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Original Research Article

Effect of mixed high amylose rice flour on pasting properties and texture of rice noodles

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ABSTRACT

Rice noodles are one of rice products which are widely consumed in Asia. Since amylose network plays an important role in structure of rice noodles, high amylose rice is usually used for making rice noodles. However, rice noodles made from different cultivars give different qualities. Unfortunately, mixed cultivars rice flour was usually used to produce rice noodles in industry, leading to high variation in noodle qualities. Therefore, the objective of this research is to investigate the effect of mixed flour made from various high amylose rice cultivars on chemical composition, pasting properties, and texture of fresh rice noodles. Simplex-centroid mixture design was applied to mixed 3 rice cultivars (Chainat1 (CNT1), Pitsanulok2 (PSL2), and Suphanburi1 (SPR1)) into 7 formulas. All rice cultivars had similar amylose (30.61-31.28%), fat (0.09 – 0.11%), and ash content (0.25 – 0.30%). Protein content of SPR1 (7.77 ± 0.01%) was the highest, following by CNT1 (6.53 ± 0.09%) and PSL2 (6.15 ± 0.16%), respectively ($p \leq 0.05$). PSL2-SPR1 mixed rice flour had amylose content (31.95 ± 0.21%) significantly higher than predictive value (31.09 ± 0.20%) ($p \leq 0.05$). Even though the amylose content values of all rice cultivars were similar, CNT1 had the highest, while SPR1 had the lowest setback and final viscosity among samples. Setback and final viscosity of all mixed formulas were slightly different from the predictive value (less than 10% difference). Hardness of CNT1-PSL2-SPR1 noodles (18291.20 ± 830.98 g) was obviously lower than predictive value (21040.29 ± 332.11 g). This might be an influence of CNT1 which had the lowest hardness (19323.05 ± 1789.57 g) among all cultivars. CNT-PSL noodles had noticeably lower adhesiveness (154.68 ± 33.55 g.sec) than predictive value (202.90 ± 14.68 g.sec). This might be an influence of PSL 2 which had the lowest adhesiveness (118.54 ± 42.85 g.sec). However, the variation in texture of mixed flour rice noodles was not directly proportional to the ratio of each rice cultivars in mixed flour. It can be said that in order to design the texture of rice noodles from mixed high amylose rice flour, it cannot be calculated based on only the textural data of pure cultivar with the mass percentage of each cultivar. The alteration effect from mixing should be considered.

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INTRODUCTION

Rice noodles are one of rice products which are widely consumed in Asia. High amylose rice (amylose content > 25%) is usually used for making rice noodles, since amylose network plays an important role in structure of rice noodles (Metres *et al.*, 1988; Fu, 2018). However, each high amylose rice cultivar gives different textural properties of rice noodles (Bhattacharya *et al*., 1999). Generally, broken rice grain, collected as mixed rice cultivars grains at miller, is usually used as raw material of rice noodle industry. The use of mixed rice cultivars may alter the qualities of rice noodles, especially texture. There were several researches about effect of mixed different amylose content rice cultivars, or mixed starch from different plant on pasting properties and texture of rice gel or rice noodles. The mixed high amylose rice with low amylose rice caused in alteration of peak viscosity, and setback viscosity of mixed rice flour. The alteration was predictable based on the mass percentage of each rice cultivar (Basutka *et al*., 2015; Choi *et al*., 2006). Puncha-arnon *et al.* (2008) reported that canna-popato, canna-mungbean, and canna-rice mixed starch gel has lower hardness than predictive value calculated based on mass percentage. The similar result was also reported by Yadav *et al.* (2011). They founded that mixed rice noodles from pigeon and rice starch had lower hardness than predictive value. Therefore, the properties of mixed flour can be classified into additive behavior, i.e., the property of the mixed flour can be predicted from each flour component, and non-additive behavior, i.e., the property of mixed flour cannot be predicted (Vu *et al*., 2016). According to the use of mixed high amylose rice cultivars in rice noodle industry, the quality of noodle such as texture may be altered, and may not be predictable from the mass percentage of each rice cultivar. This leads to the difficulty in designing the desirable texture of rice noodles from mixed rice flour. Unfortunately, the data about the effect of mixed high amylose rice cultivars on pasting properties and textural properties of rice noodles were limited. Thus, the objective of this research was to investigate the effect of mixed flour made from 3 high amylose rice cultivars including Chainat1 (CNT1), Pitsanulok2 (PSL2), and Suphanburi1 (SPR1) on chemical composition, pasting properties, and texture of fresh rice noodles.

