JOBIMB, 2024, Vol 12, No 1 SP1, 72-74
https://doi.org/10.54987/jobimb.v12iSP1.947

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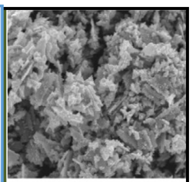

JOBIMB VOL 12 NO 1 SP1 2024
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Physicochemical and Rheological Properties of Rice Flour and Starch from Malaysian Rice Cultivars

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HISTORY

Received: 7th April 2024
Received in revised form: 5th July 2024
Accepted: 30th July 2024

KEYWORDS

Rice varieties characterization
Physicochemical properties
Rheological properties
Amylose content
Starch gels behavior

ABSTRACT

Starch consists of amylose and amylopectin polysaccharides that vary in different rice varieties. The development of new rice varieties has presented the need for characterization to determine their applications. This study aims to determine rice flours' physicochemical and rheological properties and starches from two Malaysian varieties, UPM Putra 2 (P2) and NMR 152 (NMR). P2 and NMR flours and starches were analysed for proximate amylose content, pasting, and rheological properties with commercial white rice (JM) as control. P2 and NMR starches had lower amylose contents than JM; meanwhile, their flours contained higher fat, total dietary fiber, and ash than JM flour. Based on thermal analysis, P2, and NMR exhibited similar peak viscosity but differed in breakdown and setback temperatures and final viscosity. Starch gels exhibited solid-like behaviour as their G' was greater than G", and tan δ values were smaller than unity. In conclusion, pasting and rheological properties of rice flours and starches varied for different rice varieties even though both P2 (23.1%) and NMR (23.4%) are medium-amylose starches, while JM (26.6%) is high-amylose starch. The characterization of these rice and starch is essential for them to be further processed into various food products.

INTRODUCTION

Rice (*Oryza sativa* L.) is known as the world's main staple food, alongside wheat and corn [1]. Rice can be transformed into rice flour through a milling process, either dry-, semi-dry-, or wet-milling [2]. It is used to produce various foods, including traditional Malaysian desserts. Starch is a primary component of rice grain; each starch granule consists of amylose and amylopectin polysaccharides. Rice starch is isolated by using a traditional method of alkaline steeping or a mechanical method involving wet-milling process [3]. The interaction of starch with moisture accompanied by heating affects the rheological properties (gelling and pasting) and thermal properties [4]. The relationship between starch composition and its behaviour upon heating is extensively studied by many researchers involving rice cultivars of different varieties [5-7]. In Malaysia, new rice varieties are developed by the Malaysian Agricultural Research Development Institute (MARDI) to address agricultural issues and improve yield [8]. Due to the lack of data on the physicochemical and rheological properties of rice flours and starches of Malaysian rice varieties, this study aimed to determine the physicochemical and rheological properties of rice flours and starches from two different Malaysian varieties.

MATERIALS AND METHODS

Sample preparation

NMR and P2 rice were purchased from HMN Services Sdn. Bhd., Sekinchan, Selangor. The control sample (Jasmine *Super Special Tempatan*) was purchased from the local supermarket in Serdang, Selangor. Rice samples were dehusked and milled to obtain rice flour samples. Rice starch was isolated by using a method adapted from [7].

Proximate and physicochemical analysis
Samples were analysed for moisture, ash, crude fat, and crude protein contents using the methods described by AOAC [9]. Analysis of TDF and amylose content was conducted in UniPEQ Sdn. Bhd. UKM, Bangi, Selangor. Colour was determined using Minolta Chromameter CR-410. Pasting properties were determined using a Rapid Visco Analyzer (RVA-4, Newport Scientific, Pty. Ltd., Warriewood, Australia).

Rheological analysis
Dynamic rheological properties were studied by adapting the methods of the gel system (30% w/v dry weight basis) by [10] with modifications using a Rheostress RS600 (Thermo Scientific, USA) with parallel plate geometry: 50 mm diameter, 1 mm gap.

Statistical analysis
The data measured in triplicates were reported as mean ± standard deviation. Significant differences between mean values were established by using one-way ANOVA and Tukey's test at $p \leq 0.05$ with Minitab Statistical Software Version 21.4 (Minitab, LLC).

RESULT AND DISCUSSION

Chemical Compositions
As shown in **Table 1**, no significant differences ($p>0.05$) were observed for protein content of flour samples. P2F and NMRF had similar fat and TDF contents, which were higher than the fat and TDF observed in JMF (Table 1). The inefficient dehulling process could be a contributing factor to the higher TDF, as rice hulls are high in lignin and minerals [11]. This also explains the higher ash contents of P2F and NMRF as compared to JMF (Table 1). A study by [12] found that the isolation of starch with 0.2% NaOH can successfully obtain starch that is low in residual proteins. Flours from both P2 (19.4%) and NMR (17.3%) varieties contain lower amylose than JMF (22.8%) (Table 1). Similarly, their corresponding starches also exhibit lower amylose contents than JMS. According to the classification by [3], P2 (23.1%) and NMR (23.4%) are medium-amylose starches, while JM (26.6%) is high-amylose starch.

