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Research Article

Rapid Visco Analyzer Measurements of *japonica* Rice Cultivars to Study Interrelationship between Pasting Properties and Farming System

Amit Kesarwani,[1,2] Po Yuan Chiang,[3] and Shih Shiung Chen[4]

[1] *Department of Agronomy, College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263145, India*
[2] *Department of Agronomy, National Chung Hsing University, Taichung 40227, Taiwan*
[3] *Department of Food Science and Technology, National Chung Hsing University, Taichung 40227, Taiwan*
[4] *Department of Post Modern Agriculture, Ming Dao University, Changhua County 52345, Taiwan*

Correspondence should be addressed to Amit Kesarwani; getkesar@gmail.com

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Rheological properties influence the starch softness and cooking quality. Two *japonica* rice cultivars were studied that were cultivated under organic and conventional farming. Study was conducted for 2 years in popular *japonica* cultivars, that is, Kaohsiung number 139 and Taikeng number 16, which were grown twice a year in Taiwan. The results highlighted that major pasting properties such as peak viscosity, setback value, and pasting temperature improved under organic farming; however, in further analysis, eating and cooking quality reported no significant changes except aroma in rice.

1. Introduction

Starch is the major component of rice and described its physiochemical properties, such as gel strength and pasting properties [1–3]. The *japonica* cultivars are the major rice variety used for the preparation of important snacks and food materials in Asian countries. Most of the manufacturers prefer rice flour instead of starch for preparing processed products. However, the swelling and pasting properties of starch granule were influenced not only by starch solely but also by lipids, protein, and mineral compounds [1]. The starch granules of rice play active role; if there is less swelling of starch during gelatinization, the peak viscosity of starch paste will be lower [4]. To understand the viscosity properties of rice starch, the RVA works as a physical index for the estimation and as a precursor of cooking and processing qualities [2, 5–7]. Among the different RVA profiles, setback and breakdown values play significant role as compared to peak viscosity and others in the estimation of cooking quality of rice starch properties [6]. The characteristic of RVA is closely connected to taste quality of rice, where higher peak viscosity and breakdown and the smaller setback value enhance the grain quality. The rice cooked is soft and glutinous in texture [8].

The amount of amylose content in starch is positively correlated with rate and extent of retrogradation [9]. Study showed that cooked rice with higher amylose rice starch varieties had lesser stickiness, cooked dry, while, keeping higher setback values [10] or cultivars with lower breakdown value, peak viscosity and taste meter values fall in the category of inferior qualities rice variety [5].

The cause of alteration on rheological properties is mainly genotypic; however, environmental factors also play active role in description. Recent studies focused on the rice quality influenced with increase in fertilization level and cultivation method, but the results remain inconsistent and ambiguous. The ability to improve the eating quality of rice under organic practice is recent thrust under Asian background, and it has been found that, in the long term sustainable cultivation of rice for 16 years, the organic practice of rice cultivation [11] enhances the rice eating quality by consequently improving the starch viscosity (increases starch stickiness) as higher values of breakdown and maximum viscosity of brown rice flour. Also, continuous fertilization could improve the pasting properties of the rice starch except for setback, which is found on par at 50% N rate also [12]. Earlier studies also reported the inverse relationship between enhanced N fertilization in conventional farming and deterioration in cooking quality of rice [5, 12–17]. There are few studies in which cooked rice eating quality has been related with protein content [2, 5, 12, 17, 18] or secondary structures (amylose and amylopectin), where long chain amylopectin influenced negatively the breakdown viscosity, while amylose has positive correlation [19]. Thus, to understand the mechanism of chemical or organic fertilizer influence on rheological characteristics, the objective of this study is designed to compare the pasting properties of milled rice under conventional and organic farming.

