chemical class in each cereal. Lipid is located in various parts of each grain, therefore, method and level of milling could affect lipid content drastically (Hoseney, 1998). Rice contains about 3 % lipids locating mostly in the peripheral parts of the grain. After milling, rice contains only 0.3-0.5% lipids (Hoseney, 1998). CN1 (0.56%) and RD6 (0.52%) had lower lipid content than KDM 105 (0.92%) and WF (0.86%) (Table 1). Even if the lipid content in flours was low, it could affect flour properties dramatically such as swelling and pasting properties (Eliasson and Gudmundsson, 1996).

In Table 1, it has shown that the amylose contents of flours were significantly different. CN1 contained the highest among all flours (28.59 %) and followed by WF (26.31%), KDM105 (16.46%) and RD6 (5.54%). In order to use rice flour to substitute wheat flour in noodle making, the amylose content is critical. Due to lower protein content in rice flour, the amylose is an important factor to achieve desirable structure in products (Naivikul, 2004). The moisture content of rice flours was below 13%, which is good for maintaining flour quality (Naivikul, 2004).

Swelling and solubility properties

Starch is insoluble in water at room temperature; however if the temperature increased, starch could be swollen up to a certain degree (Table 2). As shown, the degree of swelling of various flours was significantly different. It was found that the swelling power of all native rice flours was higher than those of WF. Furthermore, when compared among native rice flours with different varieties, the swelling power could be sorted as follow: CN1 (2.31-7.95 g/g) < KDM105 (2.54-8.01 g/g) < RD6 (2.98-16.23 g/g). The differences of these values were correlated to the ratio of amylose to amylopectin (amylose content) (Leach, 1965). RD6 with the lowest amylose content had the highest swelling power due to the fact that the amylose is known to inhibit granule swelling (Tester and Morrison, 1990).

After heat moisture treatment, the swelling powers were decreased as comparing with native rice flour at all temperatures because the additional interactions might be occurred during treatment such as amylose-amylose and amylose-amylopectin chains (Gunaratne and Hoover, 2002). The swelling powers after heat-moisture treatment were in order: RD6HMT (4.42-6.74 g/g)> KDM105HMT (3.12-6.24 g/g) > CN1HMT (2.95-5.84 g/g) at 65 - 85 ^{o}C. However, the swelling powers were in different order at 55^{o}C: RD6HMT (2.01 g/g) and CN1HMT (1.98

Table 1 Chemical composition of flours.

Flour type	Composition (%)^{a}				
	Moisture	Protein	Lipid	Ash	Amylose content
WF	12.61^{b}	10.62^{a}	0.86^{b}	0.25^{b}	26.31^{b}
CN1	12.45^{c}	7.62^{b}	0.56^{c}	0.48^{a}	28.59^{a}
KDM105	12.58^{b}	6.21^{d}	0.92^{a}	0.54^{a}	16.46^{c}
RD6	12.93^{a}	6.78^{c}	0.52^{c}	0.17^{b}	5.54^{d}

[a] All data reported on dry basis. Means within a column with different superscripts are significantly different (p£0.05)

Table 2 Swelling power of wheat, native and modified rice flours.

Flour type	Swelling Power (g/g)^{a}			
	55∂C	65∂C	75∂C	85∂C
WF	2.23^{d}	3.01^{f}	4.98^{e}	6.47^{e}
CN1	2.31^{c}	3.65^{d}	5.14^{d}	7.95^{c}
CN1HMT	1.98^{e}	2.95^{g}	4.45^{f}	5.84^{g}
KDM105	2.54^{b}	3.78^{c}	5.58^{b}	8.01^{b}
KDM105HMT	1.56^{f}	3.12^{e}	5.01^{e}	6.24^{f}
RD6	2.98^{a}	5.12^{a}	13.74^{a}	16.23^{a}
RD6HMT	2.01^{e}	4.42^{b}	5.21^{c}	6.74^{d}

[a] Means within a column with different superscripts are significantly different (p£0.05)

g/g) > KDM105HMT (1.56g/g) (Table 2). The combination of heat and moisture used in the experiment affected flour swelling property significantly and it might be resulted from the increase of amylose-lipid complexes (Hoover and Manuel, 1996)

Another property related to swelling is solubility (Table 3). The solubilities of all native flours were increased with increasing temperature, showing similar trend to swelling property. It is shown that RD6 with the lowest amylose content had the highest solubility. The solubilities of all native flours were in order: RD6 (2.07-7.94%)> KDM105 (1.12-5.61%) > CN1 (0.56-3.13%) > WF (0.31-1.87) (p £ 0.05). For native rice flours, the results had shown that the solubility increased with decreasing amylose content due to restriction of the swelling capacity of the starch granules.