Pasting Properties
Among the different varieties, the pasting temperature of rice flours and starches under study exhibited similar values ranging from 82.4 to 90.38°C (**Table 2**). A similar range was reported for rice flours from Nigerian rice flours [13]. NMRS and P2S exhibited the highest value for PV, which could be explained by their lower amylose content (23.4% and 23.1%) than that of JMS (26.6%). A lower PV is caused by a lower amount of amylose leaching, leading to restricted and lower starch granular swelling [14].

On the other hand, there were variations in the PV of rice flour samples, whereby NMRF (low-amylose) exhibited values similar to those of JMF and P2F despite having lower amylose content than JMF. A similar result was reported by [15], where they also found identical PV values in rice starches with different amylose content. They also mentioned that the amylose density and size of starch granules could affect the PV.

Table 2. Pasting properties of flours and starches from different Malaysian rice varieties.

Sample	PV (RVU)	BD (RVU)	FV (RVU)	SB (RVU)	PT (RVU)
JMF	59.54 ± 0.06^{c}	5.42 ± 0.71^{d}	131.79 ± 0.06^{c}	77.58 ± 0.59^{a}	87.40 ± 4.09^{a}
P2F	49.04 ± 2.30^{d}	9.33 ± 0.47^{cd}	122.21 ± 2.53^{d}	80.04 ± 0.88^{a}	90.38 ± 0.80^{a}
NMRF	54.63 ± 0.41^{cd}	16.08 ± 0.12^{b}	106.00 ± 0.24^{e}	67.04 ± 0.53^{b}	86.32 ± 4.21^{a}
JMS	115.58 ± 0.83^{b}	17.00 ± 2.71^{b}	128.75 ± 0.354^{c}	30.17 ± 2.24^{d}	86.32 ± 4.85^{a}
P2S	135.21 ± 2.42^{a}	11.13 ± 0.18^{c}	183.79 ± 0.77^{a}	60.92 ± 0.12^{c}	82.57 ± 0.46^{a}
NMRS	131.63 ± 1.47^{a}	28.83 ± 0.83^{a}	175.25 ± 2.59^{b}	69.46 ± 0.06^{b}	82.4 ± 0.09^{a}

JMF: Jasmine flour; P2F: UPM Putra 2 flour; NMRF: NMR 152 flour; JMS: Jasmine starch; P2S: UPM Putra 2 starch; NMRS: NMR 152 starch; PV: peak viscosity; BD: breakdown; FV: final viscosity; SB: setback; PT: pasting temperature. Mean ± standard deviation that do not a superscript letter are significantly different ($p<0.05$) among the same column.

According to Tangsrianugul et al. [7], a decreasing value of BD was observed with increasing amylose content for all rice flour and starch samples [7]. In this study, a similar result was found for rice flour samples, where the BD decreased from 16.08 RVU in NMRF to 5.42 RVU in JMF as the presence of amylose stabilizes the swollen starch granules [16]. Furthermore, the amylose density of starch may contribute to higher BD and SB values due to the leaching of soluble amylose from the disassociation of α-1,4 linkages when heated and gelatinized [15]. NMRF, which had the lowest amylose content, exhibited significantly lower ($P<0.05$) values of FV and SB than JMF and P2F content in lines with [15-16]. Despite having a lower amylose content, P2F had a similar value of SB with JMF. Variations in the FV and SB of rice starch samples could be explained by the high amount of protein and lipid present in the samples, where these can also contribute to greater SB and FV due to the formation of amylose-protein or amylose-lipid complexes [17].

Rheological Properties
The rheograms of rice flour and rice starches in this study are illustrated in **Fig. 1**. It was observed that G' (**Fig. 1A**) was greater than G" (**Fig. 1B**) for all samples, except NMRF, with both moduli slightly increased with frequency. The results indicated that the flour and starch gels produced from all rice varieties except NMRF behaved similarly to a semi-solid food with a solid-like behaviour [7]. Furthermore, tan δ (**Fig. 1C**) was found to be smaller than unity for all starches, but only P2F showed similar characteristics to rice starch. These variations could arise from the presence of amylopectin with different branch chain lengths, whereby both moduli positively correlate with short branch chains and negatively correlate with long branch chains [18].

Table 1. Chemical compositions of flours and starches from different Malaysian rice varieties.

Sample	Moisture (%)	Ash (%)	Crude protein (%)	Crude fat (%)	Total dietary fibre (g/100 g)	Amylose content (%)
JMF	10.02 ± 0.00^{ab}	0.39 ± 0.00^{d}	10.48 ± 0.38^{a}	3.10 ± 0.69^{b}	1.60	22.80
P2F	9.11 ± 0.04^{b}	1.19 ± 0.00^{b}	9.60 ± 0.77^{a}	5.23 ± 0.41^{a}	2.20	19.40
NMRF	7.35 ± 0.50^{c}	1.26 ± 0.01^{a}	10.86 ± 0.18^{a}	5.62 ± 0.06^{a}	2.50	17.30
JMS	7.75 ± 0.00^{c}	n.d.	3.44 ± 0.17^{b}	2.34 ± 0.12^{b}	0.10	26.60
P2S	7.75 ± 0.21^{c}	0.53 ± 0.00^{c}	4.55 ± 0.56^{b}	2.17 ± 0.56^{b}	n.d. (<0.1)	23.10
NMRS	10.87 ± 0.15^{a}	0.43 ± 0.00^{d}	3.69 ± 0.20^{b}	2.55 ± 0.05^{b}	0.50	23.40