2. Materials and Methods

2.1. Rice Sample Collection. Two commercial *japonica* rice cultivars, namely, medium and slender grain features (Taikeng-16 commonly known as TK-16) and short and round grain (Kaohsiung-139 commonly known as KSH-139), grown in Central Taiwan (Chiayi County) and Eastern Hualien County (Taiwan, ROC), respectively, were selected. These cultivars were cultivated twice a year in Taiwan as first crop (February to June) and second crop (August to November) during 2009–2011 [20]. All the products were labelled and certified [21] under Taiwan CAS agricultural product quality and Taiwan Formosa Organic Association (FOA). Rice cultivated under conventional farming used chemical fertilizers, pesticides, and recommended package of practice. Organic rice cultivars were strictly adhered to the cultivation practice given by Taiwan CAS and certification agency. Also, exclusion of any chemicals and only use of biodegradable inputs were allowed. Samples were well labelled without any physical or biological impurities and stored vacuum-packaged at room temperature until further analysis conducted.

2.2. General Chemical Analysis. Moisture, protein, ash, fat, and crude fiber were determined by American Association of Cereal Chemists approved methods [22]. Total carbohydrates content was estimated based on difference [23]. General details of mentioned physiochemical properties in both cultivars have been provided in Supplementary Material available online at http://dx.doi.org/10.1155/2016/3595326.

2.3. RVA Analysis of Rice. Milled rice sample for RVA analysis was ground with a grinder and sieved with 100-mesh screen. Three grams of the ground-milled rice was weighed (weight adjusted to 12% moisture basis) determined by AACC 44-31A [24] and with 25 mL distilled water was blended. After blending, the rice-water slurry was transferred to the RVA (RVA-Ezi, Newport Scientific, Warriewood, NSW, Australia). The pasting properties of rice flour slurry were measured on dry weight (dw) basis. The RVA was set at 50°C as the starting temperature and held at the same temperature for 1.5 min

Table 1: Detail of RVA analysis cycle of rice.

Time (HH:MM:SS)	Type (temp/speed)	Value (°C) or rpm
00:00:00	Temp	50
00:00:00	Speed	480
00:00:01	Speed	960
00:00:10	Speed	160
00:01:30	Temp	50
00:05:15	Temp	95
00:07:15	Temp	95
00:11:00	Temp	50
00:17:00	temp	50
End of test time: 00:17:00	Initial idle temp (°C) = 50	

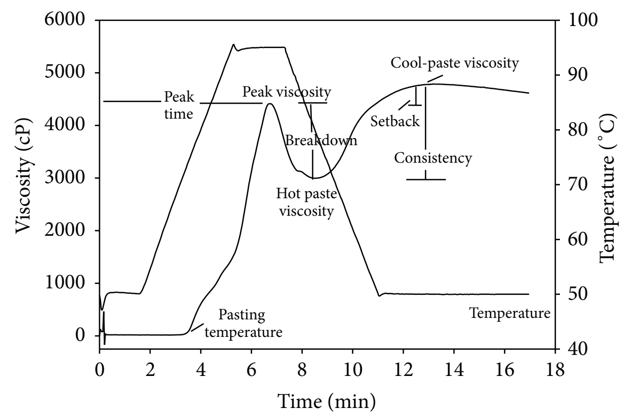

Figure 1: RVA profiles of rice starches.

(Table 1). Lately, the slurry was heated to 95°C at the rate of 12°C per min while being maintained for 2 min at paste temperature. Then, temperature is brought down to 50°C with the decreasing rate of 12°C per min and kept for 6 min at same temperature. The total processing time was about 17 min. The paste viscosity properties of the rice examined were peak viscosity (P) (maximum viscosity between the heating and holding cycles), hot paste viscosity (HP) (minimum viscosity after peak), and cool-paste viscosity (CP) (the viscosity of the paste after cooling). All values were recorded in centipoise (cP). For detailed study, three derived viscosity values were also calculated as follows (Figure 1): breakdown viscosity (BD) (peak viscosity minus hot paste viscosity), setback viscosity (SB) (cool-paste viscosity minus peak viscosity), and consistency viscosity (CON) (cool-paste viscosity-hot paste viscosity). The pasting temperature (PT) and peak time (PkT) were also recorded [25, 26]. The measurements were in triplicate.

