



Impact of amylose content on starch retrogradation and texture of cooked milled rice during storage

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ABSTRACT

Milled rice from 11 varieties, with amylose levels from 1.2 to 35.6% dry base, were collected to study the impacts of amylose content on starch retrogradation and textural properties of cooked rice during storage. The relationship between amylose content and different properties was determined using Pearson correlation. Starch retrogradation enthalpy (ΔH_r) of cooked rice was determined by differential scanning calorimetry. ΔH_r values were found to be positively correlated with amylose content ($0.603 \leq r \leq 0.822$, $P < 0.01$) during storage. Textural properties were determined by a Texture Analyser. The hardness of cooked rice showed a positive correlation with amylose content ($0.706 \leq r \leq 0.866$, $P < 0.01$) and a positive correlation with ΔH_r of cooked rice ($r = 0.650$, $P < 0.01$) during storage. The adhesiveness showed a negative correlation with amylose content ($-0.929 \leq r \leq -0.678$, $P < 0.01$) and a negative correlation with ΔH_r of cooked rice ($r = -0.833$, $P < 0.01$) during storage. Hardness showed a negative correlation with adhesiveness ($r = -0.820$, $P < 0.01$). These results indicated that amylose content has significant effects on starch retrogradation and textural properties of cooked rice. The cooked rice with high amylose content is easy to retrograde, the cooked rice with low amylose content retrograded slowly. Starch retrogradation contributes to the changes of textural properties of cooked rice during storage.

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1. Introduction

In recent years, there has been an increased demand for ready to eat meals and many products with cooked rice have been developed. Cooked rice is one of the most important ready to eat meals in South East Asia including China. These products usually are packaged in polyethylene bags after cooking and refrigerated storage to prolong their shelf life. During refrigerated storage, desired quality of cooked rice, e.g. starch retrogradation, loss of flavor/aroma and colour, increased hardness and decreased adhesiveness can change. Starch retrogradation and texture are two of the most important quality parameters of cooked rice. However, many factors influence starch retrogradation and texture of cooked rice during storage, such as rice variety, storage conditions, amylose content, starch type, degree of milling, water to rice ratio, cooking methods, cooling methods and so on.

Recently, some studies have focused on the effects of rice cultivars (Singh et al., 2005), rice starch structure (Ong and

Blanshard, 1995; Ramesh et al., 1999) and proteins on the textural properties of cooked rice (Martin and Fitzgerald, 2002), and the storage temperatures also affected the starch retrogradation and textural properties of cooked milled rice (Perdon et al., 1999). Other studies reported that amylose influences the textural properties of cooked rice (Ong and Blanshard, 1995; Singh et al., 2005), and the amylose content was correlated with the retrogradation behaviour of rice flour (Varavinit et al., 2003). The proportion of amylose and amylopectin affected the hardness of rice starch gel (Hibi and Hikone, 1998), and the ratio of amylose and amylopectin influenced starch gel retrogradation rate after storage (Mariotti et al., 2009). Varavinit et al. (2003) found gelatinization temperatures of Thai rice starch were highly positively correlated with amylose levels and low amylose starch showed a low degree of retrogradation. Lu et al. (2009) reported that amylose content influences the dynamic viscoelasticity of rice starch gel. High amylose starch showed higher moduli, lower loss tangent values and higher retrogradation rate, and Japonica rice starch showed slow retrogradation rate although it contains a similar amount of true amylose. Based on the literature cited above, amylose levels could significantly influence the starch or flour gel properties and retrogradation properties. However, there have been few investigations done on the impacts of amylose

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content on starch retrogradation and textural properties of cooked milled rice during storage. A relationship between amylose content and starch retrogradation and textural properties of cooked rice during storage are still not very clear. Therefore, the objective of this study was to correlate amylose contents of milled rice from various rice cultivars, in order to further understand the role of amylose on starch retrogradation and textural properties of cooked rice during storage.

2. Materials and methods

2.1. Materials

Eleven different cultivars of rice were used in the study (Table 1). The cultivars of YYou1 (YY1), Yixiang3003 (YX3003) and Keyou21 (KY21) were collected from Hunan Rice Research Institute, Hunan province, China; The Songnuo2 (SN2), Suijing4 (SJ4), WuYou1 (WY1) and Daohuaxiang2 (DH2), were collected from Heilongjiang Rice Research Institute, Heilongjiang province, China; Ningling42 (NJ42), was collected from the farm of NingxiaLianhu, Ningxia province, China; TYou15 (TY15) was collected from Hanzhong city, Shanxi province, China; The ZengyeSimiao6 (SM6) was purchased in the city of Zengcheng, Guang dong province, China. Thai Jasmine rice (TJ) (Produced by Thaihefa Co. LTD, Thailand) was purchased in Wal-Mart super-market. The moisture content of all milled rice was 11–13%. All the samples were stored at 4 °C in a refrigerator before experiments.

2.2. Chemical analysis

Total carbohydrates content (TCC) was determined by the phenol–sulphuric acid method (Adebooye and Singh, 2008). Apparent amylose contents (AAC) (absolute content of amylose in rice) were determined by iodine colorimeter at 620 nm using a potato starch standard mixture (Juliano et al., 1981). Protein contents (PC) (N*5.95) were determined by Micro-Kjeldahl method 920.87 of AOAC (2000) and lipid contents of samples were determined by official method 923.05 of AOAC (2000). The results were reported on a dry base. All the experiments were performed at least in triplicate and results are presented as mean values.

