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Rheological, textural, and sensory properties of Asian noodles containing an oat cereal hydrocolloid ☆

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Abstract

The purpose of this study was to use an oat hydrocolloidal fibre composition, called Nutrim-5, for extending the use of rice flour in making Asian noodles. Nutrim-5 is one of a family of β-glucan-containing hydrocolloids that is prepared by thermo-shear processing of oat flour or bran. The rheological properties of the noodle flour composites indicated that Nutrim-5 contributed binding qualities to the composites. Nutrim-5 appeared to contribute functionality to the rice flour, allowing for larger quantities to be used in the making of Asian noodles. The noodles were prepared in 20 kg batches by mixing blends of wheat flour, rice flour, and Nutrim-5 with alkali, salt solution, and egg. After mixing and kneading into smooth sheets, the noodles were cut, curled, and deep fat-fried. By using 10% by weight Nutrim-5 in the formulation, it was possible to satisfactorily make noodles using 50% rice flour. The cooking loss and tensile strength were measured and found to be satisfactory for this amount of rice flour in the noodles. A trained sensory panel also indicated that these noodles did not reveal any difference in taste.
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Keywords: Nutrium-5; Noodles; Hydrocolloidal fibres; Wheat flour; Rice flour; Rheology

1. Introduction

Asian noodles are widely consumed as the Japanese white salted noodles (WSN) and the Chinese yellow alkaline noodles (YAN) in various types and compositions. The functional and rheological properties of YAN noodles were summarized by Cooke and Bhattacharya (1999). The functional and rheological properties of these noodles, as related to wheat flour, have been a widely investigated area of research (Jun, Seib, & Chung, 1998b; Kruger, Anderson, & Dexter, 1994; Seib, 2000; Seib, Liang, Guan, Liang, & Yang, 2000; Wang & Seib, 1996). An area of principal concern was the relationship between the dough properties and the starch pasting properties of the wheat flours (Edwards, Scanlon, Kruger, & Dexter, 1996; Hatcher, Kruger, & Anderson, 1999; Jun, Chung, & Seib, 1998a; Lee & Kim, 1983; Miki, Fukui, & Yamano, 1982; Shimada, Yazawa, Yoshimatsu, Kato, & Fujimaki, 1979). The wheat cultivars were found to play a primary function in this vital property in the preparation of WSN and YAN (Ross, Quail, & Crosbie, 1997). Additional information on wheat flours for these noodles revealed a wide diversity of traits needed for their preparation (Bhattacharya & Corke, 1996; Oh, Seib, Finney, & Pomeranz, 1986). Important pasting characteristics of noodle flours could be measured by using a variety of rapid-visco analyzer (RVA) operating conditions (Batey, Curtin, & Moore, 1997). Other than wheat flour, rice flours are a useful and a very important component in many WSN and YAN formulations. The RVA also provided important information on these flours for noodle formulators (Bhattacharya, Zee, & Corke, 1999).

Many other components are useful in noodle making. The use of rye flour in noodle formulations gave some interesting quality characteristics to oriental noodles (Kruger, Hatcher, & Anderson, 1998), suggesting some

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interest in modifying nutritional quality and formulation variations. The effects of Amaranthus and buckwheat (Bejosano & Corke, 1998) also provided some interest in elaborating noodle compositions.

Very little information is available on the incorporation of oat products in making WSN and YAN. The purpose of this study was to use an oat hydrocolloidal fibre, Nutrim-5, for extending the use of rice flour in making WSN and YAN. Nutrim-5 was added to the noodle formula to add functionality to rice flour for increasing the amount used in noodles. Nutrim-5 is a hydrocolloidal product, prepared by thermomechanical processing of oat flour or bran (Inglett & Carriere, 2001). Previously, these hydrocolloidal products, called Nutrim, were found to be useful for replacing saturated fats (including coconut milk, butter, or saturated fat shortenings) in making foods. Nutrim (5% dispersed solids) was useful in preparing more nutritious foods, by replacing at least 50% coconut milk in eight Thai desserts (Inglett, Carriere, & Maneepun, 2003). It is known to contain 5% by weight of the soluble fibre β-glucan. The soluble β-glucan content of the oat products is known to contribute hypocholesterolemic properties to foods. Besides Nutrim-5's biological properties, this study was conducted to determine Nutrim-5's utility as a substitute for wheat and/or rice flours in the preparation of Asian noodles.

