Effects of drying modes followed rough rice harvesting on the texture and taste properties of rice

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Abstract: The effects of two drying modes, including timely drying operation and stacked drying operation followed by rough rice harvesting of different dates, on the texture and taste characteristics of cooked rice were studied. The heated-air temperatures of 40°C, 50°C, and 60°C were respectively used to dry rough rice. Results indicated that harvesting date, drying mode and drying temperature had significant effects on the texture and taste characteristics of cooked rice. At the drying temperatures of 40°C, 50°C, and 60°C, the hardness, adhesiveness, springiness and stickiness of cooked rice from rough rice harvested pre-frosting period and timely dried, were higher than those processed by delay drying treatment. The optimum value of smell, color, appearance, palatability and flavor of the processed rice can be obtained from rough rice dried in time and harvested at the second harvesting date. The taste value of cooked rice harvested before frosting firstly increased and then decreased with the extension of the harvesting date. It also decreased with the increase of stacking time. These results suggested that a drying treatment in time could contribute to a high taste of the rough rice.

Keywords: Rough rice, harvesting date, dried in time, stacked drying, texture, taste

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1 Introduction

Taste value is a crucial index to evaluate rice quality and depends on many factors such as variety, cultivation, harvesting, drying, processing and storage (Pearce et al., 2001; Sunthonvit et al., 2005; Wiset et al., 2005; Anderson and Guraya, 2006; Bello et al., 2006; Aquerreta et al., 2007). Most of researchers strongly focused on the effects of these factors on taste quality of rice. Moisture content of rough rice is generally in range of 20%–30% (w.b.) after harvesting. To meet the requirements for safe storage, drying treatment is a necessary processing for the post-harvesting of rough rice to reach the safe moisture content of 14.5% (w.b.) (Sablani et al., 2009; Golmohammadi, 2015). At present, the main drying mode of rough rice is to dry after a period of stacking. Phenomena, such as hot flashes and mildew, are usually found in the stacking period because of the respiration of rough rice with high moisture, which may affect the taste attributes of cooked rice (Champagne et al., 2004). Taste attributes of rice determine its consumers acceptance (Zheng et al., 2011). Therefore, it is necessary for rough rice to dry in time after harvesting to keep the rice fresh and maintain its taste attributes.

The post-harvesting conditions, such as harvesting dates and drying modes, have obvious effects on the quality of post-drying rough rice. Harvesting date obviously influences texture attributes and taste quality of cooked rice (Asano et al., 2000; Chae and Jun, 2002). Asano et al. (1999) found that taste value of rice decreased with the delaying of harvesting date. Champagne et al. (2005) studied the impacts of harvesting date on the sensory and physicochemical properties of rice, and found that the early harvested rice

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was harder and more cohesive than that harvested in delay period when cooked. The post-harvest treatment method of rough rice plays a key role in maintaining the rice quality and generally includes drying method, drying temperature, moisture content and storage time (Meeso et al., 2004; Madamba and Yabes, 2005; Madhiyanon and Soponronnarit, 2005; Rordprapat et al., 2005; Iguaz et al., 2006; Dong et al., 2010; Takuma et al., 2013). Meullenet et al. (1999) investigated that the hardness of rice subjected to delayed drying decreased. Champagne et al. (2004) observed that after a period of storage, the taste of rough rice declined with high moisture during the drying process. Wongpornchai et al. (2004) suggested that harvested rough rice followed by dried immediately under low drying temperature may keep the aroma quality. Concentration of the aroma compound in rice may decline due to the energy consumption and thermal generation caused by respiratory activity of rough rice kernels with high moisture content during stacked storage. The rough rice dried after a period of stacking decreased the taste attributes of cooked rice. Timely drying refers to a drying operation after the harvesting of rough rice in 8 hours. Timely drying mode may avoid the deterioration of the taste quality due to stacking. However, systematic studies considering effects of drying modes and harvesting date on texture attributes and taste quality of rice are limited, which constraints the taste value of high quality rough rice.

Based on the above-mentioned reviews, it is necessary to study the effect of proper harvesting date and drying modes on the texture attributes and taste quality of rough rice and obtain the optimum process parameters considering drying mode, drying temperature and harvesting date for the drying treatment of post-harvesting rough rice.