However, WF was not followed this conclusion since its solubility was lower than that of CN1, which has higher amylose content. This might due to the influence of protein in wheat that could inhibit granule swelling and reduce solubility. After heat moisture treated modification, the solubilities were decreased due to the decrease of amylose leaching and the increase of starch-lipid complexes (Hoover and Manuel, 1996).

The method used to measure swelling and solubility in this study was not suited for pregelatinized rice flours. Due to the fact that pregel flour was dispersed in water and instantly raised solution viscosity at room temperature, so it was difficult to determine the swelling power and the results may be inaccurate.

Pasting properties

The rheological changes of starch can be influenced by the structural states (Hermansson and Svegmark, 1996). When starch was heated with water, it went through some changes both physical and chemical such as swelling, granule rupture, crystallinity loss and amylose leaching (Lii *et al.*, 1996). Pasting properties are dependent on the rigidity of starch granules, which in turn affect the granule swelling potential (Sandhya Rani and Bhattacharya, 1989) and the amount of amylose leaching out in the solution (Morris, 1990). The pasting data of native and modified flours are presented in Tables 4-6. Pasting properties differed significantly among different flours. Pasting temperature of different native rice flours ranged from 71.05 - 83.95∂C, CN1 had the highest pasting temperature (83.95∂C) and followed by KDM105 (75.05∂C) and RD6 (71.05∂C), which correlate to the amylose content in each flour as mentioned earlier. When comparing rice flours and WF, it is shown that pasting temperature of WF was lower than that of rice flours.

Peak viscosity of RD6 (364.08 RVU) was found to be the highest and followed by that of: KDM105 (357.67 RVU) and CN1 (228.67 RVU). It is believed that amylopectin and amylose

Table 3 Solubility of wheat, native and modified rice flours.

Flour type	Solubility (%)[a]			
	55∂C	65∂C	75∂C	85∂C
WF	0.31[f]	0.56[g]	1.34[g]	1.87[g]
CN1	0.56[e]	0.87[e]	2.20[e]	3.13[e]
CN1HMT	0.21[g]	0.67[f]	1.98[f]	2.56[f]
KDM105	1.12[c]	2.01[c]	4.32[c]	5.61[c]
KDM105HMT	0.98[d]	1.51[d]	3.98[d]	5.23[d]
RD6	2.07[a]	3.39[a]	6.82[a]	7.94[a]
RD6HMT	1.45[b]	2.31[b]	5.79[b]	6.09[b]

[a] Means within a column with different superscripts are significantly different (p£ 0.05)

Table 4 Pasting characterisitics of wheat flour, native and modified CN 1 flours.

Flour type	Paste time (min)	Pasting Temp (∂C)	Pasting properties (RVU)				
			Peak Viscosity	Trough	Breakdown	Final Viscosity	Setback
WF	5.13^{ab}	64.10^{b}	123.08^{d}	72.42^{c}	50.67^{ab}	169.25^{d}	96.83^{c}
CN1	6.93^{a}	83.95^{a}	228.67^{a}	175.42^{a}	53.25^{a}	337.42^{a}	162.00^{a}
CN1 Pregel	3.01^{b}	51.47^{c}	198.41^{b}	150.21^{b}	48.20^{b}	283.42^{b}	133.21^{b}
CN1 HMT	7.24^{a}	88.64^{a}	154.81^{c}	142.31^{b}	12.50^{c}	201.45^{c}	59.14^{d}

Means within a column with different superscripts are significantly different (p£0.05)

Table 5 Pasting characterisitics of wheat flour, native and modified KDM105 flours.

Flour type	Paste time (min)	Pasting Temp (∂C)	Pasting properties (RVU)				
			Peak Viscosity	Trough	Breakdown	Final Viscosity	Setback
WF	5.13^{c}	64.10^{c}	123.08^{d}	72.42^{d}	50.67^{c}	169.25^{d}	96.83^{b}
KDM105	6.53^{b}	75.05^{b}	357.67^{a}	280.75^{a}	76.92^{a}	410.58^{a}	129.83^{a}
KDM105Pregel	4.80^{d}	49.90^{d}	257.53^{b}	201.00^{b}	56.53^{b}	306.83^{b}	105.83^{b}
KDM105HMT	6.67^{a}	87.10^{a}	167.17^{c}	145.17^{c}	22.00^{d}	259.17^{c}	114.00^{ab}

Means within a column with different superscripts are significantly different (p£0.05)

Table 6 Pasting characterisitics of wheat flour, native and modified RD6 and RD6 flour.