2. Materials and methods

2.1. Flour samples and composition

Wheat flour was obtained from Siam Flour Mill Company in Bangkok, Thailand. The flour had been imported and milled in the factory. Rice flour was obtained from Choheng Vermicelli Factory in Nakorn Pathom Province, Thailand, and had been wet-milled from non-glutinous rice with an intermediate amylose content. The flour samples were analyzed for proximate composition (AOAC, 1994) and amylose value (Juliano, 1971). The analysis was performed in duplicates and the data averaged. The wheat flour was analyzed for protein, 15.3%, ash, 0.59%, and amylose content, 26.2%. The composition of the non-glutinous, intermediate amylose rice flour had the following percentage contents: for protein, 8.56, ash, 0.20, and amylose content, 23.4. The composition of the Nutrim-5 had the following percentage contents: for protein, 13.0, ash, 1.1, and carbohydrate content, 72.9 (Carriere & Inglett, 2000). Nutrim-5 was obtained as a commercial product from Van Drunen Farms, Momence, IL.

2.2. Flour particle analysis and pasting properties

A Coulter Particle Counter, Model Mastesizer 2000 (Malvern, Wascester, UK), was used to measure the percent volume of flour particles distributed within selected size ranges for dry powder measurement/loose particle distribution. The particle sizes in the flours were most abundant in the 6-μm-size fraction (45.4% for wheat flour and 70.2% for the rice flour). The next largest content was the 9-μm sizes at 19.8% for the wheat flour and 24.4% for the rice flour. Smaller particle percentages were observed in the 3-μm size fraction (9.6% for wheat flour and 4.6% for rice flour), 12-μm-size fraction (4.6% for wheat flour and 0.8% for rice flour), and >12-μm (11.6% for wheat flour and 0.0% for rice flour).

The pasting properties of the flours and their blends were measured using a rapid visco analyzer (RVA, Newport Scientific Pvt. Ltd., Warriewood NSW 2102, Australia). Exactly 3.5 g (14% moisture) was weighed into the RVA aluminium sample cup and 25 ml of distilled water was added. The sample was installed in the rotor stand and the analysis was conducted immediately. The data were displayed as the viscosity versus time. The analyzed items were peak (maximum), through final, and gelatinization (pasting) temperatures. The breakdown and setback times were also obtained from the data.

2.3. Noodle preparations, cooking loss, texture analysis, and tensile properties

The Japanese white salted noodles (WSN) of this study were prepared by initially mixing the wheat and rice flour (WF:RF) in different ratios, namely, 70:30, 60:40, and 50:50. To this mixture was added 6% by weight of salt and water. The suspension was mixed at low speeds for 5 min, then rolled into a 3-mm thick sheet dough. The dough was allowed to rest for 1 h and then rolled into a 1-mm thick sheet. From this sheet, the noodle strands were cut and the resulting noodles were steamed for 10 min. The resulting steamed noodles were allowed to shape and dry at 50 °C for 3 h.

The Chinese yellow alkaline noodles (YAN) of this study were prepared by initially mixing the WF and RF in the same ratios used for the white noodles, namely 70:30, 60:40, and 50:50. To this mixture were added 1.5% salt, 2% sodium carbonate, and water. The suspension was mixed for 5 min and then rolled into a 3-mm thick sheet dough. The dough was allowed to rest for 1 h and then rolled into a 1-mm thick sheet. From this sheet, the noodles were cut and then steamed for 5 min. The steamed noodles were allowed to shape and dry by holding them at 50 °C for 3 h.

Cooking yield and cooking loss of the noodles were determined as described in the AACC Method (American Association of Cereal Chemists, 1976). Ten grams of the noodles was added to a beaker containing about 150 ml of boiling water. The beaker was covered with a watch glass and cooked for 10 min with slight agitation.

The cooked noodles allowed to drain for 5 min and were then weighed and the cooking yield calculated. The filtrate was poured into a 200 ml volumetric flask and adjusted to volume with distilled water. Ten ml of the solution was pipetted into an aluminium dish and dried to constant weight at 105 °C. Cooking loss was determined by evaporating the cooking water in a hot air oven at 105 °C to constant weight. The solid loss during cooking was calculated.

The texture quality of the cooked noodles was determined by measuring the tensile strength, break distance (extensibility), and hardness, using a TA-XT2 Texture Analyzer (Stable Micro System, England) equipped with a Spaghetti tensile ring code A/SPR.