2 Materials and methods

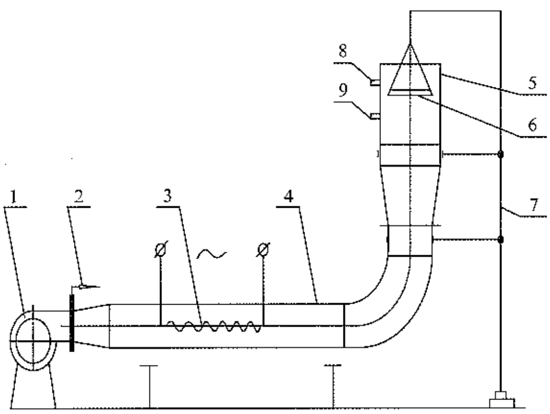
2.1 Rough rice sample

Considering the differences of factors, such as varieties and climate, the rough rice annual mature date is slightly different. In this study, harvesting dates of rough rice at the rice proper maturity period were chosen from 25th September to 11th October in 2016. Fresh rough rice (variety Chaochan 4) with a moisture content of 19.0%-24.0% (w.b.) was collected from the Rice Research Center at the Northeast Agricultural University (Harbin, China). At the beginning of the proper maturity stage, rough rice was collected every four days for four times. The previous three samples were obtained before frosting and the last one was obtained after frosting. After harvested, part of the samples were dried immediately and the rest samples were sealed in plastic bags, then stored at room temperatures of 20°C-22°C in relative humidity of 55%-65% for 3 days or 6 days, respectively and dried in stacked. The ratio of "part" and "the rest" was one to two. In order to maintain the taste quality at the same level, all rough rice samples were stored in cool and dry room before drying. These operations were completed in 2 h after rough rice was harvested. After sampling, the samples were re-sealed to prevent water loss in rough rice. The moisture content of rough rice was measured by using AOAC (1995b) official method (oven dry method, 135°C, 3 h) (Zhang et al., 2014).

2.2 Experimental procedure

Thin-layer drying experiments were performed using perforated trays in a drying chamber, as shown in Figure 1, in which the drying temperature was controlled by an auto-controller. The drying temperature was measured by using a temperature sensor (accuracy ±0.5°C; MF 54, Shanghai Pudong Sanliao Electronic Co., Shanghai, China). The surface velocity of heated air was measured using a thermal anemometer (accuracy ±0.2%; Testo 425, Testo AG, Lenzkirch, Germany). The anemometer probe was fixed to the bottom of the drying tray during rough rice drying. The relative humidity in the range of 70%–75% for all drying methods was measured using a temperature and humidity sensor (accuracy ±3%; HMP45A, Vaisala, Helsinki, Finland). The drying temperatures were fixed at 40°C, 50°C, and 60°C. Surface velocity of heated air was fixed at 0.5 m s^{-1}. The rough rice obtained at four harvesting times was dried in time and in stacking respectively. The harvesting dates, drying modes and drying temperatures are shown in Table 1. Each of the rough rice samples containing 100 g was spread in a perforated tray. When the sample weight reached the corresponding value for moisture content of

14%-15% (w.b.), rough rice was sealed in a plastic bag and stored at room temperatures of 20°C-22°C. All drying experiments were repeated three times and average value was reported. The drying rough rice sample was milled using a miller (THU-35B type, Satake Co., Tokyo, Japan) and sealed in plastic bags for further analysis.



1. Fan 2. Wind rate control board 3. Heating apparatus 4. Air duct 5. Drying cylinder 6. Dried screen 7. Scaffold 8. Anemometer probe 9. Temperature sensor

Figure 1 Schematic diagram of thin-layer drying of paddy rice

Table 1 Drying modes and drying temperatures for the different drying experiments

Harvesting dates	Drying modes	Drying temperatures, °C
The first harvest	Drying in time	40, 50, 60
The first harvest	Drying in stacked three days	40, 50, 60
The first harvest	Drying in stacked six days	40, 50, 60
The second harvest	Drying in time	40, 50, 60
The second harvest	Drying in stacked three days	40, 50, 60
The second harvest	Drying in stacked six days	40, 50, 60
The third harvest	Drying in time	40, 50, 60
The third harvest	Drying in stacked three days	40, 50, 60
The fourth harvest	Drying in time	40, 50, 60
The fourth harvest	Drying in stacked three days	40, 50, 60

2.3 Instrumental texture analysis

Texture profile analysis of each rice sample was measured using a Stable Micro System TA-XT2 texture analyzer (Texture Technologies Co., Surrey, UK) with a 2.5 mm cylindrical probe. The speeds of pre-test, test and post-test were respectively 1.0, 0.5, 0.5 mm/s, and deformation ratio was 90%. The force–time curve was recorded and analyzed by the software in TA-XT2 texture analyzer, which presented the texture characteristics of the cooked rice including hardness ($H1$), adhesiveness ($A3$), cohesiveness ($A2/A1$), springiness ($D2/D1$), stickiness ($H2$), gumminess and chewiness. Gumminess was obtained by Hardness×Cohesiveness and chewiness was obtained by Gumminess×Springiness based on the standard calculations of curve attributes of texture profile analysis. Measurements were performed in six replicates and averages were reported for each sample as presented in Tables 2-4.

2.4 Taste evaluation method

Ten professionally trained panelists employed at the National Rice Quality Test Center (Harbin, China) developed a taste profile of cooked rice samples according to GB/T15682-1995 method (rice taste standard from the Ministry of Agriculture, P. R. China). During panel tests, the cooked rice taste (100 points) was evaluated in terms of smell (25 points), appearance (10 points), color (10 points), palatability (30 points) and flavor (25 points). Preparation and taste evaluation of cooked rice referred to Zheng and Lan (2007). The taste values of cooked rice subjected to different drying modes are shown in Figures 2-7.

2.5 Data analysis

All analyses were performed in triplicate. Both texture and taste data were analyzed using ANOVA to perform the significance of all drying modes and temperatures for the objective variables. Both texture and taste data were analyzed using ANOVA. The results of ANOVA were obtained by using SPSS software (Ver. 8.2, SPSS Institute, INC., Cary, NC). The results of variance analysis at $p<0.05$ level were retained.

