Quantitative and qualitative characteristics of sugars in the seeds of soybean cultivated in Poland

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Abstract

The content of sugars (hydrolysable and soluble: mannose, sucrose, raffinose and stachyose) and of protein was determined in 42 seed samples of soybean cultivated in Poland in 1977, 1978 and 1979. Beside inter-variety and -lines variation in sugar level, year-to-year changes were observed. The tendency of negative correlation between hydrolysable sugars and protein content mentioned in the literature is confirmed.

INTRODUCTION

In the composition of soybean seed four main group components are listed — these are: proteins, fats, sugars and polysaccharides. Among them, the first two — proteins and fats — decide of the nutritional and technological value of soybean as human food. Therefore, their content plays a leading role as one of the decisive factors in the selection of new lines and varieties of soybean.

In recent years the amount and qualitative composition of sugars in soybean — especially oligosaccharides of the raffinose family — gained attention. Oligosaccharides are mentioned as a causative factor of flatulence after consuming soybean products (Rackis, 1974; Cristofaro et al., 1974; Steggerda et al., 1966). Up till now the literature data on sugars and polysaccharides in the soybean concerns mainly varieties grown in the USA, Japan and Korea (Smith and Circle, 1972). It is known, that the total amount of oligo- and polysaccharides varies in different varieties of soybean. The American varieties have on the average about 9.3% of soluble carbohydrates (in dry matter), including 4.5% sucrose, 1.5% raffinose and 3.7% stachyose; fructose and arabinose are present in trace amounts. The Japanese varieties are richer in sucrose (ca. 5.7% of dry matter) and stachyose (4.1% of dry matter) (Smith and Circle, 1972). There are only very few data about sugars in the soybean

varieties developed and cultivated in Poland (S o r a l - Ś m i e t a n a et al., 1978).

The proportions of the above mentioned main group components are closely interrelated. Krober and Cartter noticed, that the increase in protein content is accompanied by a parallel proportional decrease of fats, sugars as well as hemicelluloses and pentosans (H o w e l l, 1963). According to Cartter and Hopper, there is a negative correlation between protein content in the soybean seed and the sum of fat and total sugars (H y m o w i t z et al., 1972). With in the complex project of adaptation of soybean to be cultivated in the Polish climate and soil conditions initiated by the Institute of Plant Breeding and Acclimatization in Radzików near Warsaw, the study was undertaken to characterize the content of hydrolyzable and soluble sugars and the amount of main mono- and oligosaccharides in selected lines and varieties of soybean developed as the result of selection and genetic work. The foregoing are intended as additional information, which — together with basic information on the yield, protein content and disease resistance — can be used for selection of the best varieties for Polish conditions.

MATERIALS AND METHODS

42 seed samples of various selected lines and varieties of soybean experimentally cultivated in Poland (Experimental Stations of the Institute of Plant Breeding and Acclimatization in the years 1977, 1978, 1979) were used as experimental material.

Laboratory samples of 100 - 200 g weight were disintegrated; dry matter and total protein content (Kjeldahl method, $N \times 6.25$) were determined prior to sugar analysis.

Following sugars analyses were made:

hydrolysable sugars after acidic hydrolysis in H_2SO_4 (105°C/2h) according to the method elaborated by J a c ó r z y ń s k i and H r y n i e w i c z (1979),

soluble sugars (in 80% ethanol extracts) by the Dubois method adapted by Jacórzyński and Hryniewicz (D u b o i s et al., 1956; J a c ó r z y ń s k i and H r y n i e w i c z, 1978 b),

Hydrolysable and soluble sugars content was read from the glucose calibration curve and expressed as per cent of glucose in 100 g of sample dry matter,

the amount of mannose, sucrose, raffinose and stachyose by the descending paper chromatography (PC) method (solvent system — ethyl acetate : acetic acid : water, 3:1:3), followed by direct densitometric measurement of spots on the paper (J a c ó r z y ń s k i and K w a ś n i e w s k a, 1978; J a c ó r z y ń s k i and H r y n i e w i c z, 1978 a).

The content of sugars was expressed in per 100 g dry matter sample.

The data for hydrolysable and soluble sugars are based on 2-3 individual results, whereas the data for mannose, sucrose, raffinose and stachyose — on 3-5 individual results, each of them duplicated.