2.4. Statistical Analysis. From both farming practices, 5 samples with 3 replications were formulated for every parameter. Later, all data compilation were utilized for correlation estimation. The data were subjected to ANOVA using SAS version 8.1 (SAS Institute, Cary, NC) and expressed as means ± standard errors of each factor. Duncan's Multiple Range Test was further used to determine significant differences between means and was considered statistically significant if $P \leq 0.05$.

Table 2: F-values for amylographic characteristics (cP) of rice cultivars influenced by agricultural practice in two crop seasons.

Source	PkT	PT	P	HP	BD	CP	CON	SB
Properties	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗
Season (S)	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗
Treatment (T)	∗∗∗∗	∗∗	∗∗∗∗	∗∗∗∗	ns	∗∗∗∗	∗∗∗∗	∗∗
Cultivar (C)	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	ns	∗∗∗∗
S∗T	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗
S∗C	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗
T∗C	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗	∗∗∗∗	∗∗∗∗	∗∗∗∗	∗∗∗∗
S∗T∗C	∗∗∗∗	∗∗	∗∗∗∗	∗∗	∗∗∗∗	∗	∗∗∗∗	∗∗∗∗

PkT: peak time; PT: pasting temperature; P: peak viscosity; HP: hot paste viscosity; BD: breakdown viscosity (P-HP); CP: cool-paste viscosity; CON: consistency viscosity (CP-HP); SB: setback viscosity (CP-P); ns: values statistically nonsignificant ($P > 0.05$).
∗ = $P \leq 0.05$; ∗∗ = $P \leq 0.01$; ∗∗∗∗ = $P \leq 0.0001$.

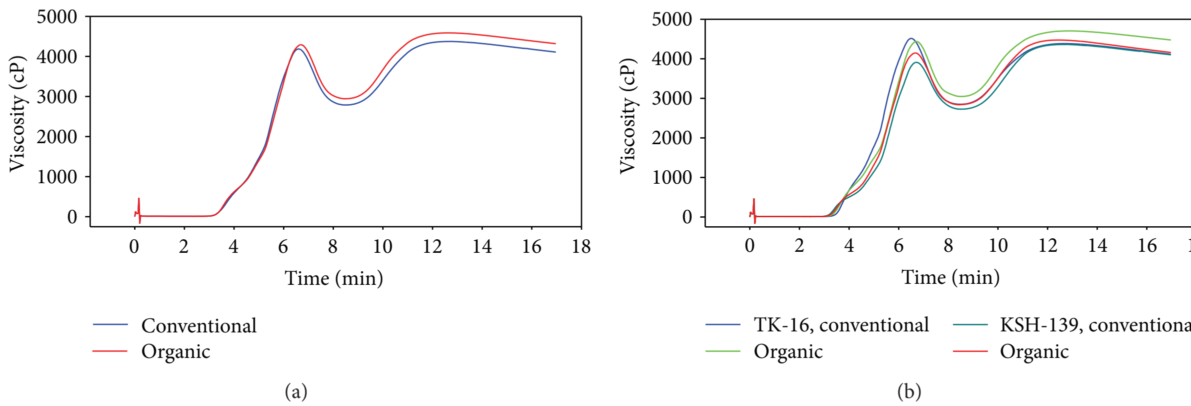

Figure 2: RVA profiles of rice cultivars compared according to (a) farming practices and (b) varietal differences.

3. Results and Discussions

RVA breakdown is caused by disruption of the gelatinized starch granule structure [27]. Thus, the extent of breakdown is caused by the difference between the viscosity when swollen, gelatinized starch granules existed and the viscosity when the gelatinized starch granules are disrupted, either partially or completely [19]. The cooking behavior of starches and the viscosity of the resulting pastes can be studied with an instrument called Rapid Visco Analyzer (RVA). The RVA profile is generally used as one of the indirect indicators for eating quality in rice sensory evaluation. Viscosities at the start of the holding period and during cooling reflect the ease of cooking starch and paste stability, respectively. Each viscosity is used to identify a particular characteristic of the rice variety.

