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INVESTIGACIÓN

Correlation of maturity groups with seed composition in soybeans, as influenced by genotypic variation

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RESUMEN

Correlación entre los distintos estados de maduración con la composición de la semilla en soja, influenciada por su variación genotípica.

Se analizaron la humedad, contenido en proteínas, carbohidratos, grasas y cenizas, y las composiciones en ácidos grasos y esteroles de las semillas de 19 cultivares de soja (Glycine max (L.) Merrill) con grupos de madurez V, VI o VII. Los contenidos de proteínas, aceites, carbohidratos y cenizas variaron entre 344-463 g kg^{-1}, 178-233 g kg^{-1}, 234-338 g kg^{-1} y 40.0-49.3 g kg^{-1} de materia seca, respectivamente. Los ácidos grasos mayoritarios fueron palmítico (9.2-12.5%), oleico (17.7-22.1%) y linoleico (53.6-56.9%). El porcentaje de ácido linolénico varió desde 8.6 hasta 10.4%. El principal componente de la fracción de esteroles del aceite fue el sitosterol (48.1-56.8%), seguido por el campesterol (18.4-21.7%) y el estigmasterol (13.4-18.0%). Se encontraron diferencias estadísticamente significativas entre los genotipos para la mayoría de los parámetros evaluados, pero no hubo variaciones significativas entre grupos de madurez.

PALABRAS-CLAVE: Ácido graso — Esterol — Genotipo — Maduración — Soja (semilla de).

SUMMARY

Correlation of maturity groups with seed composition in soybeans, as influenced by genotypic variation.

Seeds of 19 soybean cultivars (Glycine max (L.) Merrill) with maturity groups V, VI or VII were analyzed for proximate composition, fatty acids and sterols. Protein, oil, carbohydrate and ash contents varied between 344-463 g kg^{-1}, 178-233 g kg^{-1}, 234-338 g kg^{-1}, and 40.0-49.3 g kg^{-1} of dry matter, respectively. Fatty acid profiles revealed that the major acids were palmitic (9.2-12.5%), oleic (17.7-22.1%) and linoleic (53.6-56.9%). Linolenic acid ranged from 8.6 to 10.4%. Sitosterol (48.1-56.8%) was the main component of the sterol fraction, followed by campesterol (18.4-21.7%) and stigmasterol (13.4-18.0%). Statistically significant differences between genotypes were found for the majority of parameters evaluated, but there are not significant variations among maturity groups.

KEY-WORDS: Fatty acid — Genotype — Ripening — Soybean (seed of) — Sterol.

1. INTRODUCTION

Expansion of industrial uses of soybeans has stimulated research on composition of the seed, particularly with respect to oil and protein contents and iodine number of oil. As a consequence, the variability of composition has assumed importance, particularly as it is affected by genetic variation, environmental conditions and cultural practices such as date of planting (Carver *et al.*, 1986; Breene *et al.*, 1988; Schnebly and Fehr, 1993). Developing soybean varieties with superior chemical composition to meet special food applications has become a high research priority. During selection of soybeans for a particular food application or a particular seed breeding program, it is important to know the major factors affecting soybean quality such as protein and oil contents, the chemical components of protein and oil, and seed appearance (Liu *et al.*, 1995). Also, there has been an increasing concern about the study of the sterol fraction from seed oils because a specific sterol found in oats, Δ^5- avenasterol, was effective in retarding soybean oil deterioration (Duve and White, 1991).

The present work was undertaken to determine and compare the proximate composition and seed lipid components (fatty acids and sterols) of the most common soybean cultivars grown in Argentina under the same conditions at the Estación Experimental Agropecuaria (EEA-INTA) Manfredi, Córdoba. The broad objetive of our study is to contribute useful chemical information to the genetic quality of germplasm bank materials.

2. MATERIALS AND METHODS

2.1. Plant material

Nineteen soybean genotypes (*Glycine max* (L.) Merrill) with maturity groups V, VI or VII were grown in 1994/95 at the Estación Experimental Agropecuaria (EEA - INTA, Manfredi, Córdoba, Argentina). Three lots of healthy mature seeds from each cultivar were selected.

2.2. Proximate analysis

Moisture, protein, carbohydrate and ash contents were determined by the methods of the AOAC (1980).

2.3. Oil extraction

Seeds were milled and extracted with n-hexane in a Soxhlet apparatus for 12 hs. After drying the solution with anhydrous sodium sulphate, solvent was removed by vacuum distillation at 40°C. Oil percentages were determined by weight difference.