RESULTS AND DISCUSSION

Hydrolysable sugars, soluble sugars, mono- and oligosaccharides and protein contents in the analysed samples are shown in Tables 1, 2 and 3.

Wide variations in protein level owing to the soybean variety were found. Among 15 varieties and selected lines cultivated in the same Experimental Station in Przecław in 1978 (Table 2), the range of protein content was from 33.5% ('Aretic') to 40.8% dry matter ('Kiyewskaya'). Similarly in the Experimental Station Ożańsk in 1979 (Table 3) among 6 varieties the differences in protein ranged from 37.8% ('Ajma') to 46.0% dry matter ('Warszawska').

However, even within the same variety the level of protein shows some year-to-year variability and depends also on local climatic and soil conditions. Some of the analysed varieties were more stable in protein content ('Ajma', 'IHAR 78 B'), others were more sensitive ('Altona'). For example, the mean protein content for 'Ajma' was 35.0% dry matter with range 32.0-40.7% dry matter, whereas for 'Altona' — the mean value was 41.2% dry matter and the range 36.8-46.6% dry matter.

A general tendency of the inverse relation between protein and hydrolysable sugars content was observed with linear correlation coefficient $r = -0.68$ ($\alpha = 0.01$). It means that about 46% of sugars variability $n = 40$ can be explained by protein changes.

This is in agreement with earlier observations of Krober and Cartter (cit. H o w e l l, 1963) and H y m o w i t z et al. (1972).

A correlation between hydrolysable sugars and soluble sugars was also found ($r = 0.85$, $\alpha = 0.01$).

Soluble sugars content was not correlated with the content of particular oligosaccharides as reported by H y m o w i t z et al. (1972).

It is difficult to compare Polish and American data concerning the absolute amounts of soluble sugars and single oligosaccharides because of differences in the analytical procedures used. Nevertheless, relative comparison is possible. It seems that soluble sugars and sucrose content in American varieties is lower as compared with Polish ones, what is probably connected with higher protein content.

The ratio of sucrose to galactosugars (raffinose + stachyose) in the varieties grown in Poland amounted on the average to 2.9 (range for various varieties from 2.6 to 3.4) and was much higher than the same ratio for USA-grown varieties (about 1) (H y m o w i t z et al., 1972; T a n u s i et al., 1972). There were no variations in this ratio in three consecutive years of observations.

Table 1

Protein, hydrolysable sugars, soluble sugars and individual oligosaccharides content in soybean seeds grown in Poland (in 1977) g/100 g of seed, dry matter

Variety or selected line	Protein* N × 6.25	Hydrolysable sugars		Soluble sugars		Mannose**	Sucrose		Raffinose		Stachyose	
		$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
'AJMA' (Radzików)	32.1	30.4	1.55	13.3	0.66	0.1	7.1	0.65	0.8	0.11	1.2	0.14
'AJMA'	32.0	31.3	0.89	14.0	0.43	0.2	7.8	0.77	1.5	0.22	2.2	0.20
'IHAR 78/B'	37.0	30.1	1.60	14.7	0.11	0.1	5.0	0.41	0.7	0.06	1.4	0.14
'M-4149'	31.8	27.6	1.39	13.0	0.60	0.1	6.1	0.48	1.6	0.21	2.5	0.27
'M-4961'	38.7	29.8	1.64	15.2	0.62	0.1	6.2	0.40	1.7	0.20	2.8	0.34
'M-4855'	40.2	29.7	0.79	14.1	0.33	0.1	7.6	0.43	1.8	0.23	3.0	0.33
'K 3/2 F'	38.2	28.7	1.37	15.1	0.11	0.1	6.9	0.74	0.6	0.08	1.4	0.15
'K 6/4'	36.5	31.6	0.81	15.7	0.12	0.1	6.8	0.65	0.7	0.09	1.2	0.07
'Fiskeby'	37.7	28.0	1.32	14.0	0.11	<0.1	6.1	0.38	1.1	0.10	1.7	0.13
'Norman'	42.7	27.7	0.61	13.8	0.10	0.1	5.0	0.51	0.6	0.05	1.5	0.15
'ACME'	43.2	26.9	1.41	13.0	0.21	<0.1	4.4	0.25	0.7	0.09	1.3	0.14
'Altona'	46.6	25.3	1.59	11.8	0.19	0.1	5.1	0.35	1.3	0.16	1.6	0.11

*Arithmetic mean of 2 parallel analyses with a range not more than 0.035% of nitrogen amount (according to Polish Standard PN-75/A-04018).