3 Results and discussion

3.1 Effects of drying modes and drying temperatures on the texture attributes of cooked rice

The texture attributes in Tables 2-4 may describe the effects of drying modes and drying temperatures on the texture attributes of cooked rice. The results of variance analysis were retained at $p<0.05$ level.

Table 2 shows the texture attributes of cooked rice after drying at 40°C. As can be seen in Table 2, drying modes and drying temperatures have significant effects on the texture attributes of cooked rice. Hardness of cooked rice is the force required to bite through the sample using the molars. The hardness of cooked rice from the rough rice harvested before frosting had significant difference ($p<0.05$). No significant effect of drying modes on the hardness of cooked rice at the fourth harvesting date was found (p>0.05). There was significant difference in the adhesiveness of cooked rice obtained before frosting (p<0.05). Adhesiveness difference of cooked rice at the fourth harvesting date was non-significant (p>0.05). Adhesiveness is the degree to which the kernels adhere to contacting substances. The difference in the springiness of cooked rice obtained before frosting was significant (p<0.05). No significant effect of drying modes on the springiness of the fourth harvested cooked rice was appeared (p>0.05). Springiness of cooked rice is the degree of recovery to its original shape after partial compression. Cohesiveness index is defined as the degree to which the grains deform rather than crumble, crack, or break when biting with the molars. In this research, no significant effects of drying modes on the cohesiveness of cooked rice at the four harvesting dates were found (p>0.05). Gumminess of cooked rice at the four harvesting dates had significant difference (p<0.05). Gumminess of cooked rice is the degree to which the kernels adhere to each other. The difference in the chewiness of cooked rice before frosting was significant (p<0.05). Chewiness difference of cooked rice at the fourth harvesting date was non-significant (p>0.05). Chewiness refers to the amount of work taking to chew the samples. There was significant difference in the stickiness of cooked rice obtained before frosting (p<0.05). The stickiness difference of the fourth harvested cooked rice was non-significant (p>0.05). Stickiness is the degree of binding between kernels from stretched to original state. At pre-frost season, the hardness, adhesiveness, springiness and stickiness of cooked rice obtained from rough rice by drying timely, were significantly higher than those of cooked rice obtained from rough rice by delay drying treatment (p<0.05).

Table 2 Texture attributes value of rice subject to various drying modes at 40°C

Drying modes	Hardness, g	Adhesiveness	Springiness	Cohesiveness, g.s	Gumminess	Chewiness	Stickiness
1	3533±115^{a}	−696±63^{a}	0.67±0.07^{a}	0.459±0.025^{a}	1678±89^{a}	1135±143^{a}	0.266±0.015^{a}
2	3260±103^{b}	−627±58^{b}	0.57±0.15^{b}	0.474±0.024^{a}	1486±97^{b}	932±121^{b}	0.246±0.017^{b}
3	3196±143^{c}	−563±48^{c}	0.52±0.11^{c}	0.481±0.033^{a}	1543±73^{c}	1044±122^{c}	0.233±0.021^{c}
4	3716±126^{a}	−683±61^{a}	0.79±0.13^{a}	0.451±0.035^{a}	1487±10^{7a}	924±139^{a}	0.284±0.035^{a}
5	3628±139^{b}	−524±57^{b}	0.69±0.10^{b}	0.457±0.042^{a}	1452±93^{b}	903±113^{b}	0.277±0.018^{b}
6	3124±139^{c}	−504±43^{c}	0.62±0.09^{c}	0.460±0.034^{a}	1543±88^{c}	1222±134^{c}	0.245±0.027^{c}
7	3594±118^{a}	−737±39^{a}	0.67±0.08^{a}	0.458±0.028^{a}	1803±76^{a}	1247±148^{a}	0.270±0.026^{a}
8	3263±151^{b}	−539±51^{b}	0.55±0.12^{b}	0.465±0.031^{a}	1520±70^{b}	839±120^{b}	0.245±0.016^{b}
9	3588±122^{a}	−589±60^{a}	0.66±0.08^{a}	0.479±0.029^{a}	1721±81^{a}	1169±134^{a}	0.265±0.031^{a}
10	3671±145^{a}	−620±58^{a}	0.61±0.09^{a}	0.506±0.037^{a}	1866±104^{b}	1168±128^{a}	0.286±0.019^{a}

Notes: 1-3 represent the first harvest, among which, 1 represents drying in time, 2 represents drying in stacked three days, 3 represents drying in stacked six days; 4-6 represent the second harvest, among which, 4 represents drying in time, 5 represents drying in stacked three days, 6 represents drying in stacked six days; 7-8 represent the third harvest, among which, 7 represents drying in time, 8 represents drying in stacked three days; 9-10 represent the fourth harvest, among which, 9 represents drying in time, 10 represents drying in stacked three days. Data expressed as mean ±SD of triplicate determinations. Means within rows followed by the same letter are not significant different at p<0.05.