2.4. Rheological properties

In order to study the rheological properties of isolated Nutrim-5, a suspension containing 10% (w/w) Nutrim-5 was prepared in deionized water. Solid Nutrim-5 in powder form was weighed into a tared container to which the appropriate amount of deionized water was added. The sample was mixed with a Polytron colloid mill using a PCU/11 controller until it appeared homogeneous (approximately 5 min total mixing time). The rheological properties of 10% (w/w) Nutrim-5 in deionized water were measured using a controlled-strain rheometer (ARES Fluids Rheometer, TA Instruments, New Castle, DE). Samples were tested in a 50-mm parallel plate fixture, and the temperature was controlled with a circulating fluid bath that held the plate fixture at 25.0 ± 0.1 °C.

2.5. Sensory evaluation

Colour and taste are the important sensory parameters for determining the suitability of the noodles. The sensory evaluation of the white and yellow noodles was performed with an evaluation panel of 25 trained members. They were professionally trained for evaluating the following flavour and texture characteristics: colour, appearance, odour, taste, and texture using a 1–9 hedonic scale. The scale is verbally anchored with nine categories, as follows: like extremely, like very much, like moderately, like slightly, neither like or dislike, dislike slightly, dislike moderately, dislike very much, and dislike extremely. The statistical analyses of the experimental data were conducted using ANOVA and DMRT (International Rice Research Institute Irristat version, 1990).

3. Results and discussion

3.1. Wheat and rice flour properties

The pasting properties of the flours and their blends were measured by using a RVA. The rice flour had the highest peak viscosity, along with the highest final viscosity. These viscosity properties were seen in the blended flours by displaying higher increases in viscosity, both peak and final, with increasing amounts of rice flour in the blends (Table 1). The comparative RVA pasting curves for the rice and wheat flours and their three blends are shown in Fig. 1. Rice flour exhibits the greatest pasting viscosity and increases the pasting viscosities of the blends with increasing quantities of the rice flour component. The rice and wheat flour blends with Nutrim-5 also show increasing pasting viscosities with increasing rice flour component in the blend (Fig. 2).

3.2. WSN and YAN noodle properties

The protein compositions of the WSN prepared with WF:RF ratios of 70:30, 60:40, and 50:50 were 13.7%, 13.1% and 11.7%, respectively. Their ash contents for these ratios were 5.58%, 5.06%, and 4.93%, respectively (Table 2). The cooking yields were determined as described above and were found to be 119.62%, 132.38%,

Table 1
Pasting evaluation of flours and their blends by rapid visco analyzer

Material/Flour[a]	Peak viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Pasting temperature (°C)
WF	164.3	106.0	58.2	216.9	52.7	66.2
RF	316.2	217.0	99.27	529.7	213.5	78.4
WF:RF 70:30	184.9	120.0	64.9	273.5	88.6	76.7
WF:RF 60:40	196.3	128.7	67.7	300.1	103.8	77.4
WF:RF 50:50	210.8	138.8	72.0	327.9	117.1	78.2
WF:RF:NU 70:30:10	137.8	94.6	43.2	218.8	81.1	80.0
WF:RF:NU 60:40:10	157.6	109.2	48.3	263.1	105.5	80.0
WF:RF:NU 50:50:10	147.5	101.5	46.0	241.8	94.3	80.0

[a] WF, wheat flour; RF, rice flour; NU, Nutrim-5.

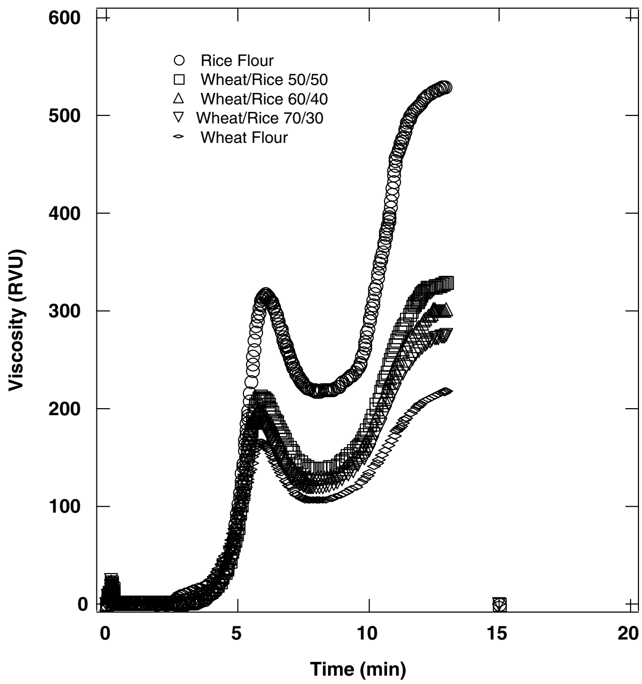

Fig. 1. Rapid viscoanalyzer experiment conducted with wheat mixed with rice flour.