Materials and methods

Materials

Three high amylose rice cultivars including Chainat1 (CNT1), Pitsanulok2 (PSL2), and Suphanburi1 (SPR1) were purchased from Chainat Rice Seed Center, Klong Luang Agricultural cooperative, and Ratchaburi Rice Research Center, respectively. Rice sample were wet milled by colloid mill according to the method from Sangpring *et al*. (2015). According to the simplex-centroid mixture design, the proportions of rice flour mixtures with ternary components are shown in Table 1. Seven mixtures with different rice cultivars (X1:CNT1, X2: PSL2 and X3: SPR1) were mixed by Ribbon mixer (Reliance Tech-Service Co.Ltd., Thailand).

Chemical composition

All flour samples were measured moisture, protein, fat, ash content of all formulas were measured according to AACC method

44-15A, AACC method 46-12, AACC method 30-25, AACC method 08-01, respectively (AACC, 1999). Amylose content of all samples were analyzed according to the method of Juliano (1971).

Table 1. Proportions of rice flour mixtures prepared according to simples mixture design.

Mixture	Ingredient proportions (%)		
	X_1	X_2	X_3
1	100	-	-
2	-	100	-
3	-	-	100
4	50	50	-
5	50	-	50
6	-	50	50
7	33	33	33

Pasting properties of rice flour

Pasting properties of all flour samples were determined following the method of Li and Corke (1999) using Rapid Visco Analyzer (RVA) (RVA 4500, Perten instrument Ltd, Australia). Flour sample (2.5 g dry basis) was suspended in 25 ml of distilled water. The suspension was equilibrated at 50 °C for 2 min, heated to 95 °C at rate of 6°C/min, held at 95 °C for 5 min, cooled to 50°C at the rate of 6 °C/min, and held at 50 °C for 5 min. The peak viscosity (PV), through, breakdown (BD), final viscosity (FV), setback viscosity (SB), and pasting temperature (PT) were analyzed.

Preparation of flat rice noodles

Flat rice noodles of all rice flour formulas were prepared according to the method of Sangpring *et al*. (2015). Rice flour was mixed with deionized water to obtain 64% moisture content flour slurry. Sixty grams of slurry were evenly poured on a stainless tray. The tray with slurry was steamed at 100 °C for 3 min. The rice noodle sheet with a thickness of 1.00 ± 0.01 mm was removed from tray, and cut into 200 × 15 mm strands.

Textural properties of flat rice noodles

All rice noodle samples were measured their texture within 15 min after preparation. Texture profile analysis (TPA) of all rice noodles samples was conducted using a texture analyzer (TA-XT PLUS; Stable Micro Systems, Ltd., Surrey, UK) with a 50 kg load cell according to the modified method of Bhattacharya *et al*. (1999). One noodle strand (15mm width and 50 mm long) was compress twice by a P/100 probe with a deformation of 75% strain at speed of 1.0 mm/s. The pause between the first and second compressions was 1 s. Hardness, adhesiveness, springiness, and cohesiveness were analyzed from the measured profile. At least 10 noodle strands were measured for each treatment. Each measurement was taken in 2 replications.

Statistical analysis

All experiment were conducted for 2 replications. Analysis of variance (ANOVA) was used to analyze all data and the differences between mean values were determined using the Duncan’s multiples range comparison test ($p \leq 0.05$). All statistical analyses were done using SPSS version 19.

RESULTS AND DISCUSSION

Chemical compositions of pure cultivars and mixed rice flour

All rice cultivars had similar amylose (30.61-31.38%), fat (0.09-0.11%), and ash content (0.25-0.30%) (Table 2). However, protein content of SPR1 (7.77 ± 0.01%) was the highest, following by CNT1 (6.53 ± 0.01%) and PSL2 (6.15 ± 0.16%), respectively ($p \leqslant 0.05$). Chemical composition of all mixed flour formulas (predictive value) were calculated based on data from pure cultivars according to mass percentage of each cultivar in formulas. Amylose and protein content of mixed flour were slightly altered from the predictive values. PSL-SPR, and CNT-PSL-SPR mixed rice flour had amylose content slightly different from predictive value as shown in Table 3 ($p \leqslant 0.05$), but it still in the range of amylose content of pure rice cultivars value. The formula which contains SPR1, eg. CNT-SPR, PSL-SPR, and CNT-PSL-SPR mixed rice flour, had slightly higher protein content than predictive values ($p \leqslant 0.05$) as shown in Table 3. This might be an influence of high protein content in SPR flour.

