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Changes in Carbohydrate Components of Hard and Soft Wheat during Kernel Maturation

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硬, 軟質 小麥의 成熟에 따른 炭水化物 特性의 變化

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Abstract

These studies were conducted to investigate the changes in carbohydrate properties of the endosperm during the stages of maturity. Original moisture continued to decrease while 1,000-kernel weight and test weight increased steadily in all varieties with maturation. Starch content of the endosperm increased continuously by 35 to 40 days after heading. The B-type starch granules synthesis of the the early mature variety, Chokwang, was depressed at the later stages of development. Amylose and amylopectin components of starch both increased as the kernel matured, and amylose-amylopectin ratio also increased during the same period. Amount of pentosan per kernel basis increased throughout the maturation period. Amylograph breakdown had a highly negative coefficient correlation with starch and pentosan content of endosperm. Results indicated that wheat maturation was characterized by an increase in the starch and pentosan content of the kernel.

Introduction

The changes in carbohydrate composition of maturing wheat have been studied by several workers.[1-3] The onset of rapid starch synthesis is accompanied by a marked decline in the concentration of sucrose and reducing sugars. Jenner[4] showed the close relationship between the concentration of sucrose in the endosperm and the rate of starch synthesis in detached ears of wheat cultures in solutions of sucrose.

Pentosans in the endosperm were reported to increase throughout kernel development.[3] This increase was attributed to the synthesis of new cell walls for the accommodation of the newly synthesized storage materials. Bice et al.[5] reported that the amylose content of wheat starch increased with maturity, and that the amylose-amylopectin ratio increased during the same period.

Differences in the rate of starch accumulation among varieties appeared to be small. Of much greater importance was the length of time during which starch synthesis took place, indicating that seasonal conditions such as temperature, rainfall, and insolation are important factors controlling the rate and duration of starch synthesis and hence overall yield.[6,7]

A considerable amount of information is available on the carbohydrate composition of mature wheat, but no information is available on changes that occur as a variety matures grown in Korea. The purpose of our studies was to take all these aspects into consideration and to try to contribute to a better knowledge of the development of the carbohydate composition during the ripening of wheat kernels.

Materials and Methods

Materials

Three varieties of wheat were examined: Chokwang (soft wheat), Suweon 219 (intermediate), and Suweon 210 (hard wheat). All varieties were grown under field conditions in Suweon, during two consecutive years, 1981 and 1982.

Samples of each variety were harvested at 5-day in-

tervals from 25 days after heading to fully ripe. A small portion of each sample was taken for moisture determination and another part were dried at 40°C in through-flow air dryers to about 12.5% moisture.

Methods

Milling: The clean, tempered wheat samples were milled with a Buhler experimental mill. Details of the milling procedure and results were given by AACC methods.[8]

Pentosan: Pentosan content in flour was determined by the volumetric bromine procedure (AACC, 52-10).

Starch. Starch content in the whole wheat flour was determined by AOAC direct acid hydrolysis method.[9]

Starch isolation: The flour sample was mixed in a Waring Blendor in a ratio of 1 part flour to 2 parts distilled water for 2 min at low speed. The suspension was centrifuged 15 min at 2,000 × G. The water-soluble supernatant was decanted and the material above the prime starch layer was removed with a flat-tip spatula. The starch layer was reslurried and centrifuged at the same speed as above. The purified prime starch was allowed to air-dry for 2 days, passed through a 70-mesh sieve, and stored for analysis.

Amylose: The percentage of amylose in starch was determined according to the colorimetric procedure described by Williams et al.[10]

Gelatinization properties of flour and starch: Flour (65*g*, 14% m.b.) was suspended in 450 ml distilled water. The temperature was raised from 25°C to 95°C, held at 95°C for 15 min, and lowered uniformly to 50°C.