Flour type	Paste time (min)	Pasting Temp (∂C)	Pasting properties (RVU)				
			Peak Viscosity	Trough	Breakdown	Final Viscosity	Setback
WF	5.13^{a}	64.10^{c}	123.08^{c}	72.42^{c}	50.67^{c}	169.25^{b}	96.83^{a}
RD6	3.80^{ab}	71.05^{b}	364.08^{a}	171.75^{a}	192.33^{a}	211.83^{a}	40.08^{b}
RD6 Pregel	1.73^{b}	50.05^{d}	281.42^{b}	105.75^{b}	175.67^{b}	156.75^{c}	51.00^{b}
RD6 HMT	6.02^{a}	80.18^{a}	95.59^{d}	80.04^{c}	15.55^{d}	101.82^{d}	21.78^{c}

Means within a column with different superscripts are significantly different (p£0.05)

affect this value since amylopectin contributing of granule swelling but amylose inhibiting the swelling (Yadav *et al*., 2006). However, the peak viscosity of WF was lower than that of rice flours due to the effect of protein rather than amylose. In Tables 4-6, they show breakdown values of all native flours as in the following order: RD6 (192.33 RVU) > KDM105 (76.92 RVU) > CN1 (53.25 RVU) > WF (50.67 RVU). The results are correlated to the degree of swelling due to the rupture of the swollen granules during the cooking phase. Consequently, the gelling on the account of reassociation (retrogradation) of starch molecules occurs upon cooling and leads to increase solution viscosity again (Yadav *et al*., 2006). Setback is the calculated value by subtracted the final viscosity with peak viscosity. The setback values of native flours are shown in Tables 4-6 in the following order: CN1 (162.00 RVU) > KDM105 (129.83 RVU) > WF (96.83 RVU) > RD6 (40.08 RVU). These values could be used to predict the final texture and freeze-thaw stablity of products.

After physical modification, different varieties of rice flours, show the same trend of pasting characteristics. Pregelatinization of rice flours shows the lower of pasting time, pasting temperature and the decrease of peak viscosity and setback. Due to the fact that pregelatinization caused granule disruption, it could cause pregel flour to absorb water and raise viscosity instantly (Glicksman, 1969; Doublier *et al.*, 1986). Consequently, when the pregel flour was reheated, it caused a decrease in paste viscosity, leading to “thinning” of the slurry. The curves of pregel flours show lower viscosity. The temperature during pregel was more conductive for amylolytic hydrolysis and hence starch breakdown, which led to lower viscosity (Yadav *et al*., 2006). All pregel flours (Tables 4-6) revealed the decrease in pasting time and temperature, peak viscosity, trough, breakdown, final viscosity and setback. Pasting temperature of different pregel flours had ranged from 49.90 – 51.47 ∂C, depended on rice varieties. CN1 pregel exhibited the highest pasting temperature (51.47 ∂C) and then RD6 pregel (50.05 ∂C) and KDM105 pregel (49.90 ∂C). As shown in Tables 4 - 6, peak viscosities of pregel rice flours appear in the different orders: RD6 pregel (281.42 RVU) > KDM105 pregel (257.53 RVU) > CN1 pregel (198.41 RVU). For final viscosity, it shown that KDM105 pregel (306.83 RVU) is higher than CN1 pregel (283.42 RVU) and RD6 pregel (156.75 RVU). Lai (2001) had presented that high amylose rice flour tended to retrograde quickly during gelatinization and drying process. In addition, the amylose molecules of gelatinized rice flour could reassociate strongly and caused the low peak viscosity and high final viscosity (Lai, 2001). Setback was calculated and appeared as followed: CN1 pregel (133.21 RVU) > KDM105 pregel (105.83 RVU) > RD6 pregel (51 RVU). As the results showed, the pasting characteristics of rice flours maybe not only dependent on the ratio of amylose and amylopectin but the minor constituents such as protein and lipid as well (Debet and Gidley, 2006).

Heat moisture treated flours (HMT flour) exhibited the higher pasting time and temperature for all rice varieties. However, the pasting parameters such as peak viscosity, breakdown, final viscosity and setback were lower than native flours (Tables 4-6). When compared HMT flour with different varieties, peak viscosity of KDM105 HMT (167.17 RVU) is higher than those of CN1 HMT (154.81 RVU) and RD6 HMT (95.59 RVU). When compared the peak viscosity between native and HMT flours within the same variety, the results reveal that the heat moisture treatment could alter the crystalline structure (Osman, 1967) and affect the pasting profiles of flour. The lower of peak viscosity indicates the decrease of swelling capacity of starch granules, leading to the higher shear stability (the decrease of breakdown value). Due to the fact that starch granules became shear resistance after heat moisture treatment, setback values were decreased when compared with native flours. These changes of pasting characteristics are probably the result of inter- and intramolecular hydrogen bonds of amylose chain and amylose-lipid complexes occurred during heat moisture treated. Since the treated starch granules changed the structure to stronger, they became extremely heat- and shear- resistant during pasting time (Hoover and Manuel, 1996).

