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QUALITATIVE DYNAMICS OF WAXY MAIZE (JIKENUO 19) IN DIFFERENT HARVEST TIMES

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Abstract

Jikenuo 19 was used as experimental material, and six harvest times were set to study the effects of different harvest times on grain quality and gelatinization characteristics, so as to provide reference for the harvest time and quality improvement of waxy maize varieties. The results showed that when the harvest time was 27 days after pollination, the sensory and cooking quality score of Jikenuo 19 was the highest. Starch content increased with the delay of harvest time, while protein and soluble sugar content decreased. With the delay of harvest time, the peak viscosity, valley viscosity, final viscosity, disintegration value, recovery value and peak time all showed a trend of first increasing and then decreasing. Compared with starch and soluble sugar, the effect of protein in grain on gelatinization characteristics was higher. The present findings reveal that the best harvest time was 27 days after pollination, which will provide reference for determining the best harvest time and improving grain quality.

Introduction

Waxy maize (Jikenuo 19) originated in China is a unique type of maize. Due to the control of *wx* recessive gene, the starch in endosperm is mostly amylopectin, which is much higher than that in common maize (Lemmens *et al*. 2020, Shukri *et al*. 2021). It has good palatability, freeze-thaw stability and high viscosity. After heating, it also has strong swelling power, excellent taste and unique flavor (Ren *et al*). Moreover, waxy maize is rich in unsaturated acid and linoleic acid which play a positive role in the prevention of atherosclerosis and angina. Rich vitamins may delay aging. Calcium, magnesium, selenium and other large elements, as well as glutathione and other substances play a healthy role (Huang *et al*. 2012, Liu 2019, Liu *et al*. 2021). Under the guidance of the concept of healthy diet, more and more consumers choose waxy maize to supplement, so the analysis of its quality and physicochemical properties becomes particularly important.

Gelatinization is one of the important indexes to measure the physicochemical properties of waxy maize starch, which is usually affected by environment and genotype (Fan *et al*. 2018). It mainly includes peak viscosity, valley viscosity, final viscosity, disintegration value, recovery value, peak time, gelatinization temperature and so on, which has a great impact on the processing quality of waxy maize (Han *et al*. 2018). Affected by amylose and amylopectin, these indexes directly control the taste and quality of food. Because almost all the starch in waxy maize is amylopectin, the study of starch gelatinization characteristics can directly show the quality of waxy maize varieties. In the present research, Jikenuo 19, a waxy maize variety bred by maize breeding research group of Jilin Academy of Agricultural Science and Technology, was used as

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material to explore the effect of harvest time on grain quality and gelatinization characteristics, so as to provide reference for the harvest time and quality improvement of waxy maize varieties.

Materials and Methods

The experiment was carried out in the maize breeding base of Jilin Agricultural Science and Technology University (43°57' N, 126°40′ E) in the spring of 2020. The soil of test field with medium- fertility is silty clay loam and the previous crop was soybean. The results showed that the basic soil nutrient status of 0 - 20 cm before sowing was 17.64 g/kg of organic matter, 1.236 g/kg of total nitrogen, 0.38 g/kg of total phosphorus, 66.85 mg/kg of alkali hydrolyzed nitrogen, 9.58 mg/kg of available phosphorus, 97.66 mg/kg of available potassium, pH 6.9, which were suitable for waxy maize planting.

Jikenuo 19, a sweet waxy maize variety with high quality and fresh food, was selected by the maize breeding research group of Jilin Academy of agricultural science and technology. The seed was purple-red-white-yellow-brown, which will be approved by crop variety identification committee of Jilin Province in 2022.

Seeds were sown on May 1, 2020 whilst the length of the plot, ridge spacing, No. of rows, plot area and density of plants were 15 m^2 and 70000 plants/hm^2, respectively. The 300 kg/hm^2 organic-inorganic compound fertilizer was applied as base fertilizer, and 800 times phoxim was used for root irrigation before ridging. Fixed seedlings were used and cultivated timely.