Table 3 illustrates the texture attributes of cooked rice after drying at 50°C. As can be seen in Table 3, drying modes have significant effects on the cooked rice texture attributes at 50°C. The texture attributes, in terms of hardness, adhesiveness, springiness, gumminess, chewiness and stickiness, of cooked rice harvested before frosting had significant difference (p<0.05). No significant effect of drying modes on the hardness, adhesiveness, springiness, gumminess, chewiness and stickiness of cooked rice at the fourth harvesting date was found (p>0.05). There was no significant difference of cohesiveness at four harvesting dates (p>0.05). The hardness, adhesiveness, springiness, gumminess, and stickiness of cooked rice harvested before frosting with timely drying, were significantly higher than those of cooked rice obtained from rough rice by delay drying treatment (p<0.05).

Table 4 represents the texture attributes of cooked rice after drying at 60°C. As can be shown in Table 4, drying modes have significant effects on the cooked rice texture attributes at 60°C. The differences of two modes in the hardness, adhesiveness, springiness, gumminess, chewiness and stickiness of cooked rice obtained before frosting were significant ($p<0.05$). However, no significant effects of drying modes on the hardness, adhesiveness, springiness, gumminess, chewiness and stickiness of cooked rice at the fourth harvesting date were found ($p>0.05$). The cohesiveness differences of the four times harvested cooked rice were not significant ($p>0.05$). The hardness, adhesiveness, springiness, gumminess, and stickiness of the cooked rice harvested before frosting decreased with the stacked time, and this decrement was significant between the rice with two drying modes ($p<0.05$). In this research, it was found that hardness, adhesiveness and springiness of the cooked rice also decreased with increase of the drying temperature in the same drying modes. This result agrees with previous studies by Kunze et al. (2008).

Table 3 Texture attributes value of rice subject to various drying modes at 50°C

Drying modes	Hardness, g	Adhesiveness	Springiness	Cohesiveness, g.s	Gumminess	Chewiness	Stickiness
1	3460±423 ^{a}	−686±67^a	0.65±0.09^a	0.439±0.035^a	1810±83^a	1211±113^a	0.301±0.012 ^{a}
2	3325±312 ^{b}	−624±62^b	0.52±0.12^b	0.446±0.025^a	1948±78^b	826±137^b	0.281±0.025 ^{b}
3	2989±334 ^{c}	−556±47^c	0.44±0.15^c	0.451±0.027^a	1623±98^c	1383±143^c	0.267±0.013 ^{c}
4	3588±116 ^{a}	−660±58^a	0.72±0.11^a	0.512±0.024^a	2043±96^a	1396±126^a	0.32±0.025^a
5	3453±222 ^{b}	−582±57^b	0.66±0.13^b	0.518±0.036^a	1757±89^b	907±129^b	0.304±0.019 ^{b}
6	3183±115 ^{c}	−516±55^c	0.57±0.12^c	0.531±0.043^a	1575±107 ^{c}	1104±143^c	0.279±0.018 ^{c}
7	3637±334 ^{a}	−682±68^a	0.63±0.09^a	0.472±0.037^a	1738±94^a	1384±128^a	0.281±0.025 ^{a}
8	3280±328 ^{b}	−577±71^b	0.49±0.08^b	0.482±0.033^a	1936±87^b	726±112^b	0.255±0.017 ^{b}
9	3572±238 ^{a}	−558±52^a	0.66±0.13^a	0.469±0.041^a	1956±106 ^{a}	900±137^a	0.279±0.025 ^{a}
10	3531±211 ^{a}	−606±67^a	0.59±0.12^a	0.462±0.029^a	1875±86^a	855±118^a	0.288±0.029 ^{a}

Notes: 1-3 represent the first harvest, among which, 1 represents drying in time, 2 represents drying in stacked three days, 3 represents drying in stacked six days; 4-6 represent the second harvest, among which, 4 represents drying in time, 5 represents drying in stacked three days, 6 represents drying in stacked six days; 7-8 represent the third harvest, among which, 7 represents drying in time, 8 represents drying in stacked three days; 9-10 represent the fourth harvest, among which, 9 represents drying in time, 10 represents drying in stacked three days. Data expressed as mean ± SD of triplicate determinations. Means within rows followed by the same letter are not significant different at $p<0.05$.

Table 4 Texture attributes value of rice subject to various drying modes at 60°C

Drying modes	Hardness, g	Adhesiveness	Springiness	Cohesiveness, g.s	Gumminess	Chewiness	Stickiness
1	3356±367 ^{a}	−601±80^a	0.61±0.09^a	0.431±0.035^a	2381±125 ^{a}	1748±133^a	0.355±0.015 ^{a}
2	3135±249 ^{b}	−526±74^b	0.47±0.12^b	0.426±0.025^a	2147±124 ^{b}	1517±154^b	0.321±0.011 ^{b}
3	2876±163 ^{c}	−437±68^c	0.42±0.15^c	0.403±0.027^a	2043±136 ^{c}	1596±138^c	0.319±0.023 ^{c}
4	3457±324 ^{a}	−630±85^a	0.67±0.11^a	0.483±0.024^a	1948±98^a	1383±147^a	0.301±0.011 ^{a}
5	3278±226 ^{b}	−552±88^b	0.61±0.13^b	0.468±0.036^a	1941±129 ^{b}	1522±120^b	0.281±0.021 ^{b}
6	3109±165 ^{c}	−456±81^c	0.53±0.12^c	0.456±0.043^a	1704±148 ^{c}	1465±151^c	0.263±0.024 ^{c}
7	3226±278 ^{a}	−582±63^a	0.57±0.09^a	0.462±0.037^a	2118±111 ^{a}	1527±163^a	0.305±0.025 ^{a}
8	2959±254 ^{b}	−427±59^b	0.45±0.08^b	0.451±0.033^a	1913±138 ^{b}	1056±149^b	0.286±0.027 ^{b}
9	3219±289 ^{a}	−528±71^a	0.56±0.13^a	0.469±0.041^a	1876±125 ^{a}	953±144^a	0.277±0.017 ^{a}
10	3368±193 ^{a}	−506±76^a	0.49±0.12^a	0.463±0.029^a	1796±121 ^{a}	861±123^a	0.259±0.019 ^{a}