Freeze-thaw stability of flour

Freeze-thaw stability is the ability of a starch paste to maintain its integrity without syneresis when subjected to repeat thermal cycling between ambient and freezing temperature. Retrogradation was expressed as the volume of water that separated out as the result of gel shrinkage. Consequently, the amounts of exuded water result from inter- and intramolecular hydrogen of the association between the separated amylose chains during frozen storage (Hoover and Manuel, 1996). The retrogradations of native flour from 1 to 5 freeze-thaw cycles were significantly different as followed: CN1 (5.39-39.93%)> KDM105 (0.77-28.93%)> RD6 (0.12-1.23%). As mentioned earlier, amylose in starch could affect retrogradation, as shown in Figure 1, the amount of exuded water increased with increasing amylose content. After pregelatinization, the degree of syneresis of pregel flours was higher than that of native flours. Furthermore, when compared among pregel flours with different varieties, the results were as followed: CN1pregel (15.76-47.65%)> KDM105pregel (10.48-42.29%) > RD6pregel (1.06-6.81%) (For 5 freeze-thaw cycles; Figure 1). The marginal increase in syneresis of pregel flours suggests that starches occur to swelling and gelatinization since the distance between separated amylose chains (resulting from the breakage of hydrogen bonds) would be extent in pregelatinization (Alexander, 1995).

After heat moisture treatment, the syneresis of flour (after each freeze-thaw cycle for 5 cycles) decreased significantly as shown in order: CN1 HMT (3.21-37.36%) > KDM105 HMT (0.11-17.55%) > RD6 HMT (1.06-6.81%). It might due to the increase in the magnitude of the bonding forces within the amorphous regions of the granule. Thus on swelling and gelatinization, the distance between separated amylose chains would be less in heat moisture treated granules than in native and pregel flours. The increase in the degree of the syneresis during storage has been attributed to the interaction between leached amylose and amylopectin chains, which leads to the development of junction zones.

CONCLUSION

In this experiment, pregel flours showed the decrease of the pasting temperature, peak viscosity, trough, breakdown, final viscosity and setback as well as the decrease of freeze-thaw stability. On the othe hand, HMT flours exhibited the increase of the pasting temperature and time as well as setback; while peak viscosity, trough, breakdown and final viscosity decreased. In addition, the swelling power and solubility of HMT flour decreased; whereas, freeze-thaw stability increased. The results from this study are valuable as they showed that the combination of rice flours is necessary in order to make wheat noodle and still maintaining texture as well as freeze-thaw stability.

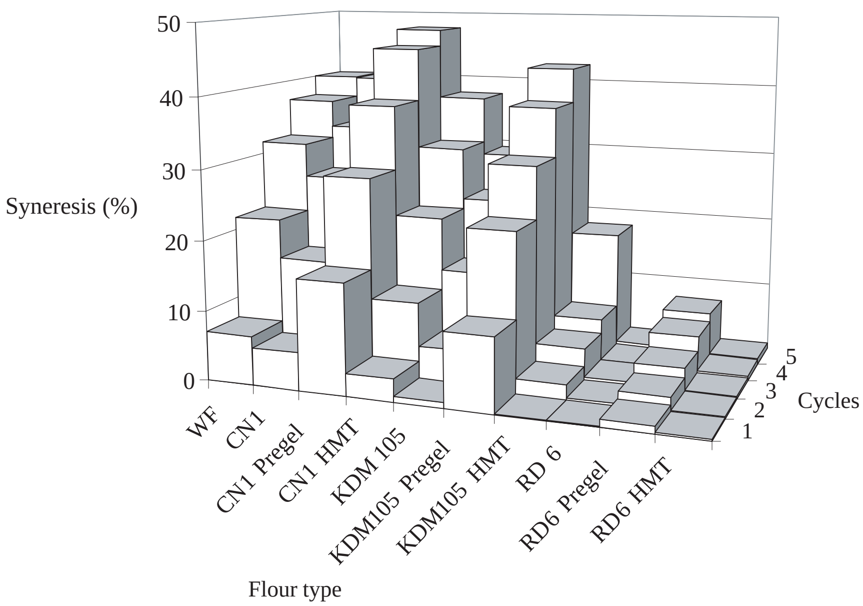

Figure 1 The degree of syneresis of native and modified flours.

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