Before silking, 40 representative plants with strong growth and similar growth were selected. The ear was labeled, bagged and self-pollinated on the same day of full bloom. About 6 bagged ears were taken at 21, 23, 25, 27, 29 and 31 days after pollination, respectively. After 20 min of green at 100°C, they were dried at 65°C to constant weight for starch gelatinization characteristics and grain nutritional value determination. Fresh ears were used for sensory and cooking quality determination.

The sensory and cooking quality of fresh ears were evaluated according to the Chinese National Standard (NY/T 524-2002). Properties of starch gelatinization was measured by Rapid Visco Analyzer, and TCw (Thermal Cycle for Windows) software was used to analyze peak viscosity, valley viscosity, disintegration value, final viscosity, recovery value, peak time and gelatinization temperature. The contents of starch and soluble sugar were determined by anthrone colorimetry. The content of protein was determined by indophenol-blue colorimetry. The contents of starch, soluble sugar and protein were showed as percentage.

Excel 2013 and SPSS 20.0 were used for data processing and statistical analysis.

Results and Discussion

There were significant differences in ear color of Jikenuo 19 under different harvest time. On the 21th and 23th day after pollination, the ear and grain were thicker, the water content was higher, most kernels were light yellow and had not changed to multicolored color (Table 1). On the other hand, on the 25th and 27th day, the grains were full, glossy and elastic (Table 1). On the 29th and 31th day, the grains were completely formed, the color was darker, the water content was lower, and the ear was hard (Table 1).

Results presented in Table 1 reveal that the total score of Jikenuo 19 was the highest (89.1 points) at 27d after pollination, and the scores of sensory quality, smell, flavor, color, waxiness and tenderness were maximum than those at other harvest times. Before 27 days, the longer the harvest time, the better the quality. After 27 days, the quality began to decline and reached the lowest level (77.0 points) at 31 days. It may be assumed that the sensory and cooking quality of Jikenuo 19 are

the best when the harvest time is 27 days, which can maintain the marketability of the ear to the greatest extent and meet its marketing needs and economic benefits.

Table 1. Sensory and cooking quality of Jikenuo 19 at different harvest time.

Harvesting time after pollination	Sensory quality	Cooking quality					
		Smell and flavor	Color	Waxiness	Tender	Thickness	Total score
21th	24.0	14.0	5.5	15.0	7.8	16.0	82.3
23th	25.0	15.0	5.8	15.8	8.0	16.0	85.6
25th	25.4	15.0	6.2	16.1	8.4	16.5	87.6
27th	25.7	15.5	6.4	16.4	8.6	16.5	89.1
29th	25.0	13.3	5.8	15.6	7.4	14.6	81.7
31th	24.5	12.2	5.4	14.7	6.5	13.7	77.0

Results showed that the contents of starch, protein and soluble sugar changed significantly with the prolongation of harvest time, and the starch content increased with the prolongation of harvest time (Fig. 1). The lowest starch content was 52.84% at 21 days after pollination. The highest content was about 64.75% at 31 days after pollination. The content of protein and soluble sugar decreased with the delay of harvest time, and the highest content was at 21 days after pollination, with the content of protein and soluble sugar being 14.16 and 8.49%, respectively. Whilst the lowest content was 13.66 and 5.42% at 31 days after pollination (Figs 2 and 3). It is apparent from the result that the main nutritional components of waxy corn grains were protein and soluble sugar in the early filling stage after unified pollination, and gradually changed to starch in the late filling stage (Qi *et al.* 2009).

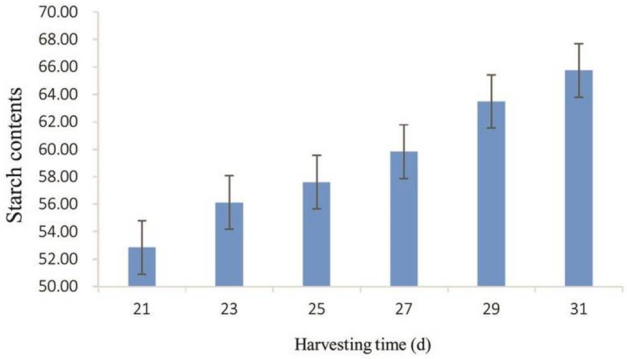

Fig.1. Starch contents at different harvesting times.