2.4. Fatty acid analysis

The crude oils were subjected to alkaline saponification (1 N KOH in methanol). Unsaponifiable matter was extracted with n-hexane. The fatty acid methyl esters (FAME) of total lipids were obtained using 1 N H_2SO_4 in methanol and analyzed by gas chromatography (GC) according to Maestri and Guzmán (1993). The theoretical iodine number was calculated according to Carreras *et al.* (1989).

2.5. Sterol analysis

A chloroform solution of unsaponifiable materials was applied uniformly on 20x20 cm TLC plates coated with 0.5 mm layer of silica gel and developed with chloroform/ethyl ether (90:10, v/v) as eluent (Gaydou *et al.,* 1983). After developing, the plates were sprayed with a solution of rhodamine in ethanol (0.5 g $litre^{-1}$) and observed under ultraviolet light. The sterol zones were carefully scraped from the plates and extracted with chloroform for subsequent GC analysis. A CBP^{-1} capillary column was used. Operating conditions were: column temperature, 200-280°C (5°C min^{-1}); injector and detector temperatures, 300°C; nitrogen carrier gas, 5 ml min^{-1}. Sterols were identified by comparing their relative retention times with those of authentic samples and those published by Padley *et al.* (1986).

2.6. Statistical analyses

All chemical determinations were conducted in triplicate. Statistical differences were estimated from one-way ANOVA test at the 5% level (P=0.05) of significance for all parameters evaluated. Least significant difference (LSD) was performed to establish relationships between each of two variables tested.

3. RESULTS AND DISCUSSION

Proximate analyses of the 19 cultivars investigated are shown in Table I. The NK 555, Asgrow 6404 and RA 702 cultivars have high protein content (444, 461 and 463 g kg^{-1}, respectively); while Federada 1, Hood 75, RA 587, Torcaza 63, Copetona 53 and Prata cultivars present an oil content higher than 220 g kg^{-1}. The carbohydrate contents constitute more than 230 g kg^{-1} in all samples, reaching values of 338 g kg^{-1} in Torcacita 58 cultivar. The ash contents range from 40.0 to 49.3 g kg^{-1}. Comparison of the average values of oil content in each maturity group shows the highest values for group VI. Mean values for protein, carbohydrate and ash contents are nearly the same. Although more data are needed to demonstrate whether there is an effect of maturity group on both protein and oil contents, there is no indication of an inverse relationship between them as suggested by Liu *et al.* (1995).

The fatty acid compositions (Table II) are characterized by a high proportion of unsaturated fatty acids which vary between 73.1-87.2%. Palmitic acid is the main saturated acid in all cultivars ranging from 9.2 to 12.5%. Among the unsaturated fatty acids, linoleic is the principal constituent (53.6-56.9%), followed by oleic (17.7-22.1%) and linolenic (8.6-10.4%) acids. The RA 587, Federada 1, Tacuarí and Hood 75 cultivars show the lowest linolenic acid contents. The average value of oleic acid content in maturity group VI is the highest. There are not significant variations among maturity groups for palmitic, stearic, linoleic and linolenic acids. Cultivars vary considerably in IVs (139.5-147.0); RA 587 has the smallest (Table I). When mean values in each maturity group are considered, no significant differences are found between them for both parameters mentioned.

The following 4-desmethylsterols were detected: cholesterol, campesterol, stigmasterol, β-sitosterol, Δ^5-avenasterol, Δ^7-stigmastenol and Δ^7-avenasterol (Table III). These results are in general agreement with those previously published by Padley *et al.* (1986). The β-sitosterol, campesterol and stigmasterol are the principal constituents, with β-sitosterol dominant in all samples (48.1-56.8%). An interesting feature is the presence of larger amounts of Δ^5-avenasterol in Montera 74 and Charata 76 cultivars. This sterol was found to be an effective agent at reducing changes in the soybean oil during heating (Duve and White, 1991). On the other hand, cholesterol is present in small quantities (trace-0.9%).

Table I

Moisture (g kg^{-1}), protein, oil, carbohydrate (Carb) and ash contents (g kg^{-1} of dry matter) of seeds, and refractive indices (RI) and iodine values (IV) of the oils from 19 soybean cultivars. Mean values ± standard deviations, n=3.