Pasting properties

Even though the amylose content values of all rice cultivars were similar, there were differences in their pasting properties as shown in Table 4. CNT1 had the highest peak viscosity, breakdown viscosity, final viscosity, and setback viscosity. This suggested that CNT1 starch granules had high swelling power, but gelatinized CNT1 starch granules were easily broken due to shear force among three cultivars. In contrast, PSL2 had lowest peak viscosity and break down viscosity. This implied that PSL2 starch had the lowest swelling power, and the gelatinized starch granule resisted to shear force. SPR1 had peak viscosity and breakdown viscosity closed to PSL2, but had the lowest final and setback viscosities among samples. This may be attributed to the highest protein which may retard the swelling leaching of solid during heating (Deryke. *et al*., 2005). Choi *et al*. (2006), Hongsprabhas (2007), and Basutka *et al*. (2015) mentioned that the pasting properties of mixed rice flour could be predicted based on mass percentage calculation. However, pasting properties of some mixed rice flour formulas in our work slightly altered from the predictive value (less than 10%) as shown in Table 5. The alteration depends on the existing of some cultivars. The formulas which contained CNT1 tended to have slightly higher final viscosity and setback than predictive values. This is similar to the result of Leethanapanich *et al.* (2016) in the comingled parboiled rice which reported that the pasting profile of commingled rice sample were similar to the individual cultivar. On the other hand, PSL-SPR formula had all pasting properties obviously lower than predictive value (more than 10%), and the values shifted close to PSL2 cultivar. Pasting temperature of all mixed flours except CNT-SPR was higher than predictive value. It was closed to the cultivar that had higher pasting temperature.

The above results indicated that pasting properties of mixed flour cannot be predicted directly based on the mass percentage of each cultivar in formulas, but it tends to shift close to the most influence cultivar. Pucha-arnon *et al*. (2008) reported that mixed starch from various source caused the alteration of pasting properties of mixed starch from predictive value. They reported that the alteration of pasting properties might relate with the difference in swelling capacity of each starch. In case of the canna-rice starch mixture, canna starch had lower in the swelling ability than the pure starch. This was attributed to rice starch surrounded the canna starch granule, and inhibited canna starch granule to swell. Therefore, the alteration in pasting properties of mixed rice flour in our work may be attributed to the difference in swelling ability of each rice cultivar. Thus, the further study on the swelling ability of starch of each rice cultivar in pure and mixed flour is necessary.

Table 2. Chemical composition of pure cultivars and mixed rice flour.

Pure cultivars/ Mixed flour	Moisture Content (%db)	Amylose Content (%db)	Ash Content ^{ns} (%db)	Fat Content ^{ns} (%db)	Protein Content (%db)
CNT1	8.45 ± 0.09 ^{cd}	30.77 ± 0.23 ^{bc}	0.30 ± 0.02	0.09 ± 0.00	6.53 ± 0.09 ^{d}
PSL2	9.94 ± 0.02 ^{a}	31.28 ± 0.45 ^{ab}	0.25 ± 0.01	0.10 ± 0.01	6.15 ± 0.16 ^{e}
SPR1	8.08 ± 0.02 ^{e}	30.63 ± 0.23 ^{bc}	0.27 ± 0.03	0.11 ± 0.02	7.77 ± 0.01 ^{a}
CNT-PSL	9.20 ± 0.05 ^{b}	30.65 ± 0.30 ^{bc}	0.24 ± 0.02	0.11 ± 0.01	6.40 ± 0.06 ^{de}
CNT-SPR	8.29 ± 0.10 ^{de}	30.97 ± 0.40 ^{bc}	0.24 ± 0.02	0.08 ± 0.00	7.47 ± 0.20 ^{b}
PSL-SPR	9.03 ± 0.05 ^{b}	31.95 ± 0.21 ^{a}	0.26 ± 0.07	0.10 ± 0.01	7.14 ± 0.03 ^{c}
CNT-PSL-SPR	8.82 ± 0.10 ^{bc}	30.42 ± 0.60 ^{c}	0.23 ± 0.03	0.10 ± 0.00	6.97 ± 0.01 ^{c}

Values are expressed as means ± SD (n=2).
Different letters in the same column indicate significant difference at $p \leq 0.05$.
ns = not significant.