Table 1. Changes in moisture content, test weight and 1,000-kernel weight of maturing wheat

Variety	Days after heading	Moisture content (%)	Test weight (*g*/ℓ)	1,000-kernel weight (*g*)
Chokwang	25	59.1	656	21.9
	30	52.2	737	30.9
	35	43.8	775	37.9
	40	27.0	777	39.1
	45	19.3	776	40.6
	50	15.1	783	40.3
Suweon 219	25	60.7	653	19.3
	30	53.2	747	29.5
	35	44.4	797	37.4
	40	32.8	809	40.5
	45	21.0	803	41.4
	50	17.1	805	41.1
Suweon 210	25	60.9	629	15.6
	30	56.4	744	23.2
	35	46.7	793	30.6
	40	34.4	817	35.2
	45	27.5	818	36.6
	50	20.9	815	36.5

Results and Discussion

Table 1 showed the changes in original moisture, test weight and 1,000-kernel weight during the maturation of a variety of Chokwang, Suweon 219 and Suweon 210. Original moisture continued to decreased steadily in all varieties with maturation. The time of initiation of maturi-

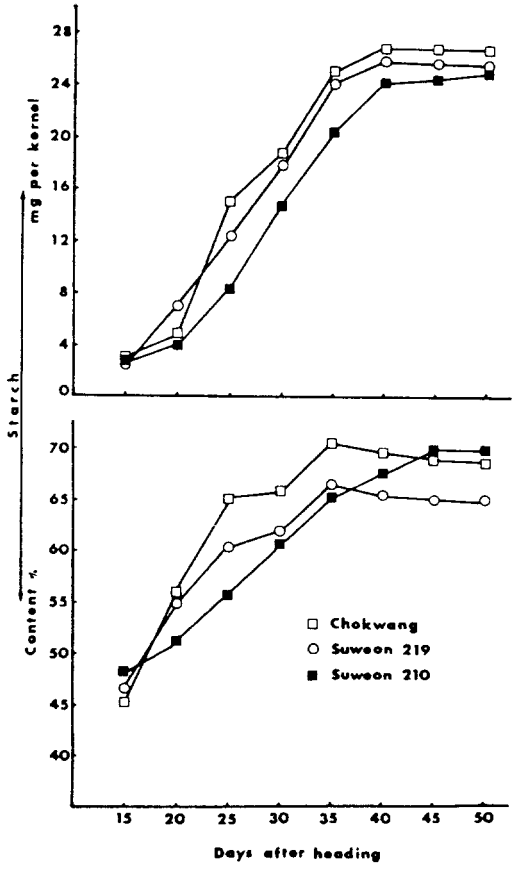

Fig. 1. Changes in starch content during maturation of soft and hard wheat

ty was not only dependent on the variety, but also on the environmental conditions.[11]

Fig. 1 shows how starch content fluctuated in the developing endospem, in both percentage terms and in terms of mg per kernel. The two cultivars, Chokwang and Suweon 219, had remarkably similar patterns of starch accumulation and responded similarly to variations in environmental conditions. Net starch weight per kernel of Chokwang and Suweon 219 increased linearly from approximately 15 to 35 days. In Suweon 210, the starch content increased and reached its maximum level by the end of the maturation period.

Table 2 presents the changes in amylose and amylopectin content in starch during maturation. Examination of the data reveals that amylose content in starch increased steadily during maturation for the tested wheats. These results confirm the findings of Abou-Guendia and D'Appolonia.[12]

The ratio of amylose to amylopectin in Chokwang variety decreased from 1:4.3 at the first stage of maturity. Similar trends were observed for the Suweon 219 and Suweon 210 variety. At the all stages of maturity slightly different ratio of amylose to amylopectin were obtained for the different varieties harvested at approximately the same moisture level which suggests that the amylose-amylopectin ratio is a varietal characteristic. The results of this work also indicate that during the early stages of development the amylopectin fraction was synthesized at a relatively faster rate than the amylose fraction.