The comparison results of starch gelatinization characteristics of Jikenuo 19 during harvest are presented in Table 2. It is evident from the result that there was no significant difference in gelatinization temperature during different harvest periods, but with the delay of harvest period, the peak viscosity, valley viscosity, final viscosity, disintegration value, recovery value and peak time all show a trend of first rising and then declining, reaching the highest at 29d of harvest

period, which could be suggested for improving the gelatinization characteristics of starch. The peak viscosity, valley viscosity, final viscosity, disintegration value and peak time ranged from 1028.00 to 1746.50 RVU, 763.50 to 1256.50 RVU 924.50 to 1574.00 RVU, 264.50 to 490.00 RVU and 5.16 to 5.43 min, respectively. In addition, the variation coefficients of peak time and gelatinization temperature were lower, while the variation coefficients of peak viscosity, valley viscosity, final viscosity, disintegration value and recovery value were higher, and the variation coefficient of disintegration value was the highest, reaching 39.71%. It shows that the peak viscosity, valley viscosity, final viscosity, disintegration value and recovery value are greatly affected by the harvest time, on the contrary, the peak time and gelatinization temperature are less affected by the harvest time (Qi *et al*. 2009).

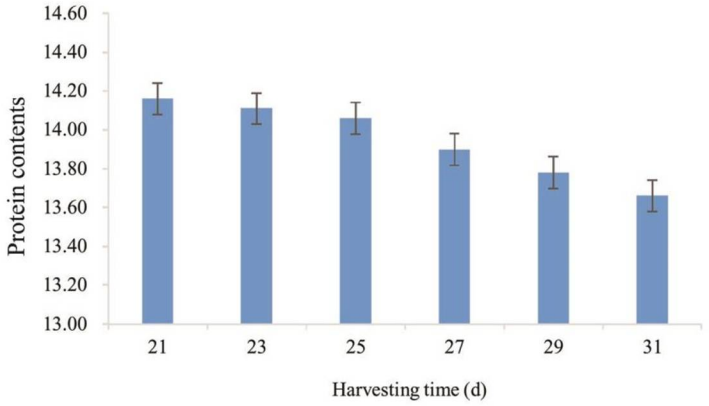

Fig. 2. Protein contents at different harvesting times.

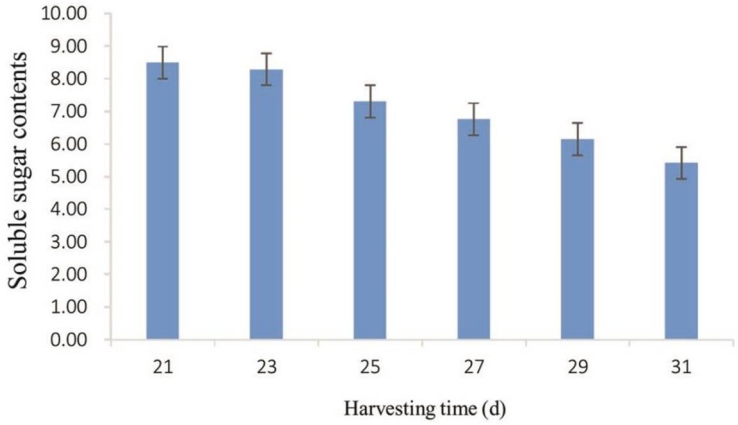

Fig. 3. Soluble sugar contents at different harvesting times.

Results of correlation analysis between nutritional quality and gelatinization characteristic value of Jikenuo 19 (Table 3) shows that peak viscosity was positive significantly correlated with protein content, through viscosity, final viscosity and disintegration value whilst through viscosity was positive significantly correlated with peak viscosity, final viscosity and disintegration value. On the other hand, final viscosity was determined to be positively correlated with peak viscosity,

through viscosity and disintegration value whereas gelatinization temperature was positively correlated with reply value only. Furthermore, disintegration value was found to be positively correlated with protein content, peak viscosity, through viscosity and final viscosity while reply value was positively correlated with gelatinization temperature only.