2.3. Rice cooking

Experiments were conducted with an automatic rice cooker (CFXB4003-A1, 4.0L, 700 W, 220 V, 50 Hz, Guangzhou domestic appliance Ltd., China). 1000-g rice was soaked in a pot for 30 min

with 1300 ml of tap water. After the rice cooked for 25 min, the thermostat coupled with micro-switch automatically switched off the automatic rice cooker. The cooked rice samples were held in the rice cooker for an additional 15 min. Finally, about 2000-g cooked rice was removed from the rice cooker to a stainless tray for pre-cooling in a –18 °C refrigerator, to room temperature. After cooling, the cooked rice in the centre layer of the tray was taken out, packaged in polyethylene bags and sealed as quickly as possible (0 h of storage).

2.4. Cooked rice storage

Packed cooked rice samples were stored in a refrigerator at 4 ± 1 °C for 0, 1, 4, 7, 11 and 14 days. The sealed bags of cooked rice were taken out at different storage times, and allowed to equilibrate for 1.5–2.0 h in an incubator (22 ± 0.2 °C) before texture determination. All experiments were performed in triplicate.

2.5. Textural profile analysis

Textural profile analysis (TPA) of the cooked rice was performed using a Texture Analyser (TA.XT.plus, Texture Technologies Corp., UK) with a 50 kg load cell with a two-cycle compression. The analyser was linked to a computer that recorded the data via a software program called Texture Expert Excede Version 1.0 (Stable Micro Systems Software). A two-cycle compression force versus time program was used to compress the samples till 90% of the original cooked grain thickness, returned to the original position and again compressed. A 6-mm diameter ebonite probe was used to compress 3 grains, with pre-test speed of 1.0 mm/s, test speed and post-test speed of 0.5 mm/s. Parameters recorded from the test curves were hardness and adhesiveness. All textural analyses were replicated ten times per sample and results are presented as mean values.

2.6. Differential scanning calorimetry

Starch retrogradation properties of cooked rice was analyzed by a Perkin Elmer pyris 6 differential scanning calorimeter (DSC) (Perkin Elmer, USA). The DSC was calibrated with indium (melting point = 156.6 °C, $\Delta H_f = 28.6$ J/g) and an empty pan as a reference. The cooked rice samples were prepared using the method of Kim et al. (1997) after texture determination, cooked rice was mixed with 99% ethanol (1:4, v/v) and dehydrated for 12 h, then passed through a Büchner funnel, dried at 37 °C in an air drier for 24 h and passed through a 100-mesh sieve after milling. A total weight of 4.0 mg cooked rice samples and distilled water (1:2, w/w) was placed in pre-weighed aluminium sample pans (PE0219-0062). The pans were sealed hermetically to prevent moisture loss and kept overnight. For all DSC runs, a sealed empty aluminium pan was used as reference. The sample was held isothermally at 20 °C for 1 min before heating from 20 to 140 °C at 10 °C/min. The peak temperature and the enthalpy (ΔH_r , J/g) associated with the retrograded starch melting peak appearing between 40 and 70 °C were calculated. ΔH_r was used to indicate the degree of starch retrogradation. The DSC measurements were performed in triplicate, and results are presented as mean values.

2.7. Statistical analysis

All tests were performed at least in triplicate. Pearson's correlation coefficient analyses and analysis of variance (ANOVA) using Duncan's multiple range test were performed at $P < 0.05$ or $P < 0.01$ using SPSS 12.0 software (SPSS Inc., USA).

Table 1
Chemical composition of the different rice varieties (% dry base).

Type	Variety	AAC	TCC	PC	LC
Waxy	SN2	$1.2^a \pm 0.2$	$80.75^a \pm 1.47$	$6.93^a \pm 0.24$	$1.11^a \pm 0.07$
Very low amylose	TJ	$5.96^b \pm 0.56$	$80.51^a \pm 1.91$	$7.94^b \pm 0.13$	$0.87^b \pm 0.19$
Low amylose	SJ4	$11.67^c \pm 0.68$	$80.75^a \pm 1.97$	$8.36^c \pm 0.19$	$1.20^a \pm 0.12$
	DH2	$12.78^c \pm 0.80$	$80.17^a \pm 1.28$	$6.93^a \pm 0.24$	$1.44^c \pm 0.10$
	NJ42	$13.18^d \pm 0.63$	$79.74^a \pm 1.25$	$7.40^d \pm 0.23$	$0.78^b \pm 0.12$
	WY1	$13.50^d \pm 0.50$	$81.03^a \pm 1.65$	$7.66^d \pm 0.29$	$1.04^a \pm 0.23$
	YY1	$14.85^e \pm 0.53$	$79.74^a \pm 1.25$	$8.16^e \pm 0.02$	$0.76^b \pm 0.12$
	YX3003	$15.20^e \pm 0.50$	$79.71^a \pm 1.28$	$8.14^e \pm 0.03$	$0.78^b \pm 0.22$
Intermediate amylose	SM6	$23.94^f \pm 0.21$	$81.33^a \pm 2.02$	$8.63^e \pm 0.39$	$0.74^b \pm 0.04$
	TY15	$27.59^g \pm 0.87$	$79.75^a \pm 1.02$	$8.33^e \pm 0.21$	$0.68^b \pm 0.2$
High amylose	KY21	$35.73^h \pm 0.68$	$80.33^a \pm 1.22$	$6.55^f \pm 0.02$	$0.78^b \pm 0.14$

Data are means $\pm$ standard deviation, $n = 3$. ^{a–h} Means in the same column followed by the same lowercase superscript letters are not different ($P > 0.05$). AAC: apparent amylose content (absolute content of amylose in rice); TCC: total carbohydrates content; PC: protein content; LC: lipid content.

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