Notes: 1-3 represent the first harvest, among which, 1 represents drying in time, 2 represents drying in stacked three days, 3 represents drying in stacked six days; 4-6 represent the second harvest, among which, 4 represents drying in time, 5 represents drying in stacked three days, 6 represents drying in stacked six days; 7-8 represent the third harvest, among which, 7 represents drying in time, 8 represents drying in stacked three days; 9-10 represent the fourth harvest, among which, 9 represents drying in time, 10 represents drying in stacked three days. Data expressed as mean ± SD of triplicate determinations. Means within rows followed by the same letter are not significant different at $p<0.05$.

3.2 Effects of drying modes and drying temperatures on the taste value of cooked rice

The taste characteristics of cooked rice, including smell, color, appearance, palatability and flavor attributes, were evaluated by the taste evaluation protocol. The analysis results of texture attributes may explain the effect of drying modes and drying temperatures on the taste characteristics of cooked rice, as illustrated in Figures 2-4, the data expressed as mean ± SD of triplicate determinations.

The results in Figure 2 indicate the effects of drying modes on the taste qualities of cooked rice after drying at 40°C. Smell and flavor values of cooked rice obtained before frosting had significant difference ($p<0.05$), but were non-significant for one harvested at the fourth time ($p>0.05$). The smell value of cooked rice is the panelists' sense for the special odors of cooked rice by olfactory perception. Flavor refers to the taste impression of cooked rice and is mainly determined by the senses of taste and smell. Before frosting, stacking time shows negative effects on the smell value and flavor value. Rough rice has unique aroma, which decays with stacking time, resulting in the decrease of the smell value of cooked rice (Wongpornchai et al., 2004). The flavor value of cooked rice had positive correlation with hardness and stickiness, with the result that the flavor value of cooked rice from rough rice dried timely was higher than that from delay drying treatment (Zheng et al., 2011). The difference in the taste properties of cooked rice, including color, appearance and palatability, was non-significant ($p>0.05$). The color value of the cooked rice refers to the panelists' sense and is determined by visual perception. Whiteness is the color of cooked rice favored by consumers (Jinorose et al., 2010). The color of cooked rice declined with stacking time. The appearance of cooked rice is the overall observation in terms of shape, integrity and transparency. Palatability of cooked rice refers to the acceptable or agreeable degree to the palate or taste of cooked rice, which decreased with the increase of stacking time. The cooked rice with fine palatability had the characteristics of high hardness, stickiness, springiness and adhesiveness. The optimum value of smell, flavor, color, appearance and palatability appeared at the second harvesting date followed by drying in time.