Table 2. Comparison of starch gelatinization characteristics during harvest.

Harvesting time (d)	Peak viscosity (RVU)	Trough Viscosity (RVU)	Final viscosity (RVU)	Disintegration value (RVU)	Reply value (RVU)	Peak time (min)	Gelatinization temperature (°C)
21	1028.00 c	763.50 d	924.50 e	264.50 f	161.00 d	5.16 b	80.20 a
23	1098.50 c	793.50 cd	969.50 e	305.00 e	176.00 cd	5.20 b	79.46 a
25	1164.50 c	827.00 c	1075.00 d	337.50 d	248.00 b	5.21 b	78.70 a
27	1598.50 b	1173.50 b	1429.50 b	425.00 b	256.00b	5.28 ab	77.08 a
29	1746.50 a	1256.50 a	1574.00 a	490.00 a	317.50 a	5.43 a	76.50 a
31	1567.00 b	1177.00 b	1376.50 c	390.00 c	199.50 c	5.27 ab	80.15 a
CV(%)	28.93	18.58	17.89	39.71	11.07	2.37	2.11

Table 3. Correlation analysis between kernel nutritional quality and gelatinization characteristic value of maize.

	Starch content	Protein content	Soluble sugar content	Peak viscosity	Trough Viscosity	Final viscosity	Gelatini-zation temp.	Disinte-gration value	Reply value
Peak viscosity	-0.40	0.80*	-0.70	1.00	0.96**	0.98**	-0.12	0.99**	-0.20
Trough viscosity	-0.78	0.48	-0.10	0.96**	1.00	0.96**	-0.18	0.96**	-0.16
Final viscosity	-0.10	0.38	-0.22	0.92**	0.95**	1.00	-0.35	0.91**	-0.04
Gelatinization temp.	-0.56	0.52	-0.70	-0.10	-0.22	-0.30	1.00	-0.05	0.87**
Disintegration value	-0.16	0.88**	-0.15	0.95**	0.94**	0.91**	-0.05	1.00	-0.25
Reply value	-0.06	0.54	-0.49	-0.20	-0.20	-0.04	0.86**	-0.24	1.00

*Indicates significant difference at the level of 0.05. ** indicates significant difference at the level of 0.01.

The suitable harvest time of waxy corn depends on its edible quality and nutritional quality. The key to determine the suitable harvest time is to study the changes of starch, protein and soluble sugar content. In this research, starch content increased with the extension of harvest time, while protein and soluble sugar content decreased with the delay of harvest time. This finding is more or less similar to the previous research results reported by Ma *et al*. (2016), Liu *et al*. (2013). The sensory and cooking quality of Jikenuo 19 ear at different harvest time were evaluated, and the best quality time was found to be 27 days after pollination.

Results of starch gelatinization characteristics of Jikenuo 19 during harvest shows that harvest time had no effect on gelatinization temperature, which indicated that gelatinization temperature had nothing to do with harvest time, and might be affected by varieties. The peak viscosity, valley viscosity, final viscosity, disintegration value, recovery value and peak time increased first and then decreased with the delay of harvest time, and reached the highest at 29d of harvest time. Hence it could be suggested that harvesting at 29th day can improve the gelatinization characteristics of starch.

The correlation between grain nutritional quality and gelatinization characteristic value of Jikenuo 19 was analyzed. The results in Table 3 show that protein content was positively correlated with gelatinization characteristic value, which indicated that protein content had great influence on gelatinization characteristic. There was a significant positive correlation between protein content and peak viscosity, valley viscosity, final viscosity, disintegration value, starch content, soluble sugar content and gelatinization temperature and recovery value, which was consistent with the previous research results reported by Lu (2011). The starch granule binding protein contained in protein has certain effect in the process of starch synthesis, so the protein is decreasing, which affects the nutritional quality and gelatinization characteristics by affecting the starch production (Chia *et al*. 2019).

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