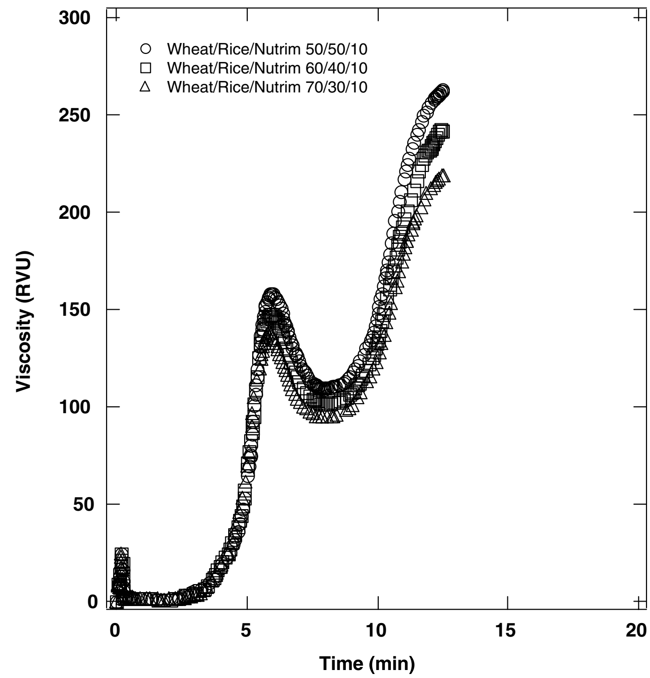

Fig. 2. Rapid viscoanalyzer experiment conducted with wheat mixed with rice flour and Nutrim-5.

Table 2
Texture analysis of rehydrated white noodle (WSN)

Composition	Protein (%)	Ash (%)	Cooking yield (%)	Cooking loss (%)	Max. force ± SD (gf)
WF:RF[a]					
70:30	13.7	5.58	119.62	5.78	18.89 ± 0.74
60:40	13.1	5.06	132.38	5.79	17.58 ± 1.44
50:50	11.7	4.93	135.60	6.83	12.80 ± 0.57
WF:RF:NU[a]					
70:30:10	13.4	4.45	120.96	5.62	13.72 ± 0.69
60:40:10	14.0	4.52	128.37	7.26	13.54 ± 0.72
50:50:10	12.4	4.42	130.81	7.38	12.67 ± 0.68

[a] WF, wheat flour; RF, rice flour; NU, Nutrim-5.

and 135.60% while the cooking loss was found to be 5.78%, 5.79%, and 6.83% for the 70:30, 60:40, and 50:50 blends, respectively. The maximum forces measured using the TA-XT 2 Texture Analyzer for the WSN at compositions of 70:30, 60:40, and 50:50 were 18.89, 17.58, and 12.80 gf, respectively.

The protein compositions of the WSN noodles prepared with WF:RF:Nutrim-5 ratios of 70:30:10, 60:40:10, and 50:50:10 were 13.4%, 14.0%, and 12.4%, respectively. The ash contents for these ratios were 4.45%, 4.52%, and 4.42%, respectively (Table 2). The cooking yields and losses for these compositions were 120.96%, 128.37%, 130.81%, and 5.62%, 7.26%, 7.38%, respectively. The maximum forces measured using the TA-XT 2 Texture Analyzer for the WF:RF: Nutrim-5 compositions were 13.72, 13.54, and 12.67 gf, respectively.

The protein compositions of the YAN prepared with WF:RF ratios of 70:30. 60:40, and 50:50 were 14.7%, 13.5%, and 13.1%, respectively. The ash contents of the YAN at the various compositions were 2.27%, 2.33%, and 2.29%, respectively. Cooking yields for the different ratios were 127.77%, 129.30%, and 130.79%, respectively, while the cooking loss for these blends were 3.32%, 3.21%, and 3.43%, respectively. The maximum forces measured using the TA-XT 2 Texture Analyzer were 17.90, 16.04, and 12.11 gf, respectively.