**Amounts at the minimum detectable level; standard deviations have been omitted.

Table 2

Protein, hydrolysable sugars, soluble sugars and individual oligosaccharides content in soybean seeds grown in Poland (in 1978) g/100 g of seed, dry matter

Variety or selected line	Protein* N × 6.25	Hydrolysable sugars		Soluble sugars		Mannose**	Sucrose		Raffinose		Stachyose	
		$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
'Ajma' (Ożańsk)	33.6	33.5	1.76	14.5	0.38	0.1	6.5	0.63	0.7	0.10	1.0	0.14
'Ajma' (Sandomierz)	36.2	32.0	1.60	14.4	0.58	0.1	5.6	0.32	0.7	0.11	0.8	0.11
'Ajma' (Radzików)	34.5	31.3	1.20	15.5	0.51	0.1	6.7	0.61	0.5	0.06	1.1	0.13
'Ajma' (Przeclaw)	33.6	31.5	1.28	15.3	0.79	0.1	4.7	0.34	0.5	0.06	1.1	0.12
'K 3/26' (Przeclaw)	37.3	29.3	0.69	15.9	0.44	0.1	7.1	0.54	0.7	0.08	1.1	0.11
'K 3/2F' (Przeclaw)	36.9	30.6	1.14	15.5	0.55	0.1	7.3	0.61	0.7	0.09	1.2	0.16
'N/M 4149' (Przeclaw)	38.0	28.6	1.19	13.6	0.21	0.1	6.5	0.50	1.6	0.20	2.1	0.23
'N/M 4855' (Przeclaw)	40.0	30.8	1.57	14.6	0.65	0.1	7.5	0.63	1.7	0.19	2.0	0.23
'IHAR NK' (Przeclaw)	39.0	28.8	1.47	14.3	0.29	0.1	6.8	0.50	1.2	0.16	1.5	0.18
'Acme' (Przeclaw)	38.4	29.9	1.03	15.0	0.66	<0.1	7.8	0.09	1.1	0.13	1.9	0.19
'Nordia 1' (Przeclaw)	38.6	30.7	0.86	14.9	0.37	0.1	6.6	0.46	0.9	0.13	1.7	0.19
'N/M 4961' (Przeclaw)	36.3	32.6	1.10	15.5	0.62	0.1	7.7	0.48	1.3	0.19	2.0	0.20
'Portage' (Przeclaw)	39.0	29.1	1.62	14.3	0.72	<0.1	5.0	0.34	0.7	0.09	1.4	0.13
'Aretic' (Przeclaw)	33.5	31.1	1.56	14.5	0.79	0.1	4.6	0.27	0.9	0.12	1.3	0.16
'Warszawska' (Przeclaw)	37.2	32.1	1.07	15.1	0.38	0.1	4.0	0.25	0.9	0.13	1.2	0.13
'Fiskeby' (Przeclaw)	34.7	30.7	1.72	15.9	0.63	0.1	6.8	0.46	1.1	0.15	1.8	0.19
'Kiyewskaya' (Przeclaw)	40.8	28.3	1.33	14.8	0.80	<0.1	4.7	0.33	0.4	0.04	1.1	0.13
'Altona' (Przeclaw)	36.8	30.1	0.48	14.6	0.71	0.1	4.9	0.30	0.5	0.06	1.1	0.12

*Arithmetic mean of 2 parallel analyses with a range not more than 0.035% of nitrogen amount (according to Polish Standard PN-75/A-04018).

**Amounts at the minimum detectable level; standard deviations have been omitted.

Table 3

Protein, hydrolysable sugars, soluble sugars and individual oligosaccharides content in soybean seeds grown in Poland (in 1979) g/100 g of seed, dry matter