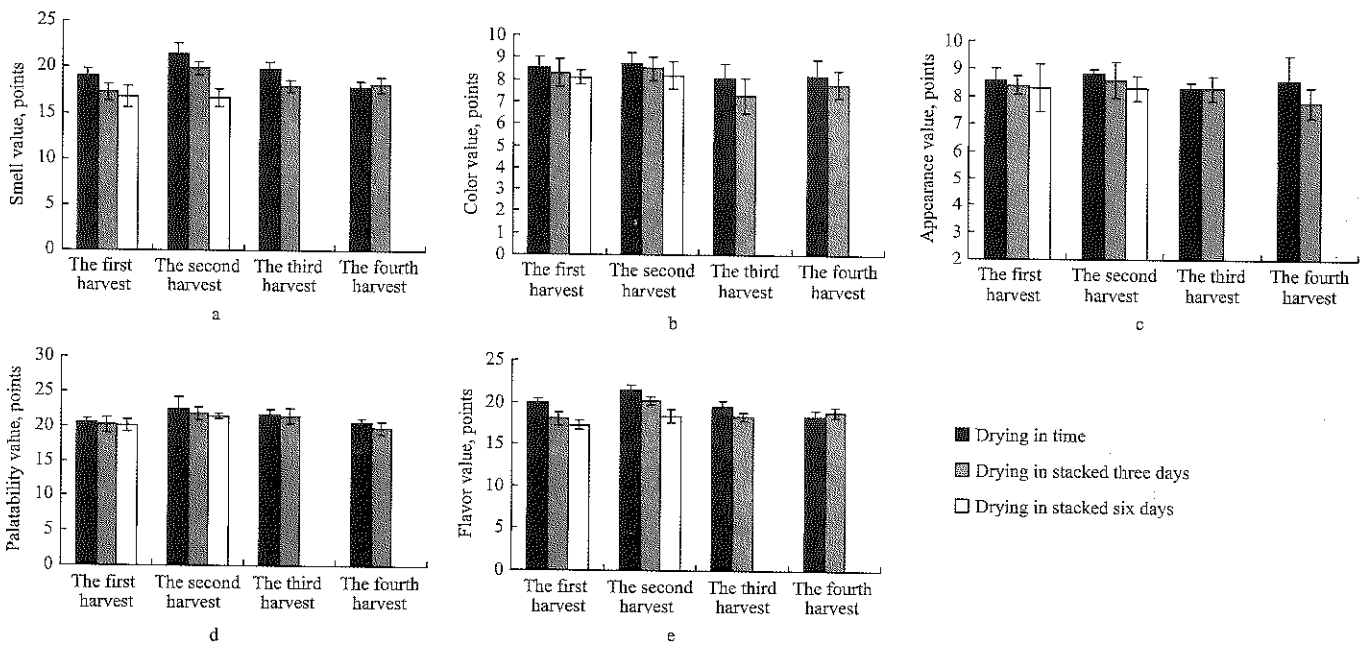


Figure 2 Taste characteristics value of rice at 40°C for different drying modes in 2016 harvesting time

The effects of drying modes on the taste qualities of cooked rice after drying at 50°C are shown in Figure 3. The smell and flavor values of cooked rice harvested before frosting had significant difference ($p<0.05$). No significant effect of drying modes on the smell and flavor value of cooked rice at the fourth harvesting date was found ($p>0.05$). The results show that stacked time has a significant negative effect on the smell and flavor value of cooked rice before frosting. The smell value of cooked rice has positive correlation with its stickiness. The flavor value of cooked rice has positive correlation with its hardness and stickiness. Therefore, the smell value of the cooked rice also decreased with decrease of the stacked time due to the decrease of hardness and stickiness (Zheng et al., 2011). The flavor value had a significant positive correlation with hardness and stickiness (Zheng et al., 2011). There was no significant difference of color, appearance and palatability value at the four harvesting dates ($p>0.05$). The color, appearance and palatability value of cooked rice had positive correlation with stacked time. The cooked rice had fine color and palatability value with the characteristics of high hardness, stickiness, springiness and adhesiveness. The optimum value of smell, color, appearance, palatability and flavor was obtained at the second harvesting time by drying in time.

Figure 4 shows the effect of drying modes on taste qualities of the cooked rice after drying at 60°C. Smell and flavor values of cooked rice harvested before frosting had significant difference ($p<0.05$). Smell and flavor values of cooked rice at the fourth harvesting date were non-significant ($p>0.05$). No significant effect of drying modes on the color, appearance and palatability value of cooked rice at the four harvesting dates was found ($p>0.05$). The change reason of taste qualities of the cooked rice after drying at 60°C was the same as that drying at 50°C. The optimum value of smell, color, appearance, palatability and flavor was found at the second harvesting time by drying in time. In this research, it is revealed that smell, color, appearance, palatability and flavor values of the cooked rice also decreased with the increase of drying temperature in the same drying mode. This result agrees with what was reported by other researchers (Zheng et al., 2011; Kunze, 2008).