Table 3. Predictive and actual chemical composition of pure cultivars and mixed rice flour

Mixed flour		Chemical Composition (%)				
		Moisture	Amylose	Ash	Fat	Protein
CNT-PSL	Predictive	9.20 ± 0.04	31.16 ± 0.20	0.27 ± 0.01	0.10 ± 0.00	6.34 ± 0.08
	Actual	9.20 ± 0.05ns	30.65 ± 0.30ns	0.24 ± 0.02ns	0.11 ± 0.01ns	6.40 ± 0.06 ns
CNT-SPR	Predictive	8.27 ± 0.04	30.70 ± 0.13	0.28 ± 0.02	0.10 ± 0.01	7.15 ± 0.04
	Actual	8.29 ± 0.10ns	30.97 ± 0.40ns	0.24 ± 0.02ns	0.08 ± 0.00ns	7.47 ± 0.20*
PSL-SPR	Predictive	9.01 ± 0.01	31.16 ± 0.20	0.26 ± 0.02	0.11 ± 0.01	6.96 ± 0.07
	Actual	9.03 ± 0.05ns	31.95 ± 0.21*	0.26 ± 0.07ns	0.10 ± 0.01ns	7.14 ± 0.03*
CNT-PSL-SPR	Predictive	8.83± 0.02	31.30 ± 0.03	0.27 ± 0.01	0.10 ± 0.00	6.82 ± 0.05
	Actual	8.65 ± 0.08ns	30.42 ± 0.60ns	0.23 ± 0.03ns	0.10 ± 0.00 ns	6.97 ± 0.01*

Predictive value is calculated based on data from pure cultivars according to mass percentage of each cultivar in formulas.
ns = Actual value was not significant with predictive value.
* = Actual value was significantly different with predictive value ($p \leqslant 0.05$).

Table 4. Pasting properties of pure cultivars and mixed rice flour.

Pure cultivars/ Mixed flour	PV (cp)	Trough (cp)	BD (cp)	FV (cp)	SB (cp)	PT (°C)
CNT1	2949.50 ± 11.31 a	1726.00 ± 8.48 a	1223.00 ± 2.83 a	3670.00 ± 16.97 a	1944.00 ± 8.49 a	77.13 ± 0.04 a
PSL2	1412.50 ± 7.78 e	919.50 ± 27.58 d	493.00 ± 35.36 e	2476.50 ± 4.95 d	1557.00 ± 22.63 c	69.93 ± 0.04 b
SPR1	1726.50 ± 26.16 d	885.50 ± 16.26 d	841.00 ± 9.90 c	2274.50 ± 45.96 e	1389.00 ± 29.70 d	75.93 ± 0.04 a
CNT-PSL	2143.00 ± 36.77 b	1283.50 ± 16.26 b	859.50 ± 20.51 c	3099.50 ± 45.96 b	1816.00 ± 8.49 b	76.30 ± 0.00 a
CNT-SPR	2324.00 ± 11.31 b	1299.5 ± 12.02 c	1024.50 ± 0.71 b	3081.5 ± 17.68 c	1782.00 ± 5.666 c	76.55 ± 0.28 a
PSL-SPR	1404.00 ± 9.90 e	808.50 ± 0.71 e	595.50 ± 9.19 d	2186.00 ± 9.90 e	1377.50 ± 9.19 d	76.10 ± 0.35 a
CNT-PSL-SPR	1904.00 ± 21.21 c	1090.00 ± 0.00 c	814.00 ± 21.21 c	2728.50 ± 2.12 c	1638.50 ± 2.12 c	76.23 ± 1.24 a

Values are expressed as means ± SD (n=2).
Different letters in the same column indicate significant difference at $p \leq 0.05$.
ns = not significant.