Variety or selected line	Protein* N x 6.25	Hydrolysable sugars		Soluble sugars		Mannose**	Sucrose		Raffinose		Stachyose	
		$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
'AJMA' (Radzików)	40.7	24.5	1.02	13.1	0.19	0.1	4.8	0.51	0.4	0.05	1.0	0.12
'IHAR 78/B' (Radzików)	38.5	25.7	0.65	13.3	0.44	0.1	4.8	0.41	0.5	0.08	1.0	0.09
'Warszawska' (Radzików)	43.5	24.2	0.36	10.6	0.23	<0.1	4.4	0.47	0.5	0.06	1.2	0.15
'ACME' (Radzików)	41.0	24.9	0.51	11.6	0.53	0.1	6.4	0.38	0.8	0.09	1.3	0.13
'Fiskeby' (Radzików)	40.1	27.3	1.46	10.8	0.16	0.1	6.3	0.61	0.8	0.12	1.3	0.16
'Altona' (Radzików)	41.0	25.4	1.40	10.5	0.06	<0.1	4.8	0.34	0.7	0.09	0.9	0.11
'Ajma' (Ożański)	37.7	25.9	1.50	12.4	0.39	<0.1	5.5	0.56	0.8	0.10	1.2	0.13
'IHAR 78/B' (Ożański)	38.0	25.7	0.36	10.9	0.44	0.1	5.1	0.56	0.8	0.11	1.1	0.12
'Warszawska' (Ożański)	46.0	23.0	0.83	10.3	0.29	<0.1	4.3	0.39	0.7	0.10	0.9	0.08
'ACME' (Ożański)	42.4	24.1	1.16	11.2	0.14	0.1	5.0	0.36	0.7	0.10	1.1	0.11
'Fiskeby' (Ożański)	38.4	23.9	0.46	11.8	0.30	0.1	4.2	0.32	0.7	0.10	1.0	0.10
'Altona' (Ożański)	40.4	22.6	0.50	11.2	0.25	0.1	5.7	0.37	0.8	0.10	1.1	0.11

*Arithmetic mean of parallel analyses with a range not more than 0.035% of nitrogen amount (according to Polish Standard PN-75/A-04018).

**Amounts at the minimum detectable level; standard deviations have been omitted.

In the opinion of Pazur et al. (1962) and Adjei-Twum and Splittstroesser (1976) the ratios between particular sugars in soybean seed change with the metabolic processes during growth of the plant, maturation of the seed and during storage of the seed after harvesting.

The relative lower amount of nutritionally negative galactosugars in soybean grown in Poland is a positive feature.

CONCLUSIONS

1. The content of hydrolysable sugars and soluble sugars in the varieties and selected lines of soybean grown in Poland analysed over a three-year period was in the range 22.6 - 33.5% and 10.3 - 15.9% in dry matter, respectively. There were obvious differences in the ranges in consecutive years.

2. The tendency to negative correlation between hydrolysable sugars and protein content mentioned in the literature has been confirmed ($r = -0.68$ for $n = 40$ significant of $\alpha = 0.01$).

3. The average ratio of sucrose to galactosugars (raffinose + stachyose) in soybean grown in Poland is 2.9 with a range of 2.6 to 3.4 for various varieties, whereas the same ratio for soybean grown in the USA is about 1. It means that the relative amount of nutritionally undesirable galactosugars in the varieties grown in Poland is lower.

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Jakościowa i ilościowa charakterystyka cukrów w nasionach soi uprawianej w Polsce

Streszczenie

Określono zawartość białka i cukrowców (cukrów po hydrolizie, cukrów rozpuszczalnych oraz mannozy, sacharozy, rafinozy i stachiozy) w próbkach różnych odmian i rodów soi uprawianej w Polsce w latach 1977, 1978 i 1979. Przebadano 12 odmian ze zbiorów w 1977 r., 18 odmian ze zbiorów w 1978 r. i 12 odmian ze zbiorów w 1979 r.

Stwierdzono duże zróżnicowanie w zawartości cukrów i białka w soi w zależności od odmiany i miejsca uprawy.

Zawartość cukrów po hydrolizie w badanych próbkach soi wahała się w granicach 22,6-33,5% suchej masy, a cukrów rozpuszczalnych od 10,3 do 15,9% suchej masy.

Stwierdzono istotną ujemną korelację ($r = -0.68$ dla $n = 40$) między zawartością białka i cukrów po hydrolizie w nasionach soi. Stosunek sacharozy do galaktocukrów (rafinoza + stachioza) w soi uprawianej w Polsce kształtował się od 2,9 do 3,4 – w porównaniu z odmianami uprawianymi w USA (na podstawie piśmiennictwa) odmiany uprawiane w Polsce są bogatsze w sacharozę, zawierają natomiast mniej galaktocukrów.