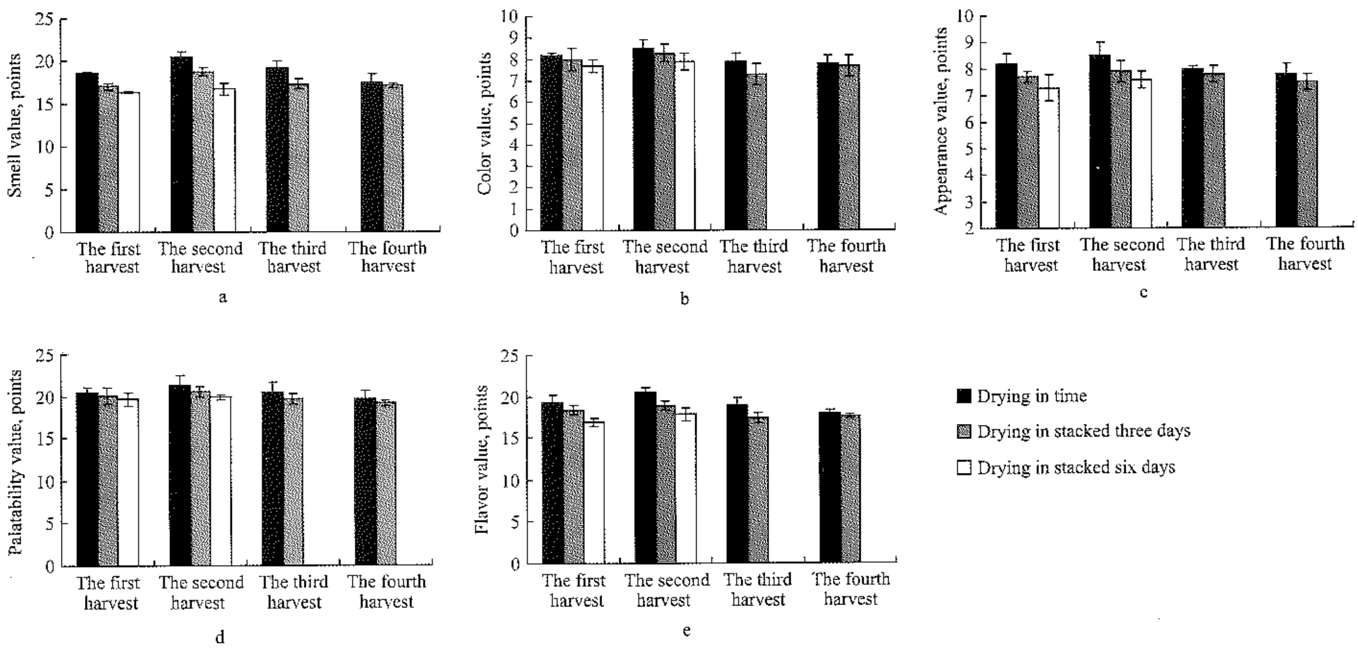


Figure 3 Taste characteristics value of rice at 50°C for different drying modes in 2016 harvesting time

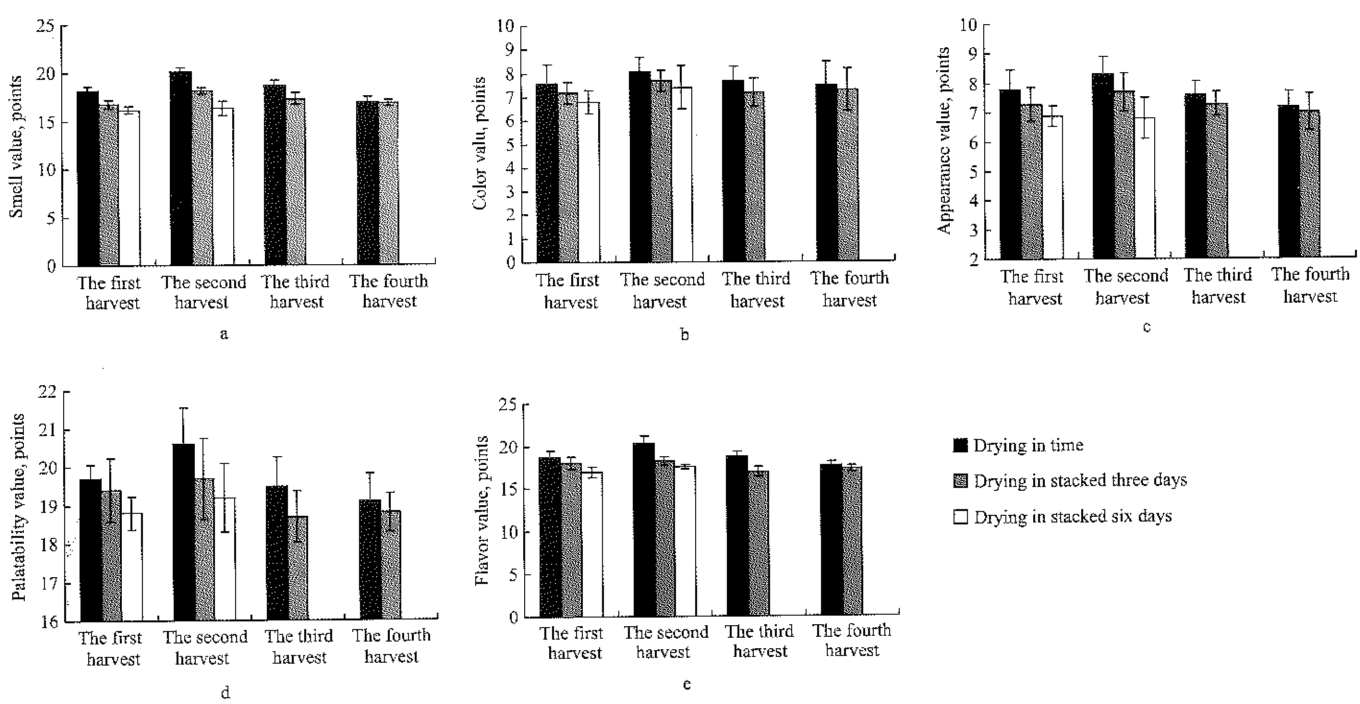


Figure 4 Taste characteristics value of rice at 60°C for different drying modes in 2016 harvesting time

3.3 Comprehensive analysis of taste value for cooked rice

The results of texture attributes in Figures 5-7 may explain the effect of drying modes and drying temperatures on the taste qualities of cooked rice. In Figures 5-7, the data expressed mean ±SD of triplicate determinations.