The protein compositions of the YAN noodles prepared with WF:RF:Nutrim-5 ratios of 70:30:10, 60:40:10, and 50:50:10 were 13.7%, 13.2%, and 12.3%, respectively. The ash contents for these ratios were 4.45%, 4.52%, and 4.42%, respectively (Table 3). The cooking yields and losses for these compositions were 124.00%, 133.86%, 148.77%, and 3.92%, 3.73%, 3.68%,

Table 3
Texture analysis of rehydrated yellow noodle (YAN)

Composition	Protein (%)	Ash (%)	Cooking yield (%)	Cooking loss (%)	Max. force ± SD (gf)
WF:RF[a]					
70:30	14.7	2.27	127.77	3.32	17.90 ± 1.39
60:40	13.5	2.33	129.30	3.21	16.04 ± 2.00
50:50	13.1	2.29	130.79	3.43	12.11 ± 0.95
WF:RF:NU[a]					
70:30:10	13.7	4.45	124.0	3.92	15.47 ± 0.78
60:40:10	13.2	4.52	133.86	3.73	16.89 ± 1.03
50:50:10	12.3	4.42	148.77	3.68	13.36 ± 0.78

[a] WF, wheat flour; RF, rice flour; NU, Nutrim-5.

Table 4
Sensory evaluation of white noodle (WSN) produced with Nutrim-5

RF:WF	N-U[a]	Appearance	Colour	Odour	Flavour	Texture	Acceptance
30:70	10	6.88a	7.06a	6.19a	6.88a	6.13a	6.38a
40:60	10	6.72a	7.06a	6.56a	6.50a	5.88a	6.22a
50:50	10	6.44a	6.94a	6.31a	6.69a	5.44a	5.69a

In a row, means followed by same alphabets are not significantly different at $p > 0.05$.
Statistical analyses were analyzed with the SAS (1994) randomized complete block design.
[a] WF, wheat flour; RF, rice flour (RF); NU, Nutrim-5.

Table 5
Sensory evaluation of yellow noodle (YAN) produced with Nutrim-5[a]

RF:WF	Nu	Appearance	Colour	Odour	Flavour	Texture	Acceptance
30:70	10	7.48a	7.43a	7.09a	7.48a	6.85a	7.09a
40:60	10	7.52a	7.29a	6.90a	7.14b	7.02a	6.98a
50:50	10	7.33a	7.52a	7.00a	7.28ab	6.60a	6.67a

Statistical analyses were analyzed with the SAS (1994) randomized complete block design.
[a] In a row, means followed by same alphabets are not significantly different at $p > 0.05$.

respectively. The maximum forces measured using the TA-XT 2 Texture Analyzer for the WF:RF:Nutrim-5 compositions were 15.47, 16.89, and 13.36 gf, respectively.

The aforementioned data indicate that the cooking losses for WSN without Nutrim-5 increase by about 1.1% with decreasing WF:RF ratios. In contrast, WSN produced with Nutrim-5 show an increase in cooking loss of about 1.8%. For YAN, the cooking losses were similar, with or without Nurim-5. There was a corresponding loss in the cooked noodle strength with decreasing WF:RF ratios for both WSN and YAN, with or without Nutrim-5. The WSN and YAN showed similar tensile strengths, both with and without Nutrim-5.

3.3. Sensory evaluation of noodles prepared with Nutrim-5

The sensory evaluations of either WSN, or YAN prepared with 70:30:10, 60:40:10, and 50:50:10 WF:RF:Nutrim-5 were compared for appearance, colour, odour, flavour, texture, and acceptance. These factors were statistically analyzed by the SAS (1994) by a randomized complete block design. The WSN results indicated a complete statistical similarity for the white noodle colour, odour, flavour, texture, and acceptance (Table 4). Similarly, the YAN results indicated a nearly complete statistical similarity for the yellow noodle colour, odour, texture, and acceptance (Table 5). However, a very slight variation was noted in the flavour of the yellow noodle prepared with the 40:60:10 and 50:50:10 WF:RF:Nutrim-5.