The pentosan contents of the tested wheat flour at the different stages of maturity are presented in Table 3. Abou-Guendia and D'Appolonia[12] reported a slightly increasing trend in wheat pentosans with maturation. In this study, only small differences were noted in the amount of pentosans at the different stages of maturity. However, if the pentosan content of the flour is expressed on a per kernel basis, the amount of pentosans in the varieties increased throughout the maturation period, which agree with the findings of Jennings and Morton.[3] These workers reported that the increse in pentosan content in

Table 2. Changes in amylose and amylopectin content during maturation of the tested wheat

Variety	Days after heading	Amylose* (%)	Amylose in starch per kernel (*mg*)	Amylopectin* (%)	Amylopectin in starch per kernel (*mg*)	Amylose: Amylopectin ratio per kernel
Chokwang	25	19.8	2.82	80.2	11.43	1:4.1
	30	21.7	4.43	78.3	15.99	1:3.6
	35	23.8	6.40	76.2	20.48	1:3.2
	40	25.9	7.18	74.1	20.17	1:2.8
	45	25.5	6.93	74.5	20.25	1:2.9
	50	25.7	6.96	74.3	20.13	1:2.9
Suweon 219	25	17.5	2.04	82.5	9.63	1:4.7
	30	19.2	3.51	80.8	14.78	1:4.2
	35	21.9	5.45	78.1	19.42	1:3.6
	40	22.1	5.84	77.9	20.57	1:3.5
	45	22.9	6.17	77.1	20.78	1:3.4
	50	23.5	6.17	76.5	21.35	1:3.5
Suweon 210	25	16.9	1.46	83.1	7.17	1:4.9
	30	18.2	2.55	81.8	11.48	1:4.5
	35	20.7	4.17	79.3	15.97	1:3.8
	40	21.9	5.20	78.1	18.56	1:3.5
	45	22.5	5.75	77.5	19.80	1:3.4
	50	23.0	5.86	77.0	19.62	1:3.3

Amylopectin percent = 100-percent amylose
* At 14.0% m.b.

Table 3. Changes in pentosan content of maturing wheat flour

Variety	Days after heading	Pentosan* (%)	Pentosan in flour per kernel, (*mg*)
Chokwang	25	3.04	0.43
	30	2.93	0.61
	35	3.00	0.79
	40	2.95	0.79
	45	2.95	0.82
	50	2.99	0.83
Suweon 219	25	3.00	0.36
	30	3.01	0.62
	35	3.06	0.80
	40	3.01	0.84
	45	2.98	0.86
	50	2.95	0.86
Suweon 210	25	3.06	0.30
	30	2.97	0.48
	35	3.02	0.66
	40	3.04	0.76
	45	3.05	0.80
	50	3.06	0.78

* At 14.0% m.b.

the endosperm per kernel 14 days after flowering was due to the increase in the new cell-wall synthesis that accompanied the enlargement of endosperm cells for the accommodation of the newly synthesized storage materials like starch.

Amylograms of the wheat flours are given in Table 4. These values summarized that pertinent data which can be obtained from the amylograph curves. A progressive decrease in temperature of initial pasting was observed during the period investigated. The 15-min. height and 50°C height increased with maturation.

Break-down characteristics in Amylograph decreased as the days after heading were increased (Fig. 2). This phenomenon indicates that the decrease in break-down is due to the increase in the integrity of the starch granules with maturation of the kernel. The results thus obtained confirmed previous reports[13,14] that most of the starch accumulation takes place at the initial stages after pollination when new cell walls are being formed, and continues to be synthesized during the maturation stages.

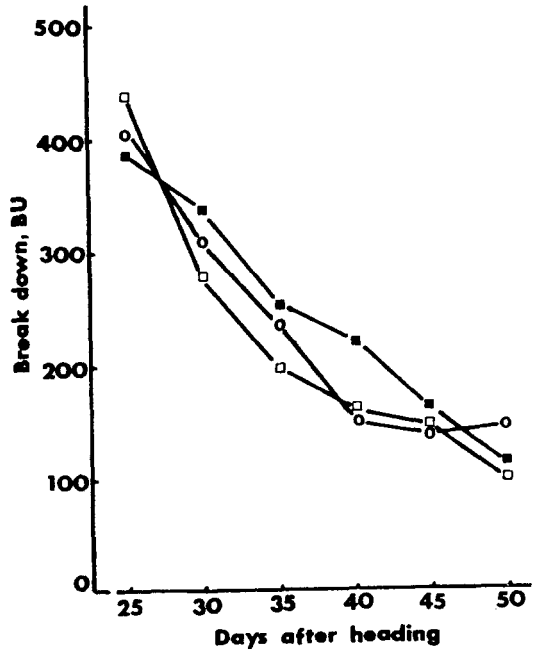

Fig. 2. Changes of break-down in amylogram during maturation of tested wheats. Varieties designated as in Fig. 1