JMF: Jasmine flour; P2F: Putra 2 flour; NMRF: NMR 152 flour; JMS: Jasmine starch; P2S: Putra 2 starch; NMRS: NMR 152 starch; n.d.: not detected. Mean ± standard deviation that do not share a superscript letter are significantly different ($p<0.05$) among the same columns.

A lower tan δ was observed in rice starches than in rice flours, which shows that rice starch gels are more rigid and elastic. Moreover, JMS had the lowest tan δ which could be attributed by the high amylose content [7]. However, its flour counterpart exhibited a solid-like behaviour at a lower frequency (<0.54 Hz) and proceeded to liquid behaviour at a higher frequency (>0.61 Hz) as the tan δ increased with frequency (Figure 1). Thus, this indicates that JMF formed a weak and softer gel due to greater leaching of compounds. The erratic behaviour of NMR flour requires further study on other properties, especially on the structures of amylopectin, as amylopectin plays a crucial role in the rheological properties of starch.

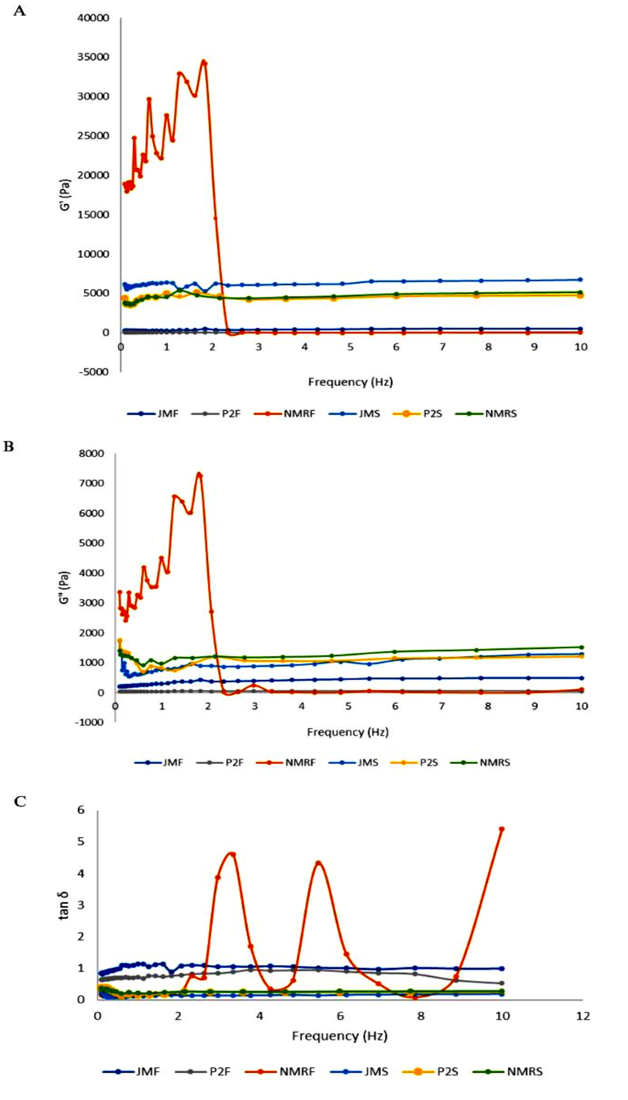

Fig. 1. Dynamic rheological measurements of rice flours and starches. Frequency dependence of (A) storage modulus (G'), (B) loss modulus (G"), and (C) loss tangent (tan δ) of rice flours and starches. JMF: Jasmine flour; P2F: UPM Putra 2 flour; NMRF: NMR 152 flour; JMS: Jasmine starch; P2S: UPM Putra 2 starch; NMRS: NMR 152 starch.

CONCLUSION

The two rice varieties, P2 and NMR, had similar amylose contents that are lower as compared to the commercial sample, JM rice. The flours of P2 and NMR contained similar protein content but higher fat, TDF, and ash contents than JMF. The isolated starch had lower protein, fat, TDF, and ash values. The amylose content affected the peak viscosity of rice starch, while the amylose content of rice flour showed a relationship with breakdown viscosity. The presence of other compounds such as protein and lipid influenced the pasting properties of rice flours and rice starches by forming complexes with amylose. Besides, rice flour and starch from all rice varieties, except NMRF, formed solid-like gels due to the higher G' observed than the G". Furthermore, the G' of rice flours and starches increased with amylose content. There was lower than δ values observed in rice starches relative to their flour counterparts.

ACKNOWLEDGMENT

This work was supported by the Universiti Putra Malaysia (Grant numbers: GP-IPM/2022/9740300).

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