Cultivar	Moisture	Protein	Oil	Carb	RI	IV	Ash
Maturity group V							
NK 555	45.7 ± 0.5	444 ± 0.7	192 ± 0.6	272 ± 0.4	1.463 ± 0.03	143.4 ± 0.9	45.8 ± 0.2
Torcacita 58	70.3 ± 0.4	344 ± 0.8	200 ± 0.5	338 ± 0.4	1.466 ± 0.04	143.6 ± 0.8	47.1 ± 0.3
Asgrow 5308	68.3 ± 0.5	379 ± 0.7	219 ± 0.4	285 ± 0.3	1.460 ± 0.05	142.9 ± 0.7	48.6 ± 0.4
Asgrow 5409	44.4 ± 0.4	367 ± 0.6	218 ± 0.5	333 ± 0.5	1.468 ± 0.05	144.0 ± 0.8	40.3 ± 0.3
Tancacha	47.6 ± 0.5	389 ± 0.7	209 ± 0.6	308 ± 0.4	1.464 ± 0.04	144.2 ± 0.9	46.3 ± 0.5
RA 587	72.0 ± 0.4	416 ± 0.6	222 ± 0.5	240 ± 0.5	1.469 ± 0.05	139.5 ± 0.8	49.3 ± 0.4
Copetona 53	69.8 ± 0.6	395 ± 0.8	233 ± 0.4	262 ± 0.4	1.466 ± 0.06	148.8 ± 0.7	40.0 ± 0.4
Federada Casilda	44.7 ± 0.5	401 ± 0.7	194 ± 0.5	316 ± 0.3	1.468 ± 0.05	146.7 ± 0.8	44.3 ± 0.4
Tacuarí	43.8 ± 0.5	411 ± 0.6	208 ± 0.4	288 ± 0.3	1.468 ± 0.05	144.3 ± 0.8	48.3 ± 0.3
Maturity groups VI							
NK 641	70.3 ± 0.5	370 ± 0.7	206 ± 0.6	309 ± 0.5	1.468 ± 0.04	143.8 ± 0.7	44.5 ± 0.3
Federada 1	70.3 ± 0.6	377 ± 0.6	221 ± 0.5	288 ± 0.3	1.472 ± 0.03	143.1 ± 0.6	43.7 ± 0.2
Hood 75	71.5 ± 0.4	384 ± 0.6	223 ± 0.4	272 ± 0.4	1.470 ± 0.02	143.0 ± 0.7	49.0 ± 0.3
Asgrow 6404	49.5 ± 0.5	461 ± 0.5	207 ± 0.5	234 ± 0.4	1.467 ± 0.04	145.5 ± 0.8	48.1 ± 0.4
Torcaza 63	69.2 ± 0.6	404 ± 0.6	223 ± 0.4	260 ± 0.3	1.469 ± 0.04	141.3 ± 0.7	43.7 ± 0.4
Prata	47.1 ± 0.5	389 ± 0.7	221 ± 0.5	300 ± 0.4	1.465 ± 0.05	145.8 ± 0.6	42.9 ± 0.3
Maturity group VII							
Montera 74	65.2 ± 0.5	404 ± 0.7	200 ± 0.3	286 ± 0.4	1.464 ± 0.04	146.0 ± 0.8	44.2 ± 0.3
Granera 73	46.4 ± 0.4	388 ± 0.8	212 ± 0.4	309 ± 0.3	1.469 ± 0.03	147.0 ± 0.7	44.2 ± 0.5
RA 702	46.5 ± 0.4	463 ± 0.9	178 ± 0.2	266 ± 0.3	1.465 ± 0.05	145.6 ± 0.5	45.9 ± 0.3
Charata 76	43.0 ± 0.5	384 ± 0.7	191 ± 0.4	334 ± 0.4	1.462 ± 0.04	145.5 ± 0.6	47.9 ± 0.4

Table II

Fatty acid composition (% of total fatty acids) and oleic to linolenic (O/Ln) ratios of seed oils from 19 soybean cultivars. Mean values ± standard deviations, n=3.