Table 5. Predictive and actual pasting properties of pure cultivars and mixed rice flour

Mixed flour		Pasting properties					
		PV (cp)	Trough (cp)	BD (cp)	FV (cp)	SB (cp)	PT (°C)
CNT-PSL	Predictive	2180.75 ± 5.61	1322.75 ± 11.78	858.00 ± 14.48	3073.25 ± 7.22	1750.50 ± 9.87	73.52 ± 0.02
	Actual	2143.00 ± 36.77ns	1283.50 ± 16.26*	859.50 ± 20.51ns	3099.50 ± 45.96 ns	1816.00 ± 8.49*	76.30 ± 0.00*
CNT-SPR	Predictive	2337.75 ± 11.64	1305.75 ± 7.49	1032.00 ± 4.20	2972.25 ± 20.00	1666.50 ± 12.61	76.52 ± 0.02
	Actual	2324.00 ± 11.31ns	1299.5 ± 12.02 ns	1024.50 ± 0.71 ns	3081.5 ± 17.68*	1782.00 ± 5.66*	76.55 ± 0.28 ns
PSL-SPR	Predictive	1569.50 ± 11.14	902.50 ± 13.07	667.00 ± 14.99	2375.50 ± 18.87	1473.00 ± 15.24	72.93 ± 0.05
	Actual	1404.00 ± 9.90*	808.50 ± 0.71*	595.50 ± 9.19*	2186.00 ± 9.90*	1377.50 ± 9.19*	76.10 ± 0.35*
CNT-PSL-SPR	Predictive	2029.54 ± 7.64	1184.67 ± 21.40	844.88 ± 18.99	2818.00 ± 35.56	1633.33 ± 16.15	74.33 ± 0.01
	Actual	1904.00 ± 21.21*	1090.00 ± 0.00*	814.00 ± 21.21 ns	2728.50 ± 2.12*	1638.50 ± 2.12ns	76.23 ± 1.24*

Predictive value is calculated based on data from pure cultivars according to mass percentage of each cultivar in formulas.
ns = Actual value was not significant with predictive value.
* = Actual value was significantly different with predictive value ($p \leqslant 0.05$).

Table 6. Texture of fresh flat rice noodles made from of pure cultivars and mixed rice flour.

Pure cultivars/Mixed flour	Hardness (g)	Adhesiveness (g.sec)	Springiness	Cohesiveness
CNT1	19323.05 ± 1789.57 ^{d}	278.15 ± 85.01 ^{ab}	0.94 ± 0.02 ^{b}	0.92 ± 0.03 ^{ab}
PSL2	21274.92 ± 1580.06 ^{bc}	118.54 ± 42.85 ^{e}	0.97 ± 0.04 ^{a}	0.89 ± 0.04 ^{cd}
SPR1	22219.61 ± 1789.94 ^{b}	205.37 ± 79.67 ^{bc}	0.96 ± 0.01 ^{ab}	0.88 ± 0.04 ^{d}
CNT-PSL	22011.97 ± 1372.68 ^{bc}	154.68 ± 33.55 ^{de}	0.97 ± 0.01 ^{a}	0.93 ± 0.02 ^{a}
CNT-SPR	23553.66 ± 1142.48 ^{a}	243.58 ± 35.49 ^{b}	0.94 ± 0.07 ^{ab}	0.91 ± 0.02 ^{bc}
PSL-SPR	21056.37 ± 1005.80 ^{c}	185.10 ± 34.81 ^{cd}	0.95 ± 0.06 ^{ab}	0.93 ± 0.02 ^{ab}
CNT-PSL-SPR	18291.20 ± 830.98 ^{e}	147.55 ± 52.49 ^{de}	0.94 ± 0.07 ^{ab}	0.94 ± 0.03 ^{a}

Values are expressed as means ± SD (n=2).
Different letters in the same column indicate significant difference at $p \leq 0.05$.
ns = not significant.