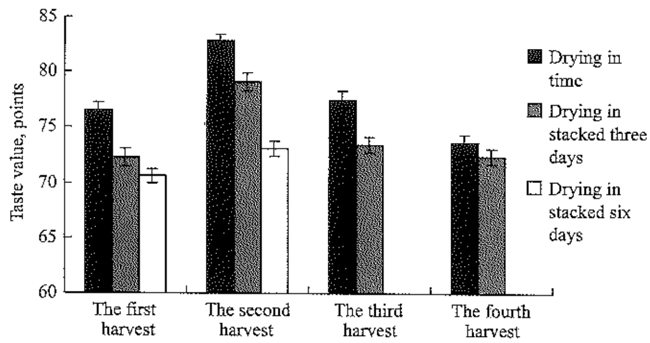


Figure 5 Comprehensive evaluation of taste value at 40°C for different drying modes in 2016 harvesting time

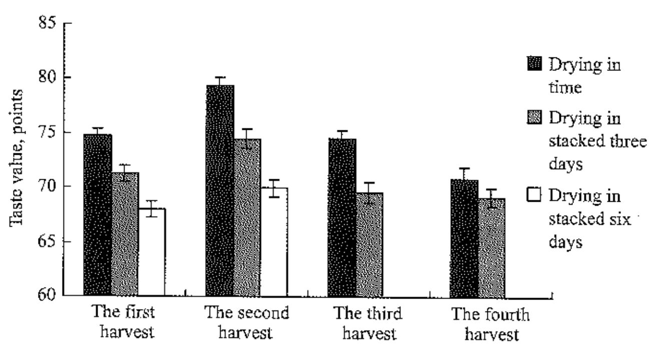


Figure 6 Comprehensive evaluation of taste value at 50°C for different drying modes in 2016 harvesting time. Data expressed mean ±SD of triplicate determinations.

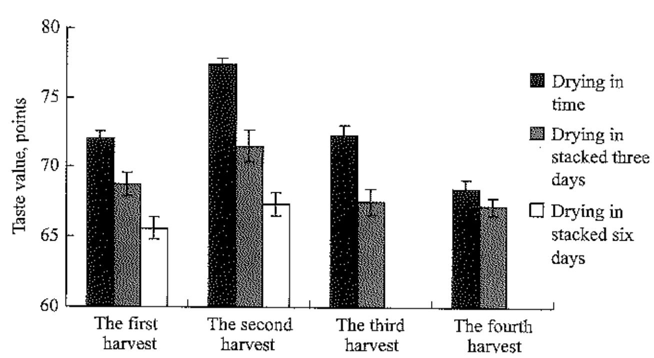


Figure 7 Comprehensive evaluation of taste value at 60°C for different drying modes in 2016 harvesting time

The results in Figure 5 present the effects of drying modes on the taste qualities of cooked rice after drying at 40°C. The differences in the taste attributes of cooked rice harvested before frosting were significant (p<0.01). There was no significant difference in taste attributes of cooked rice at the fourth harvesting date (p>0.05). For the rough rice harvested before frosting date, the taste attributes of cooked rice treated by drying timely were higher than those treated by delay drying treatment, which decreased with the increase of stacking time. The highest taste value of the cooked rice was the rough rice harvested at the 8th day after proper mature date followed by drying in time.

The results in Figures 6-7 present the effects of drying modes on the taste qualities of cooked rice after drying at 50°C and 60°C. The results showed that the changing trend of taste attributes of cooked rice after drying at 50°C and 60°C was in accordance with that of cooked rice after drying temperatures at 40°C. The increase of drying temperatures caused the decrease of taste attributes of cooked rice at the same drying modes as shown in Figures 5-7.

The taste value is in high level for the rough rice harvested in pre-frost season and followed by the drying timely treatment. The hardness, adhesiveness, springiness and stickiness of cooked rice obtained from rough rice harvested at pre-frost season dried timely, are higher than those by delay drying treatment. The highest values of hardness, adhesiveness, springiness and stickiness for the cooked rice were obtained at the 8th day of mature period and dried in time. The smell, flavor and palatability of cooked rice obtained from rough rice harvested at pre-frost season followed by dried timely, are higher than those dried by delay drying treatment. The highest values of smell, flavor and palatability for the cooked rice were obtained at the 8th day of mature period dried in time. The flavor value of cooked rice has positive correlation with hardness and stickiness (Zheng et al., 2011). The drying timely mode improves the flavor of cooked rice. The palatability of cooked rice has positive correlation with springiness, adhesiveness and stickiness (Zheng et al., 2011). The drying timely mode improves the palatability of cooked rice. The results explain the influence of texture attributes on the taste quality of cooked rice. The relationship between the texture attributes and the taste characteristics explains the reasons that rough rice harvested in time and dried timely can improve the taste quality of cooked rice.

4 Conclusions

The effects of harvesting dates, drying modes and drying temperatures on the texture and taste attributes of cooked rice are significant. The impacts of harvesting dates, drying temperatures and drying modes on the texture of cooked rice are the key reasons resulting in variations in taste. Stacking time has a negative effect on hardness, adhesiveness, springiness, stickiness, smell, flavor and palatability of rough rice. Therefore, drying in time is helpful in improving the taste properties of cooked rice. The highest taste value for the cooked rice is obtained under the optimal mode of harvesting at the 8^{th} day of mature period and drying in time. The analysis results show the influence of texture attributes on the taste quality of cooked rice. The relationship between the texture attributes and the taste characteristics explains the mechanism that harvesting in time and timely drying mode can improve the taste quality of rice.

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