Cultivar	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:0	20:1	22:0	O/Ln
Maturity group V											
NK 555	tr[a]	11.5 ± 0.2	tr	4.0 ± 0.1	19.2 ± 0.3	54.9 ± 0.4	9.6 ± 0.1	0.5 ± 0.1	0.2 ± 0.1	tr	1.99 ± 0.1
Torcacita 58	tr	11.1 ± 0.2	tr	3.9 ± 0.1	20.1 ± 0.4	55.8 ± 0.6	8.9 ± 0.2	tr	tr	tr	2.25 ± 0.2
Asgrow 5308	tr	11.1 ± 0.1	tr	3.7 ± 0.2	21.0 ± 0.3	54.4 ± 0.7	9.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	tr	2.27 ± 0.2
Asgrow 5409	tr	9.2 ± 0.1	tr	4.5 ± 0.1	20.6 ± 0.5	54.8 ± 0.7	9.5 ± 0.2	0.6 ± 0.2	0.3 ± 0.1	0.3 ± 0.1	2.17 ± 0.1
Tancacha	tr	10.5 ± 0.1	tr	3.4 ± 0.2	22.1 ± 0.5	54.7 ± 0.8	9.2 ± 0.2	tr	tr	tr	2.40 ± 0.2
RA 587	tr	11.7 ± 0.2	tr	3.1 ± 0.2	21.0 ± 0.4	53.6 ± 0.7	8.6 ± 0.3	tr	tr	tr	2.44 ± 0.3
Copetona 53	tr	10.3 ± 0.3	tr	1.6 ± 0.1	20.3 ± 0.6	56.5 ± 0.9	10.2 ± 0.2	0.3 ± 0.1	0.2 ± 0.2	0.4 ± 0.2	1.99 ± 0.2
Federada Casilda	tr	10.6 ± 0.2	tr	4.1 ± 0.3	18.5 ± 0.7	56.5 ± 0.8	10.1 ± 0.3	tr	tr	tr	1.83 ± 0.2
Tacuarí	0.1 ± 0.1	10.9 ± 0.3	0.1 ± 0.1	3.6 ± 0.4	19.1 ± 0.6	56.7 ± 0.8	8.8 ± 0.2	0.2 ± 0.1	0.2 ± 0.1	tr	2.17 ± 0.3
Maturity groups VI											
NK 641	tr	9.8 ± 0.2	tr	4.3 ± 0.1	20.8 ± 0.4	55.1 ± 0.6	9.1 ± 0.3	0.3 ± 0.1	0.2 ± 0.1	0.3 ± 0.2	2.28 ± 0.4
Federada 1	tr	12.5 ± 0.2	0.6 ± 0.1	3.8 ± 0.1	17.7 ± 0.5	56.6 ± 0.8	8.8 ± 0.2	tr	tr	tr	2.01 ± 0.3
Hood 75	tr	11.8 ± 0.3	0.1 ± 0.1	3.0 ± 0.2	20.5 ± 0.4	55.3 ± 0.7	8.8 ± 0.2	0.1 ± 0.1	0.1 ± 0.1	tr	2.32 ± 0.2
Asgrow 6404	tr	10.5 ± 0.2	tr	3.6 ± 0.3	18.0 ± 0.4	55.9 ± 0.8	10.2 ± 0.1	tr	tr	tr	1.76 ± 0.3
Torcaza 63	tr	10.6 ± 0.2	tr	4.6 ± 0.1	20.8 ± 0.4	53.7 ± 0.9	9.1 ± 0.3	0.3 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	2.28 ± 0.4
Prata	0.3 ± 0.1	10.9 ± 0.4	0.5 ± 0.1	3.8 ± 0.1	18.4 ± 0.3	55.7 ± 0.8	10.1 ± 0.2	0.1 ± 0.1	0.1 ± 0.1	tr	1.82 ± 0.3
Maturity group VII											
Montera 74	0.3 ± 0.1	9.8 ± 0.4	0.4 ± 0.1	4.4 ± 0.2	19.5 ± 0.3	55.4 ± 0.8	10.1 ± 0.2	tr	tr	tr	1.93 ± 0.4
Granera 73	0.1 ± 0.1	9.8 ± 0.3	0.3 ± 0.1	3.5 ± 0.2	20.2 ± 0.4	56.1 ± 0.7	9.8 ± 0.3	tr	tr	tr	2.06 ± 0.3
RA 702	tr	11.1 ± 0.2	0.1 ± 0.1	3.4 ± 0.2	18.9 ± 0.4	56.9 ± 0.9	9.2 ± 0.2	0.2 ± 0.1	tr	tr	2.04 ± 0.4
Charata 76	tr	10.2 ± 0.3	tr	3.3 ± 0.1	19.3 ± 0.3	54.7 ± 0.8	10.4 ± 0.2	0.1 ± 0.1	0.6 ± 0.2	1.0 ± 0.2	1.85 ± 0.4

[a]tr, trace: < 0.1%

Table III
Sterol[a] composition (% of total sterols) of seed oils from 19 soybean cultivars. Mean values ± standard deviations, n=3.