Amylograph break-down had a correlation coefficient of $r = -0.861^{**}$ with starch content, of $r = -0.914^{**}$ with amylose content and of $r = 0.969^{**}$ with flour ash (Fig. 3). This high degree of correlation indicates that the break-down is reflecting faithfully the kernel maturation response the wheats, i.e., starch synthesis depletes the pool of precursor compounds during the maturation process as suggested by Jennings and Morton.[3]

要 約

本 研究는 硬, 軟質 小麥의 成熟過程에 따른 炭水化物 特性의 變化에 대하여 검토하였다. 種實의 水分含量이 減少함에 따라 千粒重과 容積重은 增加되었다. 胚乳의 澱粉含量은 出穗後 35~40일까지 급격히 增加하였으며, 특히 早熟種인 早光은 B-type 澱粉의 合成이 억제되었다. Amylose와 amylopectin 含量은 成熟期間에 따라 增加되었으며, pentosan의 含量도 계속 증가되었다. Amylograph break-down은 成熟期間中 계속 減少되었으며, 胚乳의 澱粉含量과 高度의 負相関이 있었다.

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Table 4. Amylograph characteristics of the wheat flour during maturation

Variety	Days after heading	Initial pasting temp. (°C)	Peak height (BU)	15-min* height (BU)	50°C** height (BU)
Chokwang	25	66.3	900	645	1,295
	30	65.5	900	690	1,305
	35	64.8	1,005	765	1,425
	40	64.8	1,025	855	1,485
	45	63.3	1,000	840	1,525
	50	62.8	980	800	1,510
Suweon 219	25	63.3	855	565	1,220
	30	63.3	900	615	1,290
	35	62.5	885	700	1,235
	40	61.8	845	700	1,215
	45	61.8	810	660	1,210
	50	61.8	820	680	1,225
Suweon 210	25	64.0	870	470	1,240
	30	63.5	1,020	690	1,245
	35	64.0	1,045	840	1,365
	40	63.3	1,083	815	1,550
	45	62.5	1,030	845	1,500
	50	62.3	1,033	860	1,515

* Viscosity at the end of the 15-min period of holding at 95°C
** Viscossity at 50°C during the cooling cycle

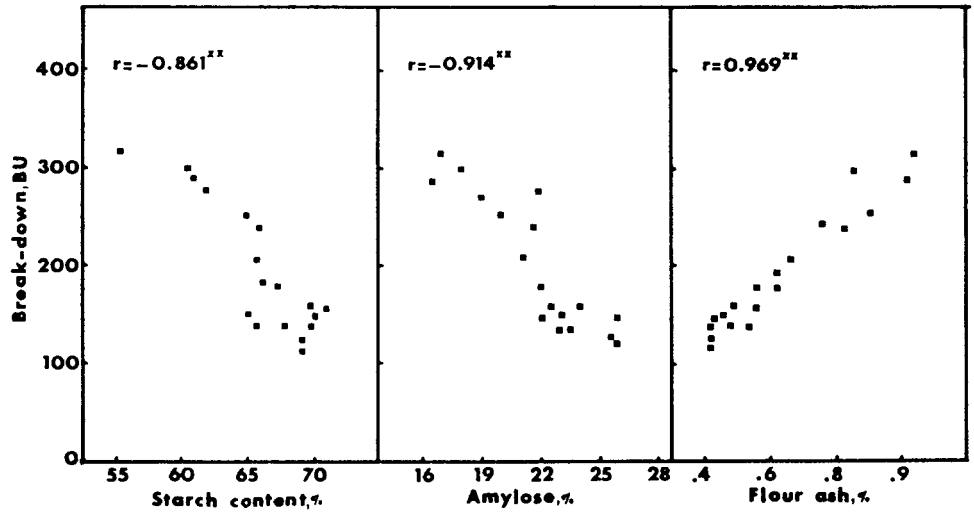

Fig. 3. Relationship between starch, amylose, flour ash content and amylograph break-down during kernel maturation

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