3.4. Rheological behaviour of Nutrim-5 suspensions

The viscosity of 10% Nutrim-5 suspensions can vary somewhat, depending on the amount of shearing energy imparted to the suspension from the colloid mill during initial mixing of the solid Nutrim-5 and water. This parameter was difficult to control precisely, since the shearing fixture of the colloid mill reacted to air pockets and the geometry of the container holding the suspen-

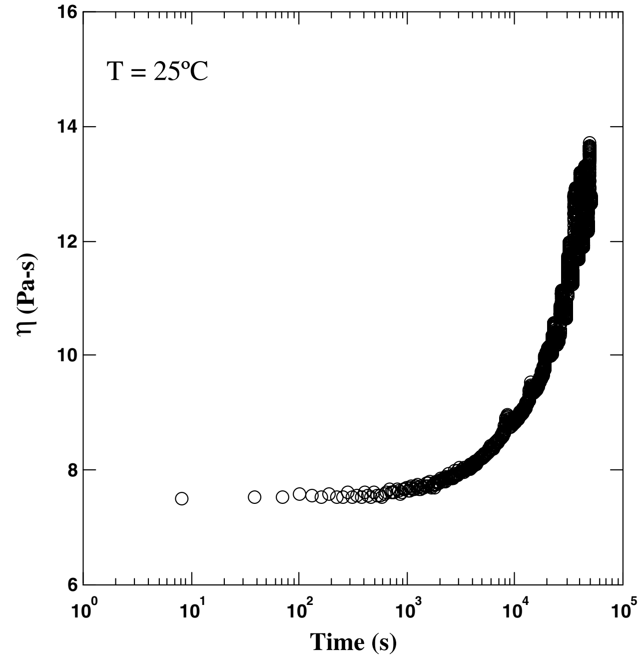

Fig. 3. Viscosity of the 10% Nutrim-5 suspension as a function of time. Measured at 25 °C using a controlled-strain rheometer.

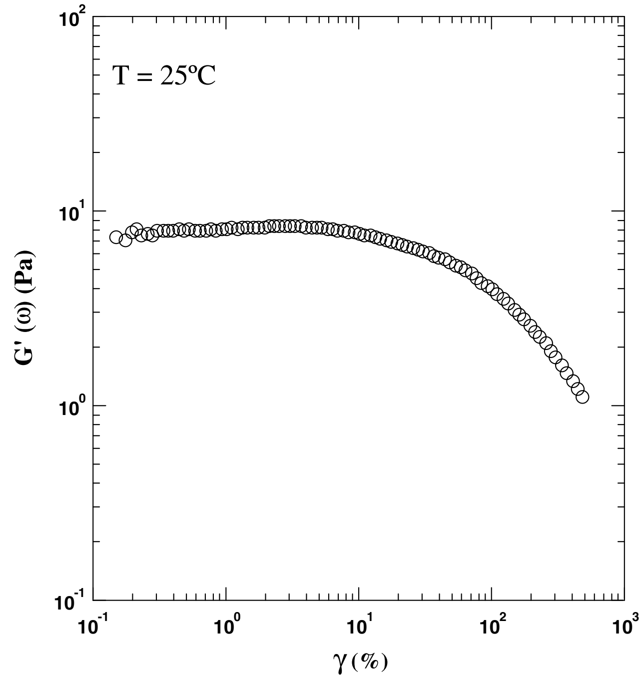

Fig. 4. Effect of strain on the oscillatory shear storage modulus $G'(\omega)$ for 10% Nutrim-5, measured at 25 °C using a controlled-strain rheometer.

sion. A dynamic time sweep experiment was done in which the 10% Nutrim-5 suspension was oscillated at 1 rad/s at a magnitude of 1% strain for 14 h. The sample was coated with mineral oil on the edges of the parallel plate fixture to prevent drying out with time, which could cause an artificial rising of the viscosity. As seen in Fig. 3, the viscosity of the 10% Nutrim-5 increased with time, most likely as a result of starch retrogradation.

To determine the linear viscoelastic region of the sample the oscillatory storage modulus G' was observed as a function of strain (Fig. 4). The storage modulus is constant (linear viscoelastic region) until strains of approximately 6% are reached, after which G' begins to drop, indicating the onset of non-linear viscoelastic behaviour.