Basically the starch retrogradation relatively controlled the increase in paste viscosity [28], whereas shear and rupturing of swollen starch granules are regulated by breakdown viscosity. Setback viscosity implies the degree of retrogradation. The study showed that usually amylographic properties are significantly influenced by abiotic factors (Table 2) (except breakdown and consistence viscosity). Also, the cultivars responded differently ($P \leq 0.05$) in each season cultivated under different farming (Figure 2).

The cultivars response was influenced by seasonal changes while cultivating under organic and conventional farming. It was estimated that second crop (S2, S4) had higher pasting properties as compared to first crop (data not shown). Similarly, it was also clear that pasting properties were significantly higher in organic farming, where second crop (S2) organic rice had much influence on pasting properties (Table 3) except pasting temperature ($P \leq 0.05$). Tamaki et al. [11] also favoured increase in peak viscosity and breakdown value due to continuous organic farming.

The inconsistent results prevail in sustainability of amylographic characteristics under studied cultivars when grown in various agronomic practices. The organically grown cultivars TK-16 and KSH-139 resulted in lower RVA values (except peak viscosity in TK-16 and peak time and pasting temperatures of KSH-139, resp.).

Increase in protein content due to higher fertilization with N nutrition only increases the water-insoluble storage proteins but reduces the proportion of cysteine (disulphide bonding compound). The disproportionate ratio of disulphide bond and insoluble protein could ultimately reduce the viscosity. Moreover, the increasing level of protein thickened the wall around starch, which probably reduced the rate of pasting [2]. These specific protein natures (oryzenin, in case of rice) encircle the starch molecule to avoid the breakdown

Table 3: Amylographic characteristics (cP) of rice cultivars as affected by treatments (conventional or organic).

Properties	Treatment	
	Organic	Conventional
PkT (min)	6.7a	6.6b
PT (°C)	71.6b	71.8a
P	4382a	4249b
HP	2939a	2784b
BD	1443a	1465a
CP	4318a	4109b
CON	1380a	1325b
SB	−63a	−140b

PkT: peak time; PT: pasting temperature; P: peak viscosity; HP: hot paste viscosity; BD: breakdown viscosity (P-HP); CP: cool-paste viscosity; CON: consistency viscosity (CP-HP); SB: setback viscosity (CP-P). Values for each parameter followed by a different letter within each row are significantly different, $P \leq 0.05$ (Duncan's Multiple Range Test).

under high shear stress to enhance the swelling process further; however, it restricted the swelling in gelatinization process of starch granule under low shear stage [3]. The different level of fertilization significantly affects the rice quality and increases the protein content, while decreasing the peak, trough, and final viscosity in rice [2, 29]. Also, rice varieties with different qualities had also difference in the rate and amount of nitrogen accumulation [5]. Other findings show that the differences in pasting properties and textural properties of cooked rice were due to difference in protein content compared to rice being grown under different fertility management [12].

Another concept also suggested that it might be attributed to balanced Mg/K ratio as a suitable index of cooking properties with significant correlation with pasting properties [11]. Likewise, in a long term cultivation of rice, Bryant et al. [7] recorded decrease in peak and final paste viscosities in fertilization through chemicals in rice; however, no differences of Rapid Visco Analyzer profile were noticed in various rice crop rotations. Earlier further conformity of above findings was also reported as reduced peak [12], breakdown viscosity [14], and increment of setback viscosity [15] in the effect of enhanced N fertilization. The cooked rice of upland rice tends to be soft and sticky when the level of N increases from lower to optimum amount, which implies the lower value of breakdown and setback viscosity [16]; however, the further dose would deteriorate the cooking quality of rice grains. The changes in protein concentration can influence the pasting properties of rice [2]. The protein contents of rice grain are negatively correlated with peak and breakdown viscosity but positively with setback values [12]. Despite the differences in protein content with no effect on RVA profile of rice cultivar, this might be attributed to other secondary structures of rice (amylose and amylopectin), where long chain amylopectin influenced negatively the breakdown viscosity, while amylose has positive correlation [19].