Table 7. Predictive and actual textural properties of fresh flat rice noodles made from pure cultivars and mixed rice flour

Mixed flour		Pasting properties			
		Hardness	Adhesiveness	Springiness	Cohesiveness
CNT-PSL	Predictive	20438.57 ± 483.25	202.90 ± 14.68	0.95 ± 0.01	0.90 ± 0.02
	Actual	22011.97 ± 1372.68*	154.68 ± 33.55*	0.97 ± 0.01^{ns}	0.93 ± 0.02*
CNT-SPR	Predictive	20899.22 ± 533.09	241.89 ± 6.42	0.94 ± 0.01	0.91 ± 0.01
	Actual	23553.66 ± 1142.48*	243.58 ± 35.49^{ns}	0.94 ± 0.07^{ns}	0.91 ± 0.02^{ns}
PSL-SPR	Predictive	21783.08 ± 247.70	167.02 ± 15.90	0.96 ± 0.00	0.88 ± 0.00
	Actual	21056.37 ± 1005.80*	185.10 ± 34.81^{ns}	0.95 ± 0.06^{ns}	0.93 ± 0.02*
CNT-PSL-SPR	Predictive	21040.29 ± 332.11	203.94 ± 9.85	0.95 ± 0.00	0.90 ± 0.01
	Actual	18291.20 ± 830.98*	147.55 ± 52.49^{ns}	0.94 ± 0.07^{ns}	0.94 ± 0.03*

Predictive value is calculated based on data from pure cultivars according to mass percentage of each cultivar in formulas.
ns = Actual value was not significant with predictive value.
* = Actual value was significantly different with predictive value ($p \leqslant 0.05$).

Texture of fresh flat rice noodles

From Table 6, SPR1 noodles had the highest hardness among all pure rice cultivars noodles, while SPR1 rice flour had the lowest final viscosity among all cultivars. This disagreed with the result of Han *et al*. (2011) which pronounced that final viscosity had positive correlation with hardness of rice noodles. The highest hardness of SPR1 noodles might due to the highest protein in this rice cultivars. This result was consistent with result of Deryke *et al*. (2005) which reported that protein in rice acted like barrier for solid leaching during cooking, leading to the high hardness in cooked rice. Hardness of CNT-PSL noodles and CNT-SPR noodles were higher than the predictive value (Table 7), while hardness of CNT-PSL-SPR noodles was lower than predictive value. The alteration of hardness of mixed flour rice noodles correlated with the alteration from predictive value of final viscosity of these samples. Han *et al*. (2011) reported that the hardness of rice noodles had positive correlation with the final viscosity of flour. In contrast, hardness of pure rice cultivar noodles in our work was not correlated with its final viscosity. One of the possible explanations of the lower hardness of mixed rice flour noodles is the difference starch swelling ability of each rice cultivar. Puncha-arnon *et al*. (2008) founded that mixed starch gel form canna-potato starch, canna-mung bean starch, and canna-rice starch had lower hardness than predictive value, due to the difference in their ability to swell. CNT-PSL noodles had lower adhesiveness than predictive value. This might be an influence of PSL2 which had the lowest adhesiveness. Cohesiveness of all mixed rice flour samples were higher than predictive value. This suggested that mixing various rice cultivars improved cohesiveness of rice noodles.

The variation of texture of mixed flour rice noodles from the predictive value may be attributed to several factors, e.g. the difference in other compositions besides amylose content, the intermolecular hydrogen bonding in flour mixture (Vu *et al*., 2016), the difference in morphology and swelling ability of starch granules (Puncha-arnon *et al*., 2008), or the synergistic effect of fine structure of mixed rice cultivars (Jane *et al*., 1999). Therefore, the further study on these topic are necessary to obtain an information to explain the alteration of texture in mixed rice flour noodles.

CONCLUSIONS

Chemical composition of mixed high amylose rice flour were predictable based on mass percentage of each cultivar, except protein content. However, pasting properties of mixed high amylose rice flour, especially final viscosity and setback, were non-additive behavior. Namely, it cannot be predicted by the proportion of each rice cultivar. The texture of mixed high amylose rice flour noodles was also non-additive behavior. It can be said that in order to design the texture of rice noodles from mixed high amylose rice flour, it cannot be calculated based on only the textural data of pure cultivar with the mass percentage of each cultivar. The alteration effect from mixing should be considered. Unfortunately, the cause of these alterations was unclear. It might be due the difference in other compositions, the difference in swelling ability of starch, the intermolecular hydrogen bonding in flour mixture, or the synergistic of the fine structure of each rice cultivar in flour mixture. The further study on the above topics are necessary.

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