Cultivar	Chol	Camp	Stig	β-Sit	Δ^5-Av	Δ^7-Stig	Δ^7-Av
Maturity group V							
NK 555	0.6 ± 0.1	19.8 ± 0.4	14.8 ± 0.3	55.9 ± 0.7	4.0 ± 0.2	3.4 ± 0.1	1.3 ± 0.1
Torcacita 58	0.5 ± 0.1	18.4 ± 0.3	15.6 ± 0.2	55.0 ± 0.8	5.2 ± 0.2	3.6 ± 0.2	1.6 ± 0.1
Asgrow 5308	tr[b]	20.5 ± 0.3	14.3 ± 0.2	51.2 ± 0.9	6.5 ± 0.1	4.4 ± 0.2	1.6 ± 0.1
Asgrow 5409	tr	21.7 ± 0.2	18.0 ± 0.3	48.3 ± 0.8	4.4 ± 0.2	3.1 ± 0.1	1.1 ± 0.1
Tancacha	tr	18.7 ± 0.2	15.9 ± 0.3	55.2 ± 0.7	5.4 ± 0.1	2.9 ± 0.1	1.6 ± 0.1
RA 587	0.7 ± 0.1	20.9 ± 0.4	15.8 ± 0.3	51.1 ± 0.7	5.8 ± 0.2	3.8 ± 0.1	1.8 ± 0.2
Copetona 53	0.4 ± 0.1	21.1 ± 0.3	15.8 ± 0.2	51.8 ± 0.9	5.6 ± 0.2	4.2 ± 0.2	1.0 ± 0.2
Federada Casilda	0.9 ± 0.1	20.5 ± 0.4	16.2 ± 0.3	52.1 ± 0.8	5.8 ± 0.1	3.6 ± 0.2	0.8 ± 0.1
Tacuarí	tr	18.7 ± 0.3	15.9 ± 0.2	53.0 ± 0.7	6.3 ± 0.2	5.4 ± 0.1	0.6 ± 0.2
Maturity groups VI							
NK 641	0.7 ± 0.1	19.4 ± 0.4	14.5 ± 0.5	53.2 ± 0.9	6.1 ± 0.1	4.9 ± 0.2	1.1 ± 0.1
Federada 1	0.4 ± 0.1	21.0 ± 0.3	14.4 ± 0.4	54.2 ± 0.7	4.5 ± 0.2	4.0 ± 0.1	1.4 ± 0.1
Hood 75	tr	19.4 ± 0.3	15.1 ± 0.2	54.4 ± 0.8	5.6 ± 0.1	3.4 ± 0.2	2.0 ± 0.2
Asgrow 6404	0.9 ± 0.2	18.5 ± 0.4	13.4 ± 0.6	56.8 ± 0.9	6.1 ± 0.1	3.1 ± 0.1	1.1 ± 0.1
Torcaza 63	tr	20.0 ± 0.3	17.3 ± 0.4	48.1 ± 0.7	5.5 ± 0.2	3.8 ± 0.2	1.4 ± 0.1
Prata	0.8 ± 0.1	19.8 ± 0.3	15.5 ± 0.5	52.2 ± 0.8	6.3 ± 0.1	4.1 ± 0.1	1.2 ± 0.1
Maturity group VII							
Montera 74	0.8 ± 0.2	18.4 ± 0.4	14.3 ± 0.3	55.1 ± 0.9	6.9 ± 0.2	3.7 ± 0.2	0.7 ± 0.1
Granera 73	tr	19.7 ± 0.3	17.3 ± 0.3	50.2 ± 0.9	6.3 ± 0.1	4.5 ± 0.1	1.9 ± 0.1
RA 702	tr	18.9 ± 0.5	17.0 ± 0.4	51.4 ± 0.8	5.1 ± 0.1	4.8 ± 0.2	2.1 ± 0.1
Charata 76	0.7 ± 0.1	20.7 ± 0.4	16.0 ± 0.3	50.8 ± 0.7	6.5 ± 0.1	4.0 ± 0.2	1.2 ± 0.1

[a]Chol, cholesterol; Camp, campesterol; Stig, stigmasterol; β-Sit, β-sitosterol; Δ^5-Av, Δ^5-avenasterol; Δ^7-Sitg, Δ^7-Stigmastenol; Δ^7-Av, Δ^7-avenasterol.

[b]tr, trace: <0.1%.

In conclusion, the results obtained in this work suggest that maturity groups do not appear to affect the differences in chemical composition of soybeans analyzed. Although statistically significant differences exist between genotypes, when mean values in each maturity group are considered for all parameters evaluated, only oil content and oleic acid percentage show significant variations.

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