The results of a hysteresis loop experiment on the 10% Nutrim-5 are shown in Fig. 5. In this experiment the sample was sheared from 0 to 300 s^{-1} and then brought back to rest. The total loop time was 12 min: 6 min from 0 to 300 s^{-1} and 6 min back. Shear-thinning behaviour can be clearly seen, and the final viscosity is lower than that during the initial shearing, indicating that there is some network structure present which is being shear-degraded. The initial shearing behaviour of the Nutrim-5 suspension was fitted with a power law constitutive equation, which can be expressed as

$$\eta = K\dot{\gamma}^{m-1}, \tag{1}$$

where η is the shear viscosity, $\dot{\gamma}$ the shear rate, K the front factor, and m the power law exponent (Bird, Armstrong, & Hassager, 1977). Most fluids exhibit pseudoplastic behaviour with an m value ranging from 0.15 to 0.6. The power law equation that fitted the initial upward cycle yielded $K = 6.042 \pm 0.006$ and

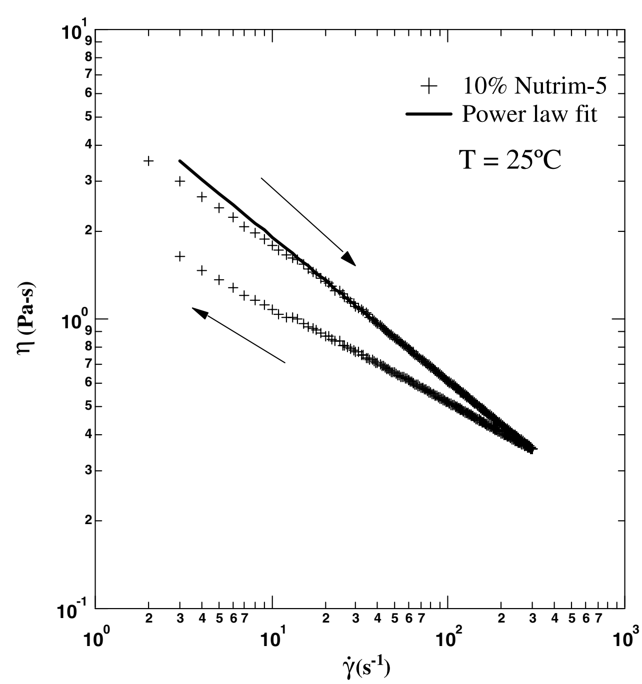

Fig. 5. Effect of shear rate on shear viscosity during a hysteresis loop experiment for 10% Nutrim-5. The arrows indicate the direction of the applied shear rate. The fit to the data that represents a power law constitutive equation, with $K = 6.042$ and $m = 0.5020$ is shown as a solid line, measured at 25 °C using a controlled-strain rheometer.

$m = 0.5020 \pm 0.0002$; thus, the 10% Nutrim-5 suspension exhibits pseudoplastic behaviour.

The purpose of this study was to use an oat hydrocolloidal fibre, Nutrim-5, for extending the use of rice flour in making WSN and YAN. The noodles studied were the white noodles, common in Japan, and the yellow noodle, common in China. Nutrim-5 was added to the noodle formula to add functionality to rice flour for increasing the amount used in noodles. Nutrim-5 is a hydrocolloidal product that was prepared by thermomechanical processing of oat flour or bran (Inglett & Carriere, 2001). Previously, these hydrocolloidal products, called Nutrim, were found to be useful in replacing saturated fats (including coconut milk, butter, or saturated fat shortenings) for making foods. Nutrim (5% dispersed solids) was useful in preparing more nutritious foods by replacing at least 50% coconut milk in eight Thai desserts (Inglett et al., 2003). It is known to contain 5% by weight of the soluble fibre β-glucan. The soluble β-glucan content of the oat products is known to contribute hypocholesterolemic properties to foods. Besides Nutrim-5's biological properties, this study was conducted to determine Nutrim-5's utility as a substitute for wheat and/or rice flours in the preparation of Asian noodles.

4. Conclusions

The rheological properties of the noodle flour composites revealed that the Nutrim-5 component could contribute synergistic binding qualities in the preparation of WSN and YAN noodles. The oat hydrocolloidal fibre component, Nutrim-5, was found to be useful for extending the quantity of rice flour used in making white and yellow Asian noodles. Nutrim-5 was added to the noodle formula to improve the functionality of rice flour for increasing this component in the noodle formulations. When Nutrim-5 was used in a composite formulation, with equal portions of rice and wheat flours, the Asian noodles, WSN and YAN, were statistically similar to the control.

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