The above findings of variation in amylographic characteristics due to crop season or agronomic practice were consistent with Kuo et al. [30] who also reported that peak viscosity, pasting temperature, and other properties were affected by the growth season. The high variation in most of the characteristics in both cultivars suggests that the genetic effects are the important part of the total variation, while findings were paralleled to the work of Gravois and Webb [31] and Kuo et al. [30] that indicated that starch viscosity properties were controlled by single-locus genes with additive effects.

An inverse relationship was established in our study of cooked rice hardness in sensory evaluation and RVA setback values (Table 4). The results were counterpart of earlier agreements which provided positive correlation between hardness (Supplementary Material) and setback values [4, 32]. Negative interaction between two properties might be attributed to growing conditions and genotypic difference of cultivars. Significant higher protein content was reported in conventionally grown rice compared to organic rice which might also be attributed to overall hardness in conventional product, whereas high temperature during grain filling stage causes the low moisture content of rice that increases hardness of spring crop compared to fall season. Lower content of amylose in organic rice and higher springiness bring the soft starch of rice compared to conventional samples (Supplementary Material). Higher content of protein tends to produce less swelling of starch grain by forming a gel layer surrounding the grain and let it absorb less water for swelling, while comparatively enhancing the hardness. Contrary results of higher cohesiveness and hardness of conventionally grown rice were reported in earlier studies with better score for eating quality compared to organic rice [33]. Higher peak and setback viscosity were reported in organic rice while breakdown values were lower compared to conventional product. There was a negative correlation found between peak and setback values in relation to crude protein content (−0.18 and −0.03, resp.) of rice (Table 4), whereas there is positive correlation with breakdown values (0.26). But all the correlation values were highly nonsignificant and in contrary to findings of Champagne et al. [12]. Their results presented that protein content was in negative correlation with peak and breakdown values and in positive correlation with setback viscosity. Negative correlation was also found between protein content and hot paste viscosity (−0.28), which was in findings similar to our earlier results.

The partial enhancement in RVA properties of rice cultivars grown under organic farming was further analyzed for sensory properties in our study. The study reflected no significant improvement in cooking and eating quality when cultivated organically [13]; also see Supplementary Material. It was clearly indicated that future analysis needs to be focused on diversified cultivar investigation. Also, physical and chemical properties need to be interlinked with the grown condition of rice in various seasons.

4. Conclusion

The pasting properties has been improved slightly under organic farming, where peak viscosity and setback value had direct correlation with starch hardness. The pasting temperature was significantly lower in organic rice which

Table 4: Correlation coefficient (r) among various physicochemical characteristics of rice grain.

Factors	Correlation coefficient (r)					
	P	HP	BD	CP	CON	SB
Amylose	0.06 (ns)	−0.25 (ns)	−0.08 (ns)	−0.16 (ns)	−0.02 (ns)	−0.08 (ns)
Crude protein	−0.18 (ns)	-0.28^{*}	0.26 (ns)	0.17 (ns)	0.38^{**}	−0.26 (ns)

P: peak viscosity; HP: hot paste viscosity; BD: breakdown viscosity (P-HP); CP: cool-paste viscosity; CON: consistency viscosity (CP-HP); SB: setback viscosity (CP-P); ns: values statistically nonsignificant ($P > 0.05$). Values are significant difference if $* = P \leq 0.05$ (significant); $** = P \leq 0.01$ (highly significant).

causes granulation and swelling of amylopectin at earlier stage. The improved starch property was noticed under Taikeng number 16 cultivar when grown under organic practice; however, improvement in eating and cooking quality remains negligible variant due to changes in farming strategy (nonsignificant). Multivariate analysis needs to be conducted using photoinsensitive rice genotypes during